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Effects of supplemental oxytocin or prostaglandin $F_{2\alpha}$ analogue in extended boar semen on piglet productivity of gilts and sows artificially inseminated in summer

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We determined the effects of oxytocin (OT) and prostaglandin $F_{2\alpha}$ analogue (PG) added to extended boar semen on the duration of artificial insemination (AI) and reproductive performance of pigs bred in July and August (temperate climate of Central Europe). Eighty gilts and second parity sows (G+SP) and sixty-four multiparous sows (M) were divided into three groups. Group OT (11 G+SP and 37 M) and group PG (20 G+SP and 28 M) were artificially inseminated twice (at the onset of estrus and 22–24 h later) using extended semen supplemented with 20 IU of OT or 5 mg of PG, respectively. Thirty-three G+SP and 15 M served as controls (C) inseminated with non-supplemented semen. The mean duration of the first AI was shorter (P<0.05) in M compared with G+SP females inseminated with PG-supplemented semen (80±22 s *vs*. 191±26 s, respectively), whereas the second AI was shorter (P<0.05) in M than in G+SP artificially inseminated with OT-supplemented semen (93±15 s *vs*. 192±28 s). The mean pregnancy rate was lower (P<0.05) in C G+SP (26/33; 85%) compared with OT G+SP females (11/11; 100%). The OT M females had more (P<0.05) stillborn piglets per litter compared with their G+SP counterparts (0.8±0.1 *vs*. 0.1±0.3). In summary, the addition of PG was associated with shorter first AI times in multiparous sows compared with G+SP, but with lower farrowing rates in younger animals. Oxytocin supplementation was associated with a shorter second AI and higher pregnancy rates in young females, but more stillborn piglets per litter in older sows.

Key words: pig, oxytocin, prostaglandin, artificial insemination, summer

Introduction

Seasonality is a primary cause of non-infectious subfertility and abortions in swine herds [21]. Seasonal subfertility is defined as a decrease in piglet productivity of gilts and sows during summer and autumn [1]. The manifestations of seasonal subfertility include delayed onset of puberty in gilts, prolonged weaning-to-estrus intervals, reduced farrowing rates, increased numbers of stillbirths and abortions, and fewer live born piglets per litter [1].

Additionally, circulating progesterone concentrations are lowest in sows during late summer/early autumn, which may indicate a propensity for early pregnancy loss in pigs [34]. Consequently, there is a noticeable decline in net piglet productivity of summer-breeding gilts and sows.

In the wild pig, decreasing day length in late summer and autumn provides a physiological cue to indicate that it is not the optimal time for breeding; this is because after the ~115-day pregnancy, the piglets would be born midwinter and had a lower chance of survival [24]. The domestic pig is a year-round breeder; however, the *Sus scrofa domesticus* has clearly retained some of the reproductive characteristics of its wild ancestor, as there is a sharp atavistic decline in fertility during the late summer and early autumn [34]. In commercial settings, photoperiodic cues are less pronounced or absent, leading to variable responses to the decreasing day length in breeding pigs [4, 3]. Summertime, however, is still the least favorable season for swine reproduction due mainly to heat stress [29]. Elevated temperatures impinge negatively on the reproductive system of sows and boars, manifesting in debilitated uterine and gonadal function [4, 3].

Implementation of reproductive technologies have influenced the way the pigs are raised for pork production [5, 27, 2, 10, 15]. The use of artificial insemination (AI) is a practice that has become widespread in the pig industry [2]. While there are various types of AI used (e.g., intracervical or intrauterine semen deposition), the ultimate goal is to deliver a sufficient number of viable sperm into the oviduct [2, 31, 11]. Any event that can reduce this reservoir of sperm can compromise swine fertility. The problem of seasonal subfertility in swine is further exacerbated by the dilution of ejaculates in semen extenders prior to liquid storage and AI (a.k.a. dilution factor) leading to the reduction in the level of hormones influencing the rate of sperm transport in the female reproductive tract [24]. Therefore, hormonal treatments administered during or through AI may be useful in reducing the effects of seasonal subfertility, and employed to develop strategies aimed at boosting fertility and reproductive health of pigs and their offspring.

Oxytocin has been found to be associated with the mounting reflex, fertilization and the contractions of myometrium; the latter suggesting it is involved in sperm transport in domestic animals. Progesterone and stress factors, including heat stress, block the release of oxytocin, which could be at least partly responsible for the decline in fertility observed in the summer months [12]. Prostaglandins play an important role in the control of ovulation, luteal function, maternal recognition of pregnancy, implantation, maintenance of gestation, parturition, and microbial-induced infections [25]. Addition of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) to extended boar semen has slightly increased the reproductive parameters of sows, specifically the conception rate and total number of live born piglets [33, 16]. The mechanisms whereby periovulatory $PGF_{2\alpha}$ affects these parameters have not yet been fully elucidated, but it is possible that the sperm transport after insemination with sufficient amount of $PGF_{2\alpha}$ is accelerated.

The main goal of this experiment was to determine and compare, in a single study, the effects of oxytocin and $PGF_{2\alpha}$ analogue added to boar semen extender on the duration of insemination and reproductive performance of gilts and pigs bred in July and August.

Materials and Methods

All procedures described in this section of the manuscript followed the guidelines contained in the EU Directive 2010/63/EU for animal experiments (http://ec.europa.eu/environment/chemicals/lab_animals/legislation_en.htm), albeit the present study conducted in a commercial facility did not require, in compliance with the EU regulations, any additional permits or animal utilization protocols. This experiment utilized gilts and sows of the Polish White Landrace × Polish Large White crosses housed in a commercial facility (maximum capacity of 700 breeding females) situated in the Poland's Łódzkie region. The buildings in farm were mechanically ventilated in response to changes in temperature readings taken by the climate-controlling computer (*Wesstron*, Augustowo, Poland). All animals received fully balanced dry mixes adjusted to their physiological condition. During the period from insemination to gestation day 104 (gd104; transfer to the farrowing unit), the mixes contained 13.5% of crude protein, 6.0% of fiber, 5.3% of ash, 2.3% of oil and crude fats, 0.7% of lysine, 0.22% of methionine, 0.8% of calcium, 0.17% of sodium, and 0.6% of phosphorus. During the period from gd104 until the ensuing weaning or culling, the mixes contained 15.6% of crude protein, 4.5% of fiber, 5.7% of ash, 4.5% of oil and crude fat, 1% of lysine, 0.3% of methionine, 0.9% of calcium, 0.16% of sodium, and 0.7% of phosphorus. For 28 days after the second AI, the animals were kept in individual stalls and then transferred to the group pens of 7–10 animals each, in which they stayed until gd104 (i.e., approximately 10 days before the expected farrowing).

Reproductive management in the farm followed the stringent weekly cycles of operation. Farrowing induced with an injection of bioactive prostaglandin F_{2a} analogue (*Alfaprostol*[a]; *Grabrostim*, Ceva, Polska) typically occurred on Thursday and Friday. Piglets were weaned on Thursday, approximately 28 days *post-partum*, and breeding sows were relocated to the AI sector of the facility. Artificial insemination procedures were then performed on Tuesday and repeated after 22–24 h on Wednesday. Throughout the entire duration of housing in the AI sector, breeding females were exposed to a teaser boar for at least 1.5 h each day and maintained under the 12-h *per diem* light regimen. Ultrasonographic pregnancy check was routinely performed on gestation days 28 and 42 (day 0=second insemination day) using an ultrasound scanner *SonoFarm mini* (*Dramiński*[a] *Ultrasound Scanners*, Olsztyn, Poland).

The research sample consisted of 144 female pigs. The animals were allocated by age to one of the three groups (each n=48):

1) control group (C) (33 gilts and second parity sows (G+SP) and 15 multiparous sows (M)): pigs were inseminated with non-supplemented semen doses;

2) oxytocin group (OT) (11 G+SP and 37 M): pigs were inseminated with inseminates containing 20 IU of oxytocin (*Oxitocinum*; *Biowet*, Puławy, Poland); and

3) prostaglandin $F_{2\alpha}$ analogue (PG) group (20 G+SP and 28 M): pigs were inseminated using semen supplemented with 5 mg of prostaglandin $F_{2\alpha}$ analogue (PG; *Dinolytic*[â]; *Zoetis*, Warsaw, Poland).

Both hormones were added to the plastic bags containing inseminates just before AI, at the doses recommended by manufacturers. The present experiment involved a series of AIs conducted during the summer months of July and August (from 12 July to 17 August). Twenty-four animals were inseminated every week (8 randomly selected females from each hormone supplementation group) using a foam-tipped insemination catheter (*Golden Pig*; *IMV*, L'Aigle, France) (intracervical semen deposition, gravity flow only). Inseminate doses (100 ml; containing 2.8×10^9 of spermatozoa) from Hypor Maxter boars, were purchased from the Boar Utilization Center (*Insefarm*; Śmiłowo, Poland, http://insefarm.pl). The average internal temperatures on the days of AI were 24.6°C in July and 23.6°C in August. The numbers and physical condition of piglets were recorded at farrowing. Live piglets with the birthweight <1 kg were classified as weak piglets.

The proportions were analyzed by χ^2-test (Brandt and Snedecor formula). The remaining numerical data were subjected to normality (Shapiro-Wilk) and equal variance tests, and then analyzed by two-way analysis of variance (ANOVA), with the main effects of animal parity (G+SP *vs.* M) and hormonal supplements used (C, OT or PG), followed by the least significance difference (LSD) test to determine the differences between individual mean values (*SigmaPlot*[â]; *Systat Software Inc.*, San Jose, CA, USA). The level of significance was set at $P<0.05$. All results are given as mean ± standard error of mean (SEM) unless otherwise indicated in table columns or the text of the manuscript.

Results and Discussion

The effects of addition of either PG or OT to the semen doses on the duration of AIs are summarized in table 1. There was a significant main effect of parity (G+SP *vs.* M) and an interaction between parity and hormonal supplement used (PG or OT) on the duration of the first AI. The mean duration of the first AI was shorter ($P<0.05$) in M sows compared with G+SP animals; this difference was seen ($P<0.05$) in PG groups but not in OT or control animals. There was a significant main effect of parity on the duration of the second AI; it was shorter in M than in G+SP animals due mainly to a difference recorded in animals AI'd with OT-supplemented semen.

Table 1. Mean (±SEM) durations of inseminations in summer-bred gilts and sows after the addition of 20 IU of oxytocin (OT) or 5 mg of prostaglandin F_{2a} analogue (PG) to 100-ml inseminate doses

Groups / Variable	G+P				M			
	C	OT	PG	Overall	C	OT	PG	Overall
Duration of 1st AI (s)	160±20	132±35	191±26 a	161±16 a	115±30	114±19	80±22 b	103±14 b
Duration of 2nd AI (s)	138±16	192±28 a	125±21	152±13 a	133±24	93±15 b	93±18	106±11 b

Note. G+SP: gilts and second parity sows; M: multiparous sows; AI: artificial insemination; ab $P<0.05$ (within rows, between G+SP and M animals allotted to the same groups or overall).

Table 2. Reproductive performance of summer-bred gilts and sows after the addition of 20 IU of oxytocin (OT) or 5 mg of prostaglandin F_{2a} analogue (PG) to 100-ml inseminate doses

Groups / Variable	G+SP				M			
	C	OT	PG	Overall	C	OT	PG	Overall
Pregnancy rate	78.8% (26/33) A	100% (11/11) B	90.0% (18/20)	85.9% (55/64)	93.3% (14/15)	97.3% (36/37)	96.4% (27/28)	96.25% (77/80)
Farrowing rate*	69.7% (23/33)	90.1% (10/11)	70.0% (14/20) a	73.4% (47/64)	86.7% (13/15)	91.9% (34/37)	92.9% (26/28) b	91.25% (73/80)
Farrowing rate**	88.5% (23/26)	90.1% (10/11)	77.8% (14/18)	85.4% (47/55)	92.9% (13/14)	94.4% (34/36)	96.3% (26/27)	94.8% (73/77)
Litter size	10.2±0.7	11.2±1.0	11.9±0.9	11.1±0.5	11.8±0.9	12.3±0.6	12.8±0.6	12.3±0.4
Live born piglets/litter	10.0±0.6	11.1±0.9	11.7±0.8	10.9±0.4	11.5±0.8	11.5±0.5	12.3±0.6	11.8±0.4
Stillborn piglets/litter	0.2±0.2	0.1±0.3 a	0.1±0.2	0.1±0.1 a	0.4±0.2	0.8±0.1 b	0.5±0.2	0.6±0.1 b
Weak piglets/litter	0.4±0.2	0.5±0.3	1.2±0.3	0.7±0.2	0.6±0.3	0.6±0.2	1.1±0.2	0.8±0.1

Note: C — control group (animals inseminated with non-supplemented semen). Farrowing rate was calculated as the proportion of all inseminated animals (*) or of the females with ultrasonographically confirmed pregnancy (**). G+P: gilts and second parity sows; M: multiparous sows; ab $P<0.05$ (within rows, between G+SP and M animals allotted to the same groups or overall); AB: $P<0.05$ (between C and OT for G+SP).

The results of the addition of hormones to inseminate doses on the reproductive outcomes in the gilts and sows of the present study are given in table 2. Oxytocin G+SP animals exhibited greater (P<0.05) pregnancy rates compared with their control counterparts (100% *vs*. 78.8%). Mean farrowing rates (expressed as the percentage of all inseminated animals) were greater (P<0.05) in M sows than in G+SP animals inseminated with PG-supplemented semen (92.9% *vs*. 70.0%). The supplementary hormones and/or parity also had an effect on certain aspects of swine fecundity. There was a significant main effect of hormone supplement used on the number of weak piglets per litter. Overall, PG females of all ages had more (P<0.05) weak piglets per litter (1.2±0.2) compared with C (0.5±0.2) and OT groups (0.6±0.2). Lastly, there was a significant main effect of parity on the number of stillborn piglets per litter. Overall, M females had more (P<0.05) stillborn piglets per litter than G+SP group (0.6±0.1 *vs*. 0.1±0.1) and this difference was due mainly to significantly more stillborn piglets per litter in OT M females compared with OT G+SP group (0.8±0.1 *vs*. 0.1±0.1).

Conclusion

The only "direct" effect of the hormones added to the inseminate doses on the fertility parameters of summer-bred pigs was observed in G+SP animals (an increase in pregnancy rates in the OT G+GP group relative to controls inseminated with non-supplemented semen). However, the use of PG and OT may have also "accentuated" the age-related differences in farrowing rates and numbers of stillborn piglets per litter, respectively; within the treatment groups, both these parameters were greater in multiparous sows compared with their younger counterparts.

Oxytocin in the inseminate dose may have stimulated cervical and myometrial contractions and had a positive impact on the movement of spermatozoa in the female reproductive tract [30]. During natural mating, stimulation of the oxytocin-producing hypothalamic neurons occurs because of movements of the boar's penis in the vagina and cervix. The copulation lasts 5–10 min and oxytocin concentrations in the mated sow rise dramatically within 2 min of the ejaculation. This increased oxytocin release results in easier and faster transport of spermatozoa to the oviducts. An earlier arrival of spermatozoa and their accumulation in the uterine tube are associated with better capacitation, fertilization rates and ensuing embryo development [30]. Therefore, this would be the logical reasoning behind the greater pregnancy rates in the OT group when compared the control group of G+SP animals [12]. However, the duration of the first and second AI did not vary significantly between those two subsets of animals. The duration of AI depends on the variation in intensity of uterine contractions [26]; therefore, gilts often take longer to inseminate than sows, which was confirmed in the present study. Similarly, the shorter duration of AI did not impinge on the improvement of reproductive efficacy in M sows compared with the G+SP group in this study, although depositing the semen too rapidly may cause a backflow of semen out of the cervix and vagina [14]. Collectively, the durations of the two AIs within the ranges recorded in this study did not seem to be a factor influencing the fertility of summer-bred gilts and sows.

The addition of PG to inseminate doses was associated with greater farrowing rates of M compared with G+SP animals. This difference appeared to be due mainly to a lower degree of early pregnancy loss as fertility rates calculated for gestating sows did not very significantly among various subsets of pigs studied. Preovulatory LH surges stimulate endometrial and intra-ovarian prostaglandin F_{2a} (PGF_{2a}) release, which in turn stimulates collagenase and elastase for follicular rupture [6]. Prostaglandin F_{2a} administration at the time of insemination leads to advanced ovulation suggesting that the exogenous PGF_{2a} may also advance the time of ovulation through intra-follicular mechanisms. This effect would ensure an ovulation to occur during the insemination period, resulting in a better chance of pregnancy. Prostaglandin F_{2a} was also found to affect sperm motility independently of uterine contractions, therefore it can increase the rate of sperm transport even after applying small amounts of the hormone [6]. Additionally, high concentrations of progesterone, possibly associated with the presence of persistent luteal tissue, have been reported in post-partum sows [13]. In a Dutch field study, 7.9% of sows were found to have serum concentrations of progesterone >3 ng/mL at weaning [13]. Some sows may retain semi active *corpora lutea* even after farrowing, but an association between high progesterone concentrations at weaning and subsequent litter size has not been confirmed. However, a study by [23] indicated that the administration of PGF_{2a} after farrowing improved the performance of sows during the subsequent pregnancy; the treated sows delivered larger litters with more viable piglets than untreated controls.

Diluted semen doses contain lower amounts of seminal plasma and hence reduced amounts of all seminal hormones including estrogens. Estrogens from boar semen increase the myometrial contractility by stimulating $PGF_{2\alpha}$ release [7; 8; 9], but they can also influence the timing of the preovulatory LH release surge and ovulations relative to natural mating or artificial insemination [7, 32, 35].

Gilts typically exhibit a 10 to 15% lower farrowing rate than multiparous sows [28]. Primiparous sows also have a 3 to 5% lower farrowing rates than multiparous sows. Therefore, we cannot rule out the possibility that a lack of differences in major fertility indices between M and G+SP in this study might be due to the presence of equal numbers or even more subfertile females in the M group than in lower-parity groups.

Any stress throughout pig gestation may result in loss of pregnancy and reduced litter size [17, 22]. However, animals selected for their reproductive potential (i.e., not culled due to subfertility) are often less tolerant to the heat than animals with lower reproductive potential [17]. By this logic, the animals with higher reproductive potential would have been the M group animals, with the younger gilts and

sows being less sensitive to the heat and hence retaining more embryos/conceptuses than their multiparous counterparts. However, based mainly on the breeding farm production records, reproductive performance of sows generally increases over the first three to four parities and then begins to decline as they reach the seventh or eighth parity. Therefore, even if OT supplementation resulted in a higher number of ovulations and fertilized eggs, the limited space for the development of fetuses to term may explain, at least partly, a greater number of stillborn piglets in the M group. Since mean litter sizes did not vary significantly between older and younger females in this study, a greater number of stillborn piglets in M compared with G+SP was less likely caused by prolonged farrowing [18, 19, 20], although such a possibility cannot be completely ruled out either.

To summarize, the summer-bred gilts and sows of the present study showed dissimilar reactions to OT and PG added to inseminate doses. The addition of PG to extended boar semen was associated with a shorter first insemination and greater farrowing rates in the M sows compared to G + SP animals. The supplementation of inseminate doses with OT was associated with a shorter second insemination but more stillborn piglets per litter in the M sows compared with G-SP group. Additionally, OT-supplemented semen yielded higher pregnancy rates in G+SP animals compared with their respective controls. This study was not conducted in a controlled laboratory setting but in a commercial facility. Thus, there may have been limitations in that the findings are biased due to standard farm management practices that deviate from artificially controlled environments, but that fact would only increase their applicability for use in practice. Both hormones tested can be used in the breeding and production facilities. Multiparous sows had positive responses to treatment with PG, whereas OT proved to be the most effective treatment for the G+SP group. Interesting questions not addressed in the present experiment would be if OT, PG and/or estrogens used in combination would improve the reproductive capacity of gilts and sows, and if the breed of the boar and semen dilution factor impinge on the effects of exogenous hormones added to boar semen.

References

1. Auvigne V, Leneveu P, Jehannin C, Peltoniemi O, Sallé E. Seasonal infertility in sows: A five year field study to analyze the relative roles of heat stress and photoperiod. *Theriogenol.* 2010; 74 (1): 60–66. DOI: 10.1016/j.theriogenology.2009.12.019.
2. Belstra BA. Review: Intrauterine (transcervical) and fixed-time artificial insemination in swine. *Annual Swine Rep*. 2002, NC State University. Avaialble at: https://projects.ncsu.edu/project/swine_extension/swinereports/2002/belstra3.html
3. Bloemhof S, Mathur PK, Khol EF, van der Waaij EH. Effect of daily environmental temperature on farrowing rate and total born in dam line sows. *J. Anim. Sci*. 2013; 91 (6): 2667–2679. DOI: 10.2527/jas.2012-5902.
4. Bloemhof S, van der Waaij EH, Merks JWM, Knol EF. Sow line differences in heat stress tolerance expressed in reproductive performance traits. *J. Anim. Sci.* 2008; 86 (12): 3330–3337. DOI: 10.2527/jas.2008-0862.
5. Buhr M. Emerging tools in artificial insemination. London Swine Conference — *The Pork Industry and Public Issues*. 5–6 April 2001: 123–135.
6. Çebi Ç, Akçay E. The effect of oxytocin and prostaglandin hormones added to semen on stallion sperm quality. *Turk. J. Vet. Anim. Sci*. 2015; 39 (6): 705–708. DOI: 10.3906/vet-1412-69.
7. Claus R. Physiological role of seminal components in the reproductive tract of the female pig. *J. Reprod. Fertil*. 1990; 40: 117–131. PMID: 2192032.
8. Claus R, Schams D. Influence of mating and intra-uterine oestradiol infusion on peripheral oxytocin concentrations in the sow. *J. Endocrinol*. 1990; 126 (3): 361–365. DOI: 10.1677/joe.0.1260361.
9. De Ambrogi M, Ballester J, Saravia F, Caballero I, Johannisson A, Wallgren M, Andersson M, Rodriguez-Martinez H. Effect of storage in short- and long-term commercial semen extenders on the motility, plasma membrane and chromatin integrity of boar spermatozoa. *Int. J. Androl*. 2006; 29 (5): 543–552. DOI: 10.1111/j.1365-2605.2006.00694.x.
10. De Rensis F, Kirkwood RN. Control of estrus and ovulation: Fertility to timed insemination of gilts and sows. *Theriogenol*. 2016; 86 (6): 1460–1466. DOI: 10.1016/j.theriogenology.2016.04.089.
11. Dimitrov S, Jeliazkov E, Levis D. Deep intrauterine and transcervical insemination of sows and gilts. *Trakia J. Sci*. 2007; 5 (1): 40–46. Available at: http://tru.uni-sz.bg/tsj/Vol5N1_2007/Dimitrov%20et%20al.pdf
12. Duziński K, Knecht D, Środoń S. The use of oxytocin in liquid semen doses to reduce seasonal fluctuations in the reproductive performance of sows and improve litter parameters — a 2-year study. *Theriogenol*. 2014; 81 (6): 780–786. DOI: 10.1016/j.theriogenology.2014.01.003.
13. Elbers ARW, Geudeke TJ, van Rossem H, Hunneman WA. An observational study into herd-level risk indicators of return to oestrus more than five days after insemination in sow herds. *Vet. Quart*. 1995; 17 (3): 110–112. DOI: 10.1080/01652176.1995.9694546.
14. Hernández-Caravaca I, Izquierdo-Rico MJ, Matás C, Carvajal JA, Vieira L, Abril D, Soriano-Úbeda C, García-Vázquez FA. Reproductive performance and backflow study in cervical and post-cervical artificial insemination in sows. *Anim. Reprod. Sci*. 2012; 136 (1–2): 14–22. DOI: 10.1016/j.anireprosci.2012.10.007.
15. Knox RV. Artificial insemination in pigs today. *Theriogenol*. 2016; 85 (1): 83–93. DOI: 10.1016/j.theriogenology.2015.07.009.
16. Kos M, Bilkei R. Prostaglandin $F_{2\alpha}$ supplemented semen improves reproductive performance in artificially inseminated sows. *Anim. Reprod. Sci*. 2004; 80 (1–2): 113–120. DOI: 10.1016/S0378-4320(03)00135-0.
17. Kraeling RR, Webel SK. Current strategies for reproductive management of gilts and sows in North America. *J. Anim. Sci. Biotechnol.* 2015; 6: 3. DOI: 10.1186/2049-1891-6-3.
18. Langendijk P, Bouwman EG, Kidson A, Kirkwood RN, Soede NM, Kemp B. Role of myometrial activity in sperm transport through the genital tract and fertilisation in sows. *Reprod*. 2002; 123 (5): 683–690. DOI: 10.1530/rep.0.1230683.
19. Langendijk P, Bouwman EG, Soede NM, Taverne MAM, Kemp B. Myometrial activity around estrus in sows: spontaneous activity and effects of estrogens, cloprostenol, seminal plasma and clenbuterol. *Theriogenol*. 2002; 57 (5): 1563–1577. DOI: 10.1016/S0093-691X(02)00657-X.
20. Langendijk P, Soede NM, Kemp B. Uterine activity, sperm transport, and the role of boar stimuli around insemination in sows. *Theriogenol*. 2005; 63 (2): 500–513. DOI: 10.1016/j.theriogenology.2004.09.027.
21. Lewis CRG, Bunter KL. Effects of seasonality and ambient temperature on genetic parameters for production and reproductive traits in pigs. *Anim. Prod. Sci.* 2011; 51: (7) 615–626. DOI: 10.1071/AN10265.
22. Liu X, Schwarz T, Murawski M, Tayade C, Kridli R, Prieto Granados AM, Sharma C, Bartlewski PM. Measurements of circulating progesterone and estrone sulfate concentrations as a diagnostic and prognostic tool in porcine pregnancy revisited. *Domest. Anim. Endocrinol*. 2020; 71: 106402. DOI: 10.1016/j.domaniend.2019.106402.

23. Lopez JV, Ptaszynska M, Gonzalez P, Jiménes M, Martens MRTM. Beneficial effects on the reproductive performance of sows of administering prostaglandin analogues after farrowing. *Vet. Rec*. 2009; 164 (26): 807–809. DOI: 10.1136/vr.164.26.807.
24. Peltoniemi OAT, Virolainen JV. Seasonality of reproduction in gilts and sows. *Soc. Reprod. Fertil. Suppl*. 2006; 62: 205–218. PMID: 16866319.
25. Peña FJ, Domínguez JC, Carbajo M, Anel L, Alegre B. Treatment of swine summer infertility syndrome by means of oxytocin under field conditions. *Theriogenol*. 1998; 49 (4): 829–836. DOI: 10.1016/S0093-691X(98)00032-6.
26. Schwarz T, Kopyra M. Influence of duration of insemination on reproductive performance in sows. *Ann. Anim. Sci. Suppl*. 2006; 2 (2): 409–414. Available at: https://agro.icm.edu.pl/agro/element/bwmeta1.element.agro-366a3f95-8005-4a55-b68c-1d3905276d7b
27. Singleton WL. State of the art in artificial insemination of pigs in the United States. *Theriogenol*. 2001; 56 (8): 1305–1310. DOI: 10.1016/S0093-691X(01)00631-8.
28. Soede NM, Hoving LL, van Leeuwen JJJ, Kemp B. The second litter syndrome in sows; causes, consequences and possibilities of prevention. Olsztyn 9th International Conference on Pig Reproduction — Pigs Reproduction for Practitioners, "Satellite Symposium", 9–12 June 2013. Available at: https://www.researchgate.net/publication/283418283_The_second_litter_syndrome_in_sows_causes_consequences_and_possibilities_of_prevention
29. Suriyasomboon A, Lundeheim N, Kunavongkrit A, Einarsson S. Effect of temperature and humidity on reproductive performance of crossbred sows in Thailand. *Theriogenol*. 2006; 65 (3): 606–628. DOI: 10.1016/j.theriogenology.2005.06.005.
30. Thackare H, Nicholson HD, Whittington K. Oxytocin — its role in male reproduction and new potential therapeutic uses. *Hum. Reprod. Update*. 2006; 12 (4): 437–448. DOI: 10.1093/humupd/dmk002.
31. Vazquez JM, Martinez EM, Roca J, Gil MA, Parrilla I, Cuello C, Carvajal G, Lucas X, Vazquez JL. Improving the efficiency of sperm technologies in pigs: the value of deep intrauterine insemination. *Theriogenol*. 2005; 63 (2): 536–547. DOI: 10.1016/j.theriogenology.2004.09.043.
32. Weiler U, Claus R. Endocrine aspects of testicular function, especially hormones in the seminal plasma and their fate in the female reproductive tract: testicular steroids and their relevance for male and female reproductive functions. *Reprod. Dom. Anim. Suppl*. 1991; 41: 41–61.
33. Willenburg KL, Miller GM, Rodriguez-Zas SL, Knox RV. Influence of hormone supplementation to extended semen on artificial insemination, uterine contractions, establishment of a sperm reservoir, and fertility in swine. *J. Anim. Sci*. 2003; 81 (4): 821–829. DOI: 10.2527/2003.814821x.
34. Wrathall AE, Wells DE, Jones PC, Foulkes JA. Seasonal variations in serum progesterone levels in pregnant sows. *Vet. Rec*. 1986; 118: 685–687. DOI: 10.1136/vr.118.25.685. PMID: 3739177.
35. Zduńczyk S, Janowski T, Raś A, Barański W. Concentrations of oestrogens in blood plasma and seminal plasma of boars during the postpuberal period. *Pol. J. Vet. Sci*. 2011; 14 (4): 539–544. DOI: 10.2478/v10181-011-0080-1.

Вплив додавання окситоцину або аналога простагландину $F_{2\alpha}$ до розрідженої сперми кнурів на відтворювальну здатність свинок і свиноматок, штучно осіменених влітку

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Досліджували вплив окситоцину (ОТ) і аналога простагландину $F_{2\alpha}$ (PG), доданих до розрідженої сперми кнурів, на тривалість штучного осіменіння (AI) і репродуктивні показники свиней, осіменених у липні та серпні (помірний клімат Центральної Європи). Вісімдесят свинок і свиноматок другого опоросу (G+SP) і шістдесят чотири свиноматки третього і наступних опоросів (M) розділили на три групи. Групі ОТ (11 G+SP і 37 M) і групі PG (20 G+SP і 28 M) двічі проводили AI (на початку тічки та через 22–24 год.) з використанням розрідженої сперми з додаванням 20 МО ОТ або 5 мг ПГ відповідно. Тридцять три G+SP і 15 M слугували контролем (C), осімененим спермою без добавок. Середня тривалість першого AI була коротшою ($P<0,05$) у M порівняно з G+SP самками, запліднених спермою з додаванням PG (80±22 с проти 191±26 с відповідно), тоді як друге AI було коротшим ($P<0,05$) у M, ніж у G+SP, осіменених спермою з додаванням ОТ (93±15 с проти 192±28 с). Середня запліднюваність була нижчою ($P<0,05$) у C G+SP (26/33; 85%) порівняно з самками ОТ G+SP (11/11; 100%). Самки ОТ M мали більше ($P<0,05$) мертвонароджених поросят на приплід порівняно з їхніми аналогами G+SP (0,8±0,1 проти 0,1±0,3). Отже, додавання PG до розрідженої сперми кнурів призводить до зменшення тривалості першого AI у багатоплідних свиноматок порівняно з G+SP, але знижує запліднюваність у молодих тварин. Додавання окситоцину до розрідженої сперми кнурів скорочує тривалість другого AI та підвищує запліднюваність у молодих самок, але збільшує кількість мертвонароджених поросят на приплід у старших свиноматок.

Ключові слова: свині, окситоцин, простагландин, штучне осіменіння, літо

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The signs of milk productivity of cows bred in different climatic zones depending on the year and season of their birth

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Data on the influence of environmental factors on the milk productivity formation of cows in different climatic zones of Ukraine are presented. It was established that animals bred in the steppe zone had the highest milk yield, milk fat content, and milk fat output, and animals from the Polissia zone had the lowest values. Among the cows from different breeding zones, intergroup differentiation was also observed by milk productivity depending on the year and season of their birth. In the forest steppe zone, the highest productivity was noted for the first-calf heifers born in 2011, in the Polissia and steppe zones — for the animals born in 2015, and for the third lactation in all breeding zones, the cows born in 2015 were the most productive. A curvilinear intergroup differentiation based on the characteristics of milk productivity was also noted between animals with different seasons of birth. The highest milk yields at "Oleksandrivske" State Enterprise and "Named after Volovikov" Joint Stock Company LLC were obtained from the first-calf heifers born in the autumn period, and at Research Farm "Askaniiske" Research State Enterprise — from animals born in summer. During the third lactation, the cows born in autumn were the most productive in all breeding zones and whose first calving occurred in the steppe zone in the spring period, in the forest steppe and Polissia zones — in autumn. The year of birth and the breeding zone had the most significant effect on fertility and fat content in milk, and it was stronger in first-calf heifers, and the season of birth of animals had the least effect on signs of milk productivity.

Key words: cows, breeding zone, year and season of birth, milk productivity, influence

Introduction

The competitiveness of dairy cattle herds and breeds is determined, first of all, by the milk productivity. The maximum possible productivity of animals determined by their genotype is estimated as the genetic potential of productivity. However, the realization of this potential largely depends on environmental factors [13]. In recent years, along with the conditions of feeding and keeping animals, significant importance have such systematic factors as the year and season of birth, as well as in connection with climate change, the area of animal breeding is becoming increasingly important [2, 5, 7, 14].

In specific natural and climatic conditions, livestock of the corresponding zonal types is more productive, since when creating Ukrainian dairy breeds, the maternal basis was precisely breeds that are well adapted and acclimatized to specific environmental conditions [8, 22, 23]. At the same time, many domestic and

foreign scientists have established a sometimes significant, but multidirectional influence of the year and season of birth and calving on the formation of milk productivity signs in cows [4, 6, 10, 12, 15, 16, 17, 21]. However, some scientists report a more significant effect of the autumn and summer seasons of birth on the productivity [1], others [20] — about significantly higher milk yields of cows born in autumn, and some observed higher productivity in animals born in the autumn and winter seasons [16, 17]. A number of authors found out that the most significant influence on the phenotypic variability of the milk productivity of first-calf heifers is caused by the "herd" factor, the year of birth is noticeably smaller, and the season of birth is the least significant [3, 5, 11, 18,19, 21].

The purpose of the study is to find out the influence of the year and season of birth and breeding zone of cows of the Ukrainian Black-and-White dairy breed on the manifestation of signs of their milk productivity.

Materials and Methods

The research was carried out in farms located in different climatic zones of Ukraine, namely: "Named after Volovikov" Joint Stock Company LLC of Rivne (Polyssia zone, n=1840), "Oleksandrivske" State Enterprise of Vinnytsia region (forest steppe zone, n=714) and Research Farm "Askaniiske" Research State Enterprise (steppe zone, n=926) on first-calf heifers and mature cows (3rd lactation) of the Black-and-White dairy breed. Animals in all farms were fed rations that provided the main elements of nutrition according to existing standards. Cows that completed at least the third lactation at the time of the research were included in the experiment. In the control cows, we investigated the signs of milk productivity (milk yield, milk fat content, and the amount of milk fat) by means of a retrospective analysis of zootechnical accounting data over the last ten years. The influence of environmental factors (herd or breeding zone, year and season of birth of animals) on the formation of signs of milk productivity of cows was studied.

To study the influence of environmental factors on the signs of milk productivity, we formed groups of animals according to belonging to the farm or breeding zone ("herd" factor) and the year and season of their birth.

The influence of environmental factors on the variability of milk yield and fat content in milk was determined by one-factor variance analysis using the *Statistica 6.1* software package.

Statistical processing of research results was carried out by methods of mathematical statistics and biometrics using *Microsoft Excel* software. The degree of intergroup differentiation was assessed by comparing group average arithmetic values for each investigated characteristic. The significance of the difference between group averages was assessed by the Student's criterion (*t*) [9]. The difference between the average values was considered statistically significant at P<0.05 (* or 1), P<0.01 (** or 2), P<0.001 (*** or 3).

Results and discussion

By the retrospective analysis of zootechnical records, we established that the milk productivity of the Ukrainian Black-and-White dairy cows depended on their breeding zone. Thus, cows from the steppe zone had the highest milk yield and milk fat output during both the first and third lactation — 6492 and 264.2 kg, respectively, which is significantly (P<0.001) more than in cows of the same age from the forest steppe zone by 377 and 45.2; 268 and 40.6, and more than in the Polissia zone by 1042 and 66.6; 1035 and 63.0 kg. In turn, for the above-mentioned lactations, 665 and 767 kg of milk and 22.3 and 22.4 kg of milk fat were obtained from the cows of "Oleksandrivske" State Enterprise, compared to animals of "Named after Volovikov" LLC at P<0.001 in all cases.

The intergroup differentiation was also observed in milk fat content in the control cows. The highest fat content in milk during both the first and third lactations was also in cows from the steppe zone — 4.08 and 4.01%, which was significantly (P<0.001) more than in cows from the forest steppe zone by 0.48 and 0.44, and from the Polissia zone by 0.45 and 0.36%. At the same time, the advantage according to the mentioned indicator between first-calf heifers from "Oleksandrivske" SE and "Named after Volovikov" Joint Stock Company LLC was 0.03 for the first, and 0.08% for the third lactation with P<0.001 in both cases.

Among the systematic factors of the environment, "herd-year-season" plays a special role, the consideration of which is important for adjusting the breeding characteristics of cows, in particular, their milk productivity. However, the year the animal was born in itself does not have a direct impact on its productivity, however, the conditions (especially feeding) created in one or another year significantly affect the formation of economically useful traits of cows. It is known that animals born in years that are unfavorable in terms of fodder, do not receive the necessary amount of nutrients for the development of the body, they lag behind in growth and in the future are characterized by lower productivity.

The analysis of yield for 305 days of lactation of the first-calf heifers of the Ukrainian Black-and-White dairy breed of different years of birth proved that the highest productivity was achieved by the first-calf heifers in 2011 in the "Oleksandrivske" SE, in the "Named after Volovikov" SP LLC and Research Farm "Askaniiske" SE — animals born in 2015 (table 1). At the same time, animals born in the years 2006–2012 in the "Named after Volovikov" LLC had the lowest milk yield (4101–6232 kg) and milk fat output (149.8–228.5 kg). According to these indicators, they were significantly inferior (P<0.05–0.001) to the same age groups from the forest steppe zone by 343–1701 and 6.8–60.0 kg and steppe — by 442–2377

and 38.5–126.4 kg, respectively. Among the cows born in 2013, the best in terms of milk yield were animals from the Polissya zone (6854 kg), in terms of milk fat yield, first-calf heifers from the steppe zone (255.5 kg), and the worst in terms of these indicators were the cows of the forest steppe (6120 and 219.6 kg). Among the animals born in 2014–2015, the most productive were the first-calf heifers of Research Farm "Askaniiske" SE, their weight was 6676 and 7250 kg, and the amount of milk fat was 264.3 and 282.6 kg, respectively.

After the third lactation, cows born in 2015 had the highest yield and yield of milk fat in all farms (table 2). At the same time, for all the studied years, the lowest indicators mentioned above were in the animals of "Named after Volovikov" LLC. In terms of milk yield and milk fat yield, cows born on this farm between 2006 and 2015 were, in most cases, significantly (P<0.05–0.001) inferior to animals born in the same years at the Research Farm "Askaniiske" State Enterprise on 353–1851 and 25.3–117.9, and in the "Oleksandrivske" State Enterprise on 96–1889 and 1.4–65.2 kg,

Table 1. Milk productivity of first-calf heifer of the Ukrainian Black-and-White dairy breed depending on the year of birth

Year of birth	n	Sign		
		yield, kg	fat, %	milk fat, kg
"Oleksandrivske" SE, forest steppe zone				
2006	68	5118±108.5	3.67±0.013	187.7±3.95
2007	69	5317±126.1	3.63±0.008	192.9±4.59
2008	71	5802±106.2	3.62±0.008	209.8±3.88
2009	73	5907±97.5	3.60±0.008	212.6±3.49
2010	74	6368±105.3	3.60±0.009	228.9±3.82
2011	76	6864±120.4	3.59±0.007	246.5±4.19
2012	67	6575±94.5	3.58±0.006	235.3±3.30
2013	75	6120±103.8	3.59±0.007	219.6±3.65
2014	72	6249±136.1	3.59±0.007	223.9±4.82
2015	69	6754±121.5	3.54±0.012	238.7±4.07
"Named after Volovikov" LLC, Polissia zone				
2006	167	4345±65.0*** 3	3.61±0.004*** 3	157.0±2.36*** 3
2007	191	4331±57.6*** 3	3.61±0.003* 3	156.3±2.09*** 3
2008	275	4101±54.5*** 3	3.65±0.004*** 3	149.8±2.01*** 3
2009	177	4490±85.7 *** 3	3.67±0.007*** 3	164.7±3.15*** 3
2010	137	5402±94.7*** 3	3.68±0.007*** 3	198.8±3.45*** 3
2011	138	5244±129.1*** 3	3.68±0.011*** 3	192.9±4.77*** 3
2012	159	6232±110.6* 2	3.67±0.005*** 3	228.5±4.07 3
2013	146	6854±155.2*** 1	3.62±0.007** 3	247.3±5.42***
2014	211	6502±100.9	3.57±0.007* 3	232.3±3.59 3
2015	239	7219±100.6**	3.58±0.006** 3	258.5±3.57*** 3
Research Farm "Askaniiske" SE, steppe zone				
2006	61	6033±119.1***	4.29±0.040***	258.3±5.20***
2007	60	6262±137.5***	4.13±0.049***	257.7±5.60***
2008	66	6478±149.8***	4.26±0.033***	276.2±6.72***
2009	101	5896±104.8	4.35±0.032***	256.2±4.88***
2010	91	6052±96.3*	4.15±0.016***	250.8±4.04***
2011	92	6615±96.5	4.06±0.034***	268.6±4.65***
2012	125	6674±98.6	4.00±0.013***	267.0±4.23***
2013	109	6496±79.6**	3.94±0.014***	255.5±3.13***
2014	104	6676±85.0**	3.96±0.007***	264.3±3.51***
2015	117	7250±85.1**	3.90±0.003***	282.6±3.25***

Table 2. Milk productivity of mature cows of the Ukrainian Black-and-White dairy breed depending on the year of birth

Year of birth	n	Sign		
		yield, kg	fat, %	milk fat, kg
"Oleksandrivske" SE, forest steppe zone				
2006	68	6851±132.2	3.58±0.011	245.2±4.77
2007	69	6590±122.6	3.56±0.011	234.8±4.42
2008	71	6367±149.9	3.58±0.007	229.1±5.43
2009	73	5961±133.7	3.58±0.011	213.3±4.71
2010	74	6530±145.4	3.56±0.008	232.2±5.21
2011	76	7146±148.6	3.54±0.010	252.7±5.14
2012	67	7010±150.5	3.54±0.009	247.9±5.20
2013	75	7373±137.4	3.59±0.007	264.6±3.65
2014	72	7249±151.6	3.62±0.009	261.9±5.30
2015	69	7895±128.9	3.60±0.012	284.2±4.75
"Named after Volovikov" LLC, Polissia zone				
2006	167	4962±96.4*** 3	3.63±0.007*** 3	180.0±3.64*** 3
2007	191	5225±104.8*** 3	3.64±0.007*** 3	190.0±3.80*** 3
2008	275	5268±77.9*** 3	3.66±0.006*** 3	192.4±2.81*** 3
2009	177	5865±121.6*** 3	3.62±0.008** 3	211.9±4.35 3
2010	137	6257±123.4 3	3.64±0.009*** 3	227.3±4.42 3
2011	138	6419±137.1***	3.59±0.012** 3	229.7±4.74** 3
2012	159	6168±101.7*** 3	3.58±0.005*** 3	220.8±3.61*** 3
2013	146	7140±117.5 1	3.58±0.008 3	255.4±4.17*** 3
2014	211	6661±84.1*** 3	3.74±0.012*** 3	249.0±3.07* 3
2015	239	7526±90.3* 2	3.75±0.010*** 3	281.8±3.38 3
Research Farm "Askaniiske" SE, steppe zone				
2006	61	6813±173.8	4.35±0.046***	297.9±9.07***
2007	60	6321±179.4	4.33±0.037***	274.6±8.68***
2008	66	6543±223.6	4.14±0.035***	270.5±9.36***
2009	101	6670±147.6***	3.99±0.022***	266.0±5.96***
2010	91	6980±144.2*	4.01±0.017***	279.7±5.89***
2011	92	6774±145.6	4.03±0.010***	273.2±6.08*
2012	125	7547±109.7**	3.92±0.004***	295.9±4.22***
2013	109	7501±122.3	3.90±0.003***	292.2±4.70***
2014	104	7646±115.9*	3.90±0.002***	297.8±4.46***
2015	117	7879±84.5	3.90±0.007***	307.1±3.08***

Note. In this and the following tables *; **; *** — the significance between the "Oleksandrivske" State Enterprise and the "Named after Volovikov" LLC and "Oleksandrivske" State Enterprise and the Research Farm "Askaniiske" State Enterprise, 1; 2; 3 — significance between "Named after Volovikov" LLC and Research Farm "Askaniiske" SE.

respectively. Cows of the steppe zone of all studied years of birth significantly (P<0.05; 0.001) outperformed the animals of the forest steppe zone by 22.9–52.7 kg in terms of milk fat yield, and a significant (P<0.05–0.001) advantage was observed in terms of milk yield only in cows born in 2009; 2010; 2012 and 2014 by 397–709 kg, respectively.

One of the most important quality characteristics of milk is its fat content. It was established that among the first-calf heifers and adult cows born in 2006–2015, animals from the Research Farm "Askaniiske" State Enterprise had the most fat milk (3.90–4.35% both heifers and cows). On the second position there were the animals from "Named after Volovikov" LLC (3.57–3.68 and 3.58–3.75%) and the lowest fat content was observed in the milk of cows of "Oleksandrivske" SE (3.54–3.67 and 3.54–3.62%), except the first-calf heifers born in 2006–2007 and 2014 and adult cows born in 2013, where this indicator was lower in animals from "Named after Volovikov" LLC.

Considerable attention is paid in cattle breeding to the problem of the optimal season for the birth of calves. This is due to the fact that the season brings together a number of environmental factors that affect mothers and their offspring. Among them are the quality and range of fodder in the diet, climatic changes and the microclimate of the premises, peculiarities of metabolic processes and hormonal activity in the animal's body throughout the year. In dairy farming, despite the revealed advantages of individual seasons, the production of calves is planned relatively evenly throughout the year. This is due to the year-round need for dairy raw materials [10].

According to the results of our research, the highest milk yield and milk fat yield in the "Oleksandrivske" SE and "Named after Volovikov" LLC were noted for first-calf heifers born in autumn, and in the Research Farm "Askaniiske" SE — for animals born in the summer period (table 3). The lowest values of the above characteristics in the last two farms were observed in first-calf heifers born in winter, and in the first farm — in animals born in spring. It is worth noting that first-calf heifers from the Polissia zone, born in spring, were inferior in terms of milk to peers from the forest steppe and steppe zones by 701 (P<0.001) and 1187 (P<0.001) kg, respectively, while those born in summer — by 488 (P<0.001) and 1051 (P<0.001) kg, in autumn by 387 (P<0.01) and 499 (P<0.01) kg, and in winter by 1212 (P<0.001) and 1337 kg (P<0.001). There was also a difference in this indicator between animals from the forest steppe and Polissia zones. In the above mentioned seasons, the former were inferior to the latter by 486 (P<0.001), 563 (P<0.001), 132 and 125 kg. A similar pattern was observed in relation to the amount of milk fat. The fat content in milk, depending on the seasons, in animals of all farms had a wave-like character.

During the third lactation in all farms, cows born in autumn had the highest yield and yield of milk fat, while the lowest values of these indicators were observed in animals born in winter (table 4). The animals whose birth also occurred in the autumn period turned out to be the most fat-milk animals. The highest values of milk yield, milk fat content, and milk fat yield in cows of all birth seasons were noted in the steppe zone, and the lowest values were in the Polissia zone. Animals from the steppe zone, based on the above characteristics, significantly (P<0.05–0.001) outnumbered animals from the Polissia zone by 670–1224, respectively; 0.34–0.39 and 48.7–69.3, and from

Table 3. Milk productivity of first-calf heifer of the Ukrainian Black-and-White dairy breed depending on the season of birth

Sign	Season of birth			
	spring (n=245)	summer (n=137)	autumn (n=111)	winter (n=221)
Sub-division of "Oleksandrivske" SE, forest steppe zone				
Yield, kg	5929± ±71.0	6168± ±89.4	6449± ±97.2	6123± ±73.9
Fat, %	3.61± ±0.005	3.59± ±0.007	3.61± ±0.008	3.60± ±0.004
Milk fat, kg	213.6± ±2.47	220.8± ±3.09	232.2± ±3.33	220.0± ±2.62
"Named after Volovikov" LLC, Polissia zone				
Yield, kg	5228± ±75.1*** 3	5680± ±93.0*** 3	6062± ±76.6** 2	4911± ±70.5*** 3
Fat, %	3.65± ±0.004*** 3	3.64± ±0.005*** 3	3.61± ±0.004 3	3.63± ±0.004*** 3
Milk fat, kg	190.5± ±2.72*** 3	206.6± ±3.34** 3	218.1± ±2.70** 3	178.2± ±2.52*** 3
Research farm «Askaniiske» SE, steppe zone				
Yield, kg	6415± ±77.7***	6731± ±62.8***	6581± ±138.0	6248± ±64.2
Fat, %	4.09± ±0.019***	4.05± ±0.018***	4.07± ±0.017***	4.11± ±0.017***
Milk fat, kg	261.5± ±3.16***	271.6± ±2.54***	267.4± ±2.91***	256.6± ±2.70***

Table 4. Milk productivity of mature cows of the Ukrainian Black-and-White dairy breed depending on the season of birth

Sign	Season of birth			
	spring (n=245)	summer (n=137)	autumn (n=111)	winter (n=221)
"Oleksandrivske" SE, forest steppe zone				
Yield, kg	6837± ±80.0	6987± ±111.2	7117± ±129.1	6802± ±87.1
Fat, %	3.57± ±0.005	3.56± ±0.007	3.59± ±0.009	3.58± ±0.006
Milk fat, kg	243.7± ±2.83	248.9± ±3.94	255.2± ±4.65	243.2± ±3.12
"Named after Volovikov" LLC, Polissia zone				
Yield, kg	5876± ±65.6*** 3	6243± ±91.6*** 3	6635± ±70.5*** 3	5812± ±73.8*** 3
Fat, %	3.64± ±0.005*** 3	3.62± ±0.007*** 3	3.68± ±0.007*** 3	3.65± ±0.005*** 3
Milk fat, kg	213.9± ±2.36*** 3	226.1± ±3.30*** 3	244.4± ±2.65* 3	212.2± ±7.71*** 3
Research farm «Askaniiske» SE, steppe zone				
Yield, kg	7100± ±107.6*	7275± ±90.9*	7305± ±90.4	7007± ±83.3
Fat, %	3.99± ±0.014***	4.02± ±0.015***	4.02± ±0.017***	4.01± ±0.013***
Milk fat, kg	283.2± ±4.30***	291.7± ±3.65***	293.1± ±3.78***	280.3± ±3.21***

the forest steppe zone by 188–288 kg, 0.42–0.45% and 37.1–42.8 kg (the exception was the yield in autumn and winter periods between cows from the steppe and Polissia zones, the difference is not significant).

In our opinion, intergroup differentiation based on milk productivity between cows of different years and seasons of birth is caused by the action of a complex of natural (climatic) factors, care, maintenance and feeding (quantity and quality of fodder, nutritional balance of diets, etc.). However, there was no significant intergroup one-way difference in fat content in the milk of cows of different seasons of birth.

The results of our research show that among the studied environmental factors, the year of birth had the most significant effect on fertility and fat content in milk, and it was stronger in firstborns (table 5). It is worth noting that the fat content in cows' milk was also significantly influenced by their breeding zone. At the same time, the last factor had the greatest impact on milk fat output: 61.97% in first-calf heifers and 54.62% in adult cows.

The studied characteristics of milk productivity for both lactations were least affected by the season of the cows' birth. Although it is worth noting that the calculated indicators of the influence of the studied systematic factors of the environment on yield, the fat content in milk and the amount of milk fat in all cases were highly significant. We believe that in order to minimize the reliable influence of the factors "herd", "year" and "season of birth" of animals, it is necessary to create a strong fodder base in each farm, proper maintenance and breeding of heifers, and in the hot season to carry out forced ventilation of the premises.

Table 5. The influence of environmental factors on the formation of milk productivity of cows, %

Indicator	Lactation			
	I		III	
	$\eta_x^2 \pm m_\eta$	F	$\eta_x^2 \pm m_\eta$	F
The influence of the breeding zone on the milk productivity				
N of degrees of freedom of the factor:				
organized	2		2	
unorganized	3477		3477	
Yield, kg	8.95±0.057***	170.9	8.81±0.057***	168.0
Fat, %	21.91±0.055***	487.7	17.93±0.056***	379.8
Milk fat, kg	61.97±0.035***	2832.8	54.62±0.040***	2092.3
The influence of the year of birth on the milk productivity				
N of degrees of freedom of the factor:				
organized	9		9	
unorganized	3470		3470	
Yield, kg	29.57±0.237***	161.9	19.05±0.250***	90.7
Fat, %	22.77±0.246***	113.7	16.36±0.252***	75.4
Milk fat, kg	4.60±0.259***	18.6	1.51±0.259***	5.9
The influence of the season of birth on the milk productivity				
N of degrees of freedom of the factor:				
organized	3		3	
unorganized	3476		3476	
Yield, kg	4.04±0.086***	48.8	2.13±0.086***	25.2
Fat, %	3.65±0.086***	43.9	2.55±0.086***	30.3
Milk fat, kg	0.89±0.086***	10.4	1.36±0.086***	15.9

Conclusion

Formation of milk productivity of cows of the Ukrainian Black-and-White dairy breed was significantly influenced by their breeding zone. Animals bred in the steppe zone were characterized by the highest milk yield, milk fat content, and amount of milk fat during the first and third lactations, and the lowest by individuals from the Polissia zone. Curvilinear intergroup differentiation based on milk productivity was also noted in animals with different years and seasons of birth. In the forest steppe zone, the highest productivity was noted for first-calf heifers born in 2011, in the Polissia and steppe zones in animals born in 2015. During the third lactation, cows born in 2015 were the most productive in all breeding zones. The highest milk yields in the "Oleksandrivske" SE and the "Named after Volovikov" LLC were obtained from the first-calf heifers born in the autumn period, and in the Research Farm "Askaniiske" SE in summer. During the third lactation, the most productive cows in all farms were cows born in the autumn months. The year of birth and breeding zone of cows had the most significant influence on fertility and milk fat content, and the season of birth had the least effect.

References

1. Chemysova V, Kramar N. Seasonality of birth and its effect on milk productivity of cows. *Anim. Husb. Ukraine*. 2012; 1–2: 6–9. (in Ukrainian)
2. Collier RJ, Dahl GE, VanBaale MJ. Major advances associated with environmental effects on dairy cattle. *J. Dairy Sci.* 2006; 89 (4): 1244–1253. DOI: 10.3168/jds.S0022-0302(06)72193-2.
3. Fedorovych YI, Fedorovych VV, Mazur NP, Bodnar PV, Fil SI. The influence of environmental factors on the dairy productivity of cows. *Bull. SNAU. Ser. Livestock.* 2019; 3 (38): 44–53. DOI: 10.32845/bsnau.lvst.2019.3.7. (in Ukrainian)
4. Gladiy MV, Polupan YP, Bazyshina IV, Bezrutchenko IM, Polupan NL. The influence of genetic and paratypic factors on the economically useful traits of cows. *Anim. Breed. Gen.* 2014; 48: 48–61. (in Ukrainian)
5. Khmelnychyi LM, Pryimachok VV, Prokopovych MO, Kholod SO, Hryshyn SY. Dependence of dairy productivity cows of Ukrainian Red-and-White Dairy breed on genotypic and paratypic factors. *Bull. SNAU. Ser. Livestock.* 2021; 1 (44): 23–28. DOI: 10.32845/bsnau.lvst.2021.1.3. (in Ukrainian)
6. Khmelnychyi LM, Salogub AM, Shariy SV. Influence of genotypic and paratypic factors on the level of the suckling productivity of cows of the Ukrainian Red-and-White milk breed. *Anim. Breed. Genet.* 2011; 45: 299–308. (in Ukrainian)
7. Khomyak OA. Impact of climate change on the health and productivity of farm animals. *Collection of theses of the International practical conference with the FAO participation "Climate change and agriculture. Challenges for agricultural science and education"*. 2018: 239–242. (in Ukrainian)
8. Kozyr VS, Kovalenko VP, Hekkiyev AD. Productivity of Holstein of various environmental and genetic generation and Ukrainian Black-and-White dairy breeds in conditions of the steppe zone of Ukraine. *Anim. Breed. Gen.* 2017; 53: 130–139. DOI: 10.31073/abg.53.17. (in Ukrainian)
9. Lakin GF. *Biometry*. A textbook for biol. spec. univer. 4th ed., rev. suppl. Moscow, Higher School, 1990: 352 p.

10. Nosevych DK, Verbelchuk IM. The influence of seasonal factors on the dairy heifers productivity. *Sci. Bull. NULES Ukraine. Ser. Technol. Prod. Proc. Anim. Husb. Prod.* 2018; 289: 170–177. Available at: http://journals.nubip.edu.ua/index.php/Tekhnologiya/article/view/11765 (in Ukrainian)
11. Piddubna LM, Zakharchuk DV, Korniychuk DO. Evaluation of influence of the factor complex on milk productivity of cows. *Bull. SNAU. Ser. Livestock.* 2021; 2 (45): 113–120. DOI: 10.32845/bsnau.lvst.2021.2.17. (in Ukrainian)
12. Polishchuk TV. Impact of birth season on productive characteristics of cows. *Agr. Sci. Food Technol.* 2019; 4 (107/1): 113–122. Available at: http://techfood.vsau.org/en/particles/impact-of-birth-season-on-productive-characteristics-of-cows (in Ukrainian)
13. Polupan YP. Ontogenetic and selection regularities of the formation of economically useful traits of dairy cattle. Thesis. Dr. S.-Mr. Sci. Chubynske, 2013: 694 p. (in Ukrainian)
14. Polupan YP, Bazyshyna IV, Bazyshyna AY, Pochukalin AY, Pryyma SV, Polupan NL. Influence of year and season on milk productivity of cows. *Anim. Breed. Gen.* 2022; 63: 71–90. DOI: 10.31073/abg.63.08. (in Ukrainian).
15. Poppe M, Mulder HA, Kamphuis C, Veerkamp RF. Between-herd variation in resilience and relations to herd performance. *J. Dairy Sci.* 2021; 104 (1): 616–627. DOI: 10.3168/jds.2020-18525.
16. Poslavska JV, Fedorovych YI, Babik NP. The influence of season of birth and calving on their dairy production. *Sci. Herald LNUVMB. Ser. Vet. Sci.* 2015; 17 (3): 297–302. (in Ukrainian)
17. Reznikova NL. The influence of the season of birth and first calving on the main selected traits of dairy cows. *Sci. Bull. "Ascania Nova".* 2009; 2: 89–97. (in Ukrainian)
18. Salogub AM. The influence of genotypic and paratypic factors on the characteristics of dairy products-activity of cows of the Ukrainian Red-and-White dairy breed. *Bull. SNAU. Ser. Livestock.* 2019; 3 (38): 37–43. Available at: http://nbuv.gov.ua/UJRN/Vsna_tvar_2019_3_7 (in Ukrainian)
19. Sklyarenko YI. Features of milk productivity of cows of Ukrainian brown dairy breed and the influence of genotypical and paratypical factors on its formation. *Sci. Mess. LNUVMB. Ser. Argicult. Sci.* 2018; 20 (89): 8–16. DOI: 10.32718/nvlvet8902. (in Ukrainian)
20. Vedmedenko OV. The effect of genotypes and paratype factors on cow productivity. *Podilian Bull. Agricult. Engineer. Econom.* 2019; 1 (30): 31–38. DOI: 10.37406/2706-9052-2019-1-4. (in Ukrainian)
21. Voytenko SL. The possibility of increasing milk productivity in cows of local breeds. *Bull. PSAA*. 2016; 4: 72–75. Available at: https://www.pdau.edu.ua/sites/default/files/visnyk/2016/04/16.pdf (in Ukrainian)
22. Voytenko SL, Karunna TI, Shaferivsky BS, Zheliznyak IM. Influence of genotypic and paratype factors on realization of dairy productivity of cows. *BullAU. Ser. Livestock*. 2019; 1–2: 21–26. DOI: 10.32845/bsnau.lvst.2019.1-2.3. (in Ukrainian).
23. Yefimenko MY. Formation the inbred structure of dairy cattle created breeds. *Anim. Breed. Genet.* 2012; 46: 50–53. (in Ukrainian)

Прояв ознак молочної продуктивності корів у різних кліматичних зонах розведення залежно від року та сезону їх народження

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Наведено дані щодо впливу чинників довкілля на формування молочної продуктивності корів у різних кліматичних зонах України. Встановлено, що найвищі надої, вміст жиру в молоці та вихід молочного жиру були у тварин, яких розводять у зоні Степу, а найнижчі — в особин із зони Полісся. Між коровами з різних зон розведення також спостерігали міжгрупову диференціацію за ознаками молочної продуктивності залежно від року і сезону їх народження. У зоні Лісостепу найвищою продуктивністю відзначалися первістки, які народилися у 2011 р., у зоні Полісся та Степу — тварини 2015 р. народження, а за третю лактацію у всіх зонах розведення найпродуктивішими виявилися корови, народжені у 2015 р. Криволінійну міжгрупову диференціацію за ознаками молочної продуктивності відзначили і між тваринами з різними сезонами народження. Найвищі надої у ДП ДГ «Олександрівське» і ТОВ СП «Імені Воловікова» одержано від первісток, які народилися в осінній період, а в ДП «Дослідне господарство «Асканійське» — в особин, народжених влітку. За третю лактацію у всіх зонах розведення найпродуктивнішими були корови, народжені в осінні місяці і перше отелення яких припадало на весняний період у зоні Степу, на осінній — у зоні Лісостепу та Полісся. Найсуттєвіший вплив на надій та вміст жиру в молоці мали рік народження та зона розведення корів, причому сильнішим він був у первісток, а найменше на ознаки молочної продуктивності впливав сезон народження тварин.

Ключові слова: корови, зона розведення, рік і сезон народження, молочна продуктивність, сила впливу

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Productivity energy level of cows of Gray Ukrainian breeds and their reproductive qualities

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We have studied the reproductive abilities of the animals and the development of the offspring during the post-sucking period on cows of the Gray Ukrainian breed in the 1st–3rd lactations. To evaluate the cows and the offspring, in addition to traditional signs, indicators of net energy of body maintenance and net energy of growth were introduced, as integrated indicators of the state of the organism, which depend to a greater extent on the origin than on the conditions of keeping. We have established that the researched population of animals of the Gray Ukrainian breed in the ecological and fodder conditions of the steppe zone of Ukraine shows excellent maternal instincts, reproductive function and small foetus rate not lower than the standard for the breed, almost equal distribution of offspring by sex. The yield of calves per 100 cows is 97–98%, live weight of calves at birth is 25–26 kg for heifers and 27–28 kg for bulls; high milk yield: the weaning live weight at 8 months of age is 200 kg for heifers and 230 kg for bulls, the service period of cows for 1–3 lactation period is 155–91 days, the intercalving period is 433–371 days, the small foetus coefficient is 0.54–0.49, net energy for maintaining vital activity in cows is 40–45 MJ and in newborn calves — 4.5–4.6 MJ, the net energy of growth of young calves when weaned from their mothers is 19–20 MJ and for the entire period of suckling is 3800–4900 MJ. In the section of lactations, correlational dependences were established between the net energy of maintaining cows and their offspring, which makes it possible to carry out more purposeful selection and selection of animals for further breeding and preservation of the herd of this breed.

Key words: energy, breed, cows, offspring, productivity, growth, reproduction

Introduction

The Gray Ukrainian breed is characterized by high adaptation to ecological, climatic (high temperatures) and fodder (pasture-free maintenance) conditions of maintenance and productive use in the steppe zone of Ukraine, small foetus and high stress resistance [2–4, 11]. It is characterized by strong constitution, calm temperament, manufacturability, longevity (10–12 years and more), harmonious physique, long stature (over a long period, average daily gains are 1000 g/day), high conversion of feed into products, and resistance to common infectious and invasive diseases, the proportionality of the development of muscle tissue, the slaughter yield is within 58–60%, the meat index is 4.0–4.5, the ratio of protein to fat in the carcass is 1 : 1,

the obtained beef has good taste qualities (juiciness, aroma, tenderness) and culinary properties (cooking), the pH of the meat is 6.7–6.9, which contributes to the long-term storage of the product and attracts the consumer [1, 6, 13].

The use of modern breeds of cattle is mainly aimed at increasing their productivity. At the same time, the reproductive capacity of the breeding stock naturally decreases, which negatively affects the effectiveness of breeding the only gene pool of the Gray Ukrainian breed in Ukraine, which is kept in production conditions. Preservation of this autochthonous meat cattle involves the expansion of the population array, stabilization of the genetic potential of growth energy and prevention of a decrease in reproductive functions for its further reproduction, which is relevant for the breeding process in the meat cattle breeding of Ukraine and ensuring the diversity of the biocenosis in the world [5, 7, 8].

Materials and methods

In the experimental farm "Polyvanivka" of the State Institution "Institute of Grain Crops of the National Academy of Agrarian Sciences of Ukraine" from the total population of clinically healthy 266 cows of the Gray Ukrainian breed, the 189 cows with live weight 470–500 kg were selected for the first lactation. The research was conducted during three lactations: on the second lactation on 177 cows and the third lactation on 158 cows (the decrease in the number of cows occured due to the elimination of animals for various production reasons). The subjects of the study were cows and calves of the Gray Ukrainian breed. The subject of research was reproductive capacity and energy potential (status) of cows and calves.

Cows in the summer period were kept untethered on a walking and feeding area (20 m^2 per animal) with a hard surface, the feeding front was 1.2 m/animal. In the winter period cows were kept tethered and fed 2 times a day. In summer the ration consisted of green mass of cereal and leguminous herbs, hay, straw and concentrates. In winter it contained corn silage, hay, straw and concentrates. The specific weight of concentrates in the rations was 9–18%.

Cows consumed 2.2–2.5 kg of dry substance (DS) per 100 kg of live weight with an energy concentration 8.5–9.2 MJ/kg DS and 10–12 g of crude protein in 1 kg of DS. The particle size of coarse (hay, straw), juicy (silage) and green feed was 5–7 cm. The animals had constant free access to mineral feed (table salt, tricalcium phosphate, monocalcium phosphate, chalk). Watering was carried out freely from troughs with fresh water every day.

Calves up to 8 months of age were kept on free suckers with free access to hay and concentrates after one week of age. Calves were weighed every month to determine average daily gains. Before 5–10 days calving, at the beginning of the suckling period (35–45 days) and after 70–80 days, the condition (fatness) of cows was determined according to the author's 5-point method [9]. In order to find non-traditional methods of assessing the individual development of young animals and the reproductive capacity of animals of various origins, the energy status of cows was determined by the net energy of support of the cows themselves and the net energy of support and growth of the offspring according to the method of V. V. Tsyupko et al. [12].

The energy needs of animals for support are determined by the heat output of the animal's body in thermoneutral conditions. In numerous experiments, it was established that heat losses for animals of different live weights, especially within the boundaries of animals of the same species, are the same or close in terms of a unit of live weight to the degree of 0.75 ($LW^{0.75}$), which may be determined by the features of the form body, as well as participation in the heat transfer of the lungs. Based on this, it is customary to call $LW^{0.75}$ the exchangeable or metabolic body weight. The need for energy for the basic (starvation) metabolism of any living organism without the costs of receiving and processing food can be considered a primary need for energy.

It was established that, on average, for all species of animals, the basic metabolism is about 70 kcal or 293 kJ per 1 kg of $LW^{0.75}$. The basic metabolism in heifers and castrated bulls is 15% higher and amounts to 335 kJ, and in cows and non-castrated bulls it is about 400 kJ per 1 kg of $LW^{0.75}$ [12].

The net needs for the increase in live weight represent the energy content in the daily increase. The energy content of 1 kg of gain depends mainly on the live weight of animals, with a much smaller influence of the level of this gain.

The calculation of energy deposition in the daily gain of castrate bulls was determined by the equation:

$$NEFD = \frac{LWG\ (4.1 + 0.0332LW - 0.000009LW^2)}{(1 - 0.1475LWG)},$$

where NEFD — net energy of fat deposition (gain), MJ/day;
LWG — live weight gain, kg per day;
LW — live weight, kg.

The energy content in the growth of heifers is 15% higher, and in uncastrated bulls it is 15% lower than in castrated bulls.

According to the given method, based on the live weight of cows and young animals, the expenses for basic metabolism (net maintenance energy) were determined per decade, and the net energy of growth was determined once a month. Data for the entire period of suctioning were calculated by summing up the monthly results. In the section of 3 lactations, the correlations between the energy of the basic metabolism of cows and offspring were calculated.

The research results were processed statistically according to Plokhinsky [10].

Results and Discussion

Long-term studies of the reproductive capacity of the Gray Ukrainian breed of cattle of the experimental farm "Polyvanivka" (over 40 years) testify to the consolidation of this population, and the coefficient of variation of individual traits confirms the possibility of effective selection and breeding work in the herd.

Each calving took place in good sanitary conditions. During the first 2–3 months, a newborn heifer (future cow) received at least 500 liters of milk, and from the age of one week it was given enough hay and concentrated fodders. Special attention was paid to puberty and fertilization, which are influenced by the environment, stresses, microclimate, feeding, drinking, diseases — controlled management (planning and regulation) of appetite, service and intercalving periods in each lactation was established.

It was established (table 1) that with an increase in the number of lactations, the duration of the service period decreases, which contributes to a more complete manifestation of the genetic potential, reproductive function of the brood stock and an increase in the coefficient of variability.

The increased duration of the service period (*lim* 29–161 days), and, therefore, the intercalving period in 2021 in cows of different ages of 1–3 lactations (*lim* 312–443 days), convinces of the need to inseminate them as soon as possible after calving. This will increase the rate of utilization of the genetic potential of the reproductive capacity of the population and ensure the stable development of the gene pool for its further use in selection work.

With an increase in the number of lactations, the coefficient of small foetus also decreases, that is, calves are born with a live weight close to the standard of the breed. Obviously, the age of the cows contributes to the involution of the reproductive organs for the development of the fetus according to the breed standard.

The condition of cows (fatness) in general characterizes the health state in animals and their energy status. For cows in the last month of pregnancy, it is desirable that it should be at the level of 3.5–4.0 points. During the experiment, it was established that 5–10 days before calving, the condition of cows (n=16) was 2.61±0.102 points (Cv=15.6%), 30–35 days after calving — 2.30±0.164 points (Cv=16%), and on the 70–80th day of the suckling period — 2.23±0.096 points (P>0.95; Cv=14.8%).

The energy of cows to some extent determines not only their viability, but also creates prerequisites for the energy formation in the offspring (table 2).

The energy to support the vital activity of suckling cows increased dynamically with the next calving as their live weight increased (continued growth of the firstborns). So, compared to the first lactation, it was 7.7% more in the second, and 11.4% in the third. At the same time, with an increase in the number of lactations of cows, there was no increase in the net energy of life support in newborn calves, which indicates that their live weight is balanced regardless of the age of the cows, and that the parents' low fertility is consolidated. In this regard, in order to preserve the gene pool of the Gray Ukrainian breed, it is advisable to select young animals for further use, one-third from cows of each of the first three lactations. Data on the net energy of calf support are presented in table 3.

In general, the energy of the mother has a positive effect not only on the development of the fetus, but also on the further life of newborn calves during the weaning period, on their growth energy. However, the net energy of progeny maintenance during the suckling period practically did not depend on the age of the cows during

Table 1. Reproductive capacity of cows

Lactation	Biometric data			
	X±Sx	σ±Sx	lim	Cv±Sx
Service-period, days				
I	155.4±8.26	113.6±5.84	36–161	73.1±3.76
II	130.5±9.34	123.6±6.61	33–142	94.7±5.06
III	91.3±7.47	124.1±6.69	29–102	95.6±5.44
Intercalary period, days				
I	438.6±8.26	113.8±5.83	388–443	25.9±1.32
II	412.3±9.38	124.8±6.63	359–417	30.2±1.60
III	354.1±8.73	129.1±6.74	312–361	31.4±1.68
Coefficient of small fertility, unit				
I	5.4±0.04	0.56±0.029	3.8–7.7	10.4±0.53
II	4.9±0.04	0.55±0.031	3.4–7.4	11.2±0.64
III	5.0±0.04	0.55±0.032	3.5–7.3	10.9±0.49

Table 2. Energy of cows and newborn calves, MJ/day

Lactation	Biometric data			
	X±Sx	σ±Sx	Lim	Cv±Sx
Net energy to support vital activity of cows, MJ/day				
I	40.3±0.14	2.00±0.102	34.7–54.7	4.9±0.25
II	43.4±0.19	2.49±0.140	37.1–57.7	5.7±0.32
III	44.9±0.22	2.51±0.144	39.4–59.1	5.8±0.34
Net energy to support vital activity of newborn calves, MJ				
I	4.5±0.03	0.53±0.027	3.0–5.4	11.7±0.60
II	4.6±0.02	0.27±0.014	3.6–5.2	13.8±0.30
III	4.5±0.03	0.31±0.019	3.5–5.1	12.4±0.41

Table 3. Net energy of growth of calves

Lactation	Biometric data			
	X±Sx	σ±Sx	lim	Cv±Sx
Net energy to support vital activity of calves at weaning, MJ/day				
I	19.3±0.08	1.17±0.062	14,5–22,7	6.0±0.31
II	19.4±0.11	1.30±0.076	14,0–22,6	6.7±0.31
III	19.6±0.17	1.36±0.081	14,2–21,9	6.6±0.42
Net energy of growth of calves during the suckling period (240 days), MJ				
I	3779.8±26.6	352.31±21.287	2325–4825	9.3±0.56
II	3789.8±32.45	386.70±23.811	2400–4875	10.2±0.62
III	3805.3±33.12	391.42±21.639	2421–4816	10.9±0.74

the first three lactations (r = –0.05…+0.13), which is obviously related to the optimal conditions of feeding and maintenance during the period of the mothers' body and the standard for breeds with calf weight at birth. There is a slight correlation of net energy expenditure for the maintenance of vital activity of young animals at birth and at weaning (r=0.185).

Correlation analysis shows that the relationship between the live weight of cows, the net energy of their body and the net energy of maintaining the organism with the growth intensity of offspring in the embryonic and post-embryonic periods and their net energy is weak, and in the connection of the reproductive function with the energy of the offspring, it is even negative.

At the same time, according to most indicators, there is a certain tendency to improve relations with the age (lactation) of cows. This regularity can be used in further selection and breeding work with the population.

Table 4. Correlation between the net energy of maintaining cows and calves and reproductive functions of cows (n=134)

Correlation relationship	Lactations		
	1	2	3
ES — net energy of support, — service-period	0.07±0.086	0.13±0.092*	–0.07±0.099
NE of cow — ICP	0.07±0.086	0.13±0.092*	–0.07±0.099
Service-period — NE growth of the calf during the suckling period	–0.03±0.086	0.14±0,092*	0.02±0.099
ICP — NE growth of the calf during the suckling period	–0.03±0.086	0.14±0.092*	0.02±0.099
Service-period — NES at the birth of the calf	–0.03±0.086	–0.05±0.094	0.04±0.099
ICP — NES at the birth of the calf	–0.03±0.086	–0.05±0.094	0.04±0.099
Service-period — NES when the calf is weaned	–0.04±0.086	0.13±0.092*	0.03±0.099
ICP — NES when the calf is weaned	–0.04±0.086	0.13±0.092	0.03±0.099

Note. LM — live mass, NE — net energy of the body, NES — net energy of support, SP — service-period, ICP — inter calvings period; * — P<0.2.

Conclusions

1. Long-term research into the reproductive capacity of Gray Ukrainian cattle at the "Polyvanivka" research farm shows the consolidation of animals of this population and the possibility of effective selection and breeding work in the herd.

2. A decrease in the duration of the service period with an increase in the number of calving cows implies impregnation of most cows in the first heat.

3. There is a weak correlation between the reproductive function of cows and the intensity of offspring growth with some tendency to improve with the age (lactation) of their mothers.

References

1. Basovskiy DM. Modern problems of maintenance of Ukrainian local and small breeds of cattle by method of *ex situ*. *Anim. Breed. Genet*. 2015; 49: 221–224. (in Ukrainian)
2. Eisner FF. On the conservation of gray Ukrainian cattle. *Sci. Tech. Bull. South. VASKHNIL Res. Inst. Anim. Husb. LIP Ukrainian SSR*. Kharkiv, 1986; 44: 3–4. (in Ukrainian)
3. Hodovanets LV, Humennyi VD. We save Gray Ukrainian. *Anim. Husb. Ukr*. 1987; 4: 68–69. (in Ukrainian)
4. Humennyi VD. Interabreed selection at preservation of genefond of the Gray Ukrainian breed. *Anim. Breed. Genet*. 2009; 43: 108–115. (in Ukrainian)
5. Humennyi VD, Vovk SO, Vuytsyk Y, Pilyarchyk R. Methodological and organizational measures to preserve the gene pool of Gray Ukrainian cattle breeds. *Sci. Herald LNUVMB. Ser. Vet. Sci.* 2014; 16 (2/3): 69–75. (in Ukrainian)
6. Kozyr VS, Barabash VI, Oliynyk SO, Chegorka PT. *Gray Ukrainian cattle: past, present, future*. A monograph. Dnipropetrovsk, Delita Publ., 2008: 243 p. (in Ukrainian)
7. Kozyr VS, Denysyuk OV, Khalak VI, Dimchya HG, Maistrenko AN, Sokrut OV. The concept of purposeful preservation of Gray Ukrainian rock and its use in the subsequent rock-forming process: The guidelines. Dnipro, Nova Ideology publ., 2020: 62 p. (in Ukrainian)
8. Mokhnachova NB. Peculiarities of the genetic structure of Gray Ukrainian breed cattle by complex genotypes. *Anim. Breed. Genet*. 2018; 55: 235–242. (in Ukrainian)
9. Petrenko VI, Mykhalchenko SA, Dimchya GG, Maistrenko AN. *Improved Parameters of Standardized Feeding of High-Yielding Dairy Cattle of Ukraine*. The scientific and practical recommendations. Dnipropetrovsk, University of ISGSZ NAAS, 2015: 86 p. (in Ukrainian)
10. Plokhinsky NA. *Guide to Biometrics for Livestock Specialists*. Moscow, Kolos, 1969: 256 p.
11. Reznikova Y, Polupan Y, Dzhus P. Natural resistance of the Ukrainian Gray cows. *Biol. Tvarin*, 2016; 18 (1): 111–116. DOI: 10.15407/animbiol18.01.111. (in Ukrainian)
12. Tsyupko VV, Pronina VV, Vasilevsky NV, Zlobina GS. Rated feeding of cattle of dairy and combined directions of productivity. The methodological recommendations). Kharkiv, IZH UAAN, 1995: 77 p. (in Ukrainian)
13. Vdovychenko YV, Fursa NM. The productivity and reproductive qualities of animals of the cattle of Gray Ukrainian breed of Ascanian selection. *Sci. Bull. Askania Nova*. 2017; 10: 157–166. (in Ukrainian)

Енергетичний рівень продуктивності корів сірої української породи та їхні репродуктивні якості

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На коровах сірої української породи у 1–3-й лактацій вивчали відтворювальні здатності тварин і розвиток молодняку впродовж підсисного періоду. Для оцінювання корів і молодняку, крім традиційних ознак, ввели показники чистої енергії підтримки тіла і чистої енергії приросту як інтегрованих показників стану організму, які більше залежать від походження, ніж від умов утримання. Встановлено, що досліджуване поголів'я тварин сірої української породи в екологічних і кормових умовах степової зони України проявляє відмінні материнські інстинкти, відтворну функцію і дрібноплідність, не нижчу від стандарту породи, практично рівнозначну розподілу приплоду за статевою ознакою: вихід телят на 100 корів становить 97–98%, маса тіла телят при народженні — 25–26 кг (телички) і 27–28 кг (бугайці); а також високу молочність: маса тіла молодняку при відлученні у 8-місячному віці становить 200 кг для телиць і 230 кг для бугайців, сервіс-період корів за 1–3-ю лактації — 155–91 днів, міжотельного періоду — 433–371 день; коефіцієнт дрібноплідності — 0,54–0,49, чиста енергія підтримки життєдіяльності корів — 40–45 МДж, новонароджених телят — 4,5–4,6 МДж, чиста енергія приросту молодняку за відлучення від матерів — 19–20 МДж і за весь період підсосу — 3800–4900 МДж. У розрізі лактацій встановлено кореляційні залежності між чистою енергією підтримки корів і їхнього приплоду, що дає можливість цілеспрямованіше проводити відбір і підбір тварин для подальшого розведення та збереження стада цієї породи.

Ключові слова: енергія, порода, корови, приплід, продуктивність, приріст, відтворення

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Lipid composition and peroxidation products in the body tissues in bees under the action of different doses of nanotechnological Ge citrate and the probiotic *Lactobacillus casei* B-7280

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RSF: Conceptualization; Data curation; Formal analysis; Investigation.
MMT: Writing — review & editing.
IIK: Data curation; Formal analysis; Investigation; Methodology; Resources; Software.
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Modern methods of preserving honey bees focus on increasing their viability, feeding level and productivity development during different growth periods. There is a tendency to use new effective remedies of natural origin. Their action mechanisms differ from synthetic substances and drugs due to the activation of the body's protective reactions at the physiological level. The probiotic *Lactobacillus casei* IMV B-7280 has an effective stimulating effect on physiological processes in bees under various environmental and experimental conditions. The physiological effect of this probiotic is associated with normalizing of the intestinal bacterial microflora and participation in modulating body's protective reactions. The resistance of honey bees also depends on mineral nutrition, which affects metabolic processes at the tissue, organ and system levels and determines the vitality and resistance of the organism. Mineral elements are involved in protein, lipid, carbohydrate and energy metabolism, they activate enzyme systems. Therefore, the aim of the research was to determine the effect of the probiotic *L. casei* B-7280 in combination with different doses of Ge nanotechnological citrate (NTC) on the lipid composition and peroxidation products content in bees' tissues. Bees of the control group were fed 60% sugar syrup (SS) in the amount of 1 cm^3/group/day. The bees of the first experimental group (R1) were fed 1 cm^3 of SS, 0.1 μg of Ge NTC and a solution of probiotic *L. casei* B-7280 (10^6 cells/cm^3); the second experimental group (R2) received 0.2 μg of Ge citrate and probiotic *L. casei* B-7280 (10^6 cells/cm^3). The feeding duration was 34 days. It was established that feeding sugar syrup, *L. casei* and different doses of Ge citrate increased the content of phospholipids, mono- and diacylglycerols in the R2 group, cholesterol esterification in the R1 group, and decreased free cholesterol, non-esterified fatty acids compared to the K group and P period. The results indicate a dose-dependent effect of Ge NTC on lipid metabolism in body tissue homogenates. There was an increase in the triacylglycerols level in the lipids in all groups during the experimental period. The biological effect of nanotechnological Ge citrate and *L. casei* cause a decrease of lipid peroxidation processes in bees of the experimental groups.

Key words: bees, Ge citrate, probiotic, lipids, peroxidation products

Introduction

In addition to beekeeping products, the honeybee (*Apis mellifera*) plays an essential role in preserving biodiversity, ecosystem stability, and agricultural production by pollinating entomophilous plants, which increases its yield. In recent decades, the honeybee population's significant losses have threatened the ecosystem and the country's food security. Under these conditions, researchers and beekeepers pay special attention to factors that worsen the body's resistance, the functional state of its systems, and the productivity of bees. Therefore, the scientific support of modern beekeeping is aimed at obtaining safe ecological products, developing means and methods for stimulating reproduction, increasing the resistance of bees to various pathogens, and protecting them from adverse environmental conditions [21]. It has been shown that the influence of abiotic, biotic origin, and anthropogenic activity disrupts physiological processes in the body of *A. mellifera*, suppressing the antioxidant and immune systems, which leads to the death of entire colonies [1, 19, 29].

Therefore, today, an extremely urgent task is to find new means and BARs for activating the protective systems of the honeybee and to find out the mechanisms of their beneficial effects. The honeybee's defense responses include cellular and humoral responses that combine interconnected systems, including antibacterial peptides, hemagglutinins, phenoloxidase, and antioxidant systems (AOS). Under normal conditions, there is a balance between the generation of reactive oxygen species (ROS) and antioxidant processes. Oxidative stress occurs when the dynamic balance between the formation of ROS exceeds the ability of antioxidant protection to remove the toxic substances formed. Many studies have linked oxidative stress to stressors affecting honeybee health and colony productivity. Low temperature, high flight activity, pathogenic microorganisms in hives, and pesticides used to control pests on various crops disrupt the oxidative homeostasis of honeybees [25, 27].

Deterioration of the forage base or its sudden change is one factor that negatively affects the health of bees and the development of colonies and can cause their death [14, 33]. A deficiency of feed or a slight violation of the component composition can weaken the AOS, detoxification, and immune systems of bees, resulting in their body becoming more vulnerable to chemical plant protection drugs and diseases of various etiologies.

These factors contribute to the excessive generation of ROS in the body of bees, which leads to the development of oxidative stress [17]. Reactive oxygen species can react with polyunsaturated fatty acids of lipid membranes and induce lipid peroxidation (LPO), affecting cell membranes' physiological function. The final product of these reactions is malondialdehyde (MDA), a marker of LPO and, as a result, the oxidative stress. Therefore, there is a trend of active study of new effective means of natural origin to fight diseases and improve honey bees' health, which helps to avoid many side effects. It has been proven that the mechanisms of their action differ from synthetic substances and drugs due to the activation of the body's protective reactions at the physiological level [9, 11, 32].

Research on the physiological justification of the use of probiotics, the antibacterial and antifungal properties of which are due to high antagonistic activity against a wide range of pathogenic and conditionally pathogenic microorganisms, and the possibility of their synergistic combination with microelements, deserve special attention in the system of prevention of bee diseases [21, 24].

It is known that a well-balanced structure of the intestinal bacterial microflora of honey bees is the basis for their physiological growth, development, reproduction, strengthening of the immune response, and resistance to the action of pathogens [4, 21].

The probiotic *Lactobacillus casei* IMV B-7280 is characterized by an excellent therapeutic effect in various experimental infectious-inflammatory models [8, 23, 24]. The physiological effect of this probiotic is associated with the normalization of the intestinal bacterial microflora and participation in the modulation of inflammatory reactions. In the gastrointestinal tract, probiotics exert both a direct effect on pathogenic and conditionally pathogenic microorganisms and an indirect effect by activating specific and nonspecific protective systems of the body [8, 21].

It is known that the vital activity of the organism of honey bees also depends on mineral nutrition, which affects metabolic processes at the level of tissues, organs, and systems and affects the vitality and resistance of the organism [7, 22]. They participate in protein, lipid, carbohydrate, and mineral metabolism, activate enzyme systems, etc. Literary data indicate the possibility of using biotic trace elements produced by nanotechnology as highly active compounds in animal husbandry and veterinary medicine [3, 7, 20].

Adding some elements to bee feed, as metabolic stimulators of organic and inorganic origin, introduced in different doses, affects the correction of physiological and biochemical processes and increases their productivity and resistance [11, 20, 36]. Such mineral components include Co, Ge, Se, Cr, Ni, and others. The results of previous studies of the Institute of Animal Biology NAAS using citrates of certain microelements and probiotics [21, 31] provide a theoretical basis for developing new nano- and biotechnological means and drugs to increase the resistance and reproduction of bees. The effect of various amounts of mineral and organic compounds obtained based on nanotechnological citrates on the metabolic processes of the bees' bodies was clarified. Several works were published based on the research results [7, 9, 19, 20]. It has been established that adding nanocarboxylates of biotic elements is more effective than their mineral salts in bee feeding [21]. However, the biological effect of the newly synthesized nanotechnological mineral element Ge in combination with probiotic preparations of the *L. casei* B-7280 class has not been studied.

In connection with the purpose mentioned above of the research, we determined the effect of the probiotic drug *Lastobasillus casei* IMV B-7280 in combination with different doses of germanium citrate on the lipid composition and the content of lipid peroxidation products in the bees body.

Materials and Methods

Conducting the research

The research was conducted on the Carpathian breed honey bees, selected from the laboratory apiary of the Institute of Animal Biology NAAS. The research used the lyophilized probiotic strain *Lactobacillus casei* IMV B-7280, which was isolated in the department of problems of interferon and immunomodulators from the associated culture of biological material and deposited in the Ukrainian Collection of Microorganisms of the Zabolotny Institute of Microbiology and Virology NAS of Ukraine. The research was carried out under the conditions of a laboratory thermostat on three bee colonies, similar in weight, colony strength, and queen age. From this, 50–60 bees were selected and formed into three groups. Bees of the control and experimental groups were kept in cages-containers with a volume of 4 dm^3 in similar conditions of a TC-80M-3 laboratory thermostat with microventilation at a temperature of 30° C and humidity of 74–76% during the study.

Bees of the control (C) group were fed 60% sugar syrup (SS) in 1 cm^3/group/day. Experimental 1 group of bees (R1) in addition to 1 cm^3 of sugar syrup received 0.1 μg of Ge in the form of nanotechnological citrate (NTC) [18] and a solution of the probiotic *L. casei* B-7280 at a concentration of 10^6 cells/cm^3; experimental group 2 of bees (R2) additionally received 0.2 μg of Ge in the form of citrate and the probiotic *L. casei* B-7280 at a concentration of 10^6 cells/cm^3.

The duration of drinking SS, Ge citrate, and probiotic is 34 days. In the preparatory period (P), as well as on the 34th day of the experimental period, live bees were selected from the control and experimental groups for physiological and biochemical studies to determine the content of total lipids and the ratio of their classes and products of lipid peroxidation in tissue homogenates of the entire organism.

Obtaining total lipids

Homogenized tissue (1 g) was extracted with 20 cm^3 of a mixture of chloroform-methanol in a ratio of 2 : 1 (v/v) according to the Folch method [13]. A solution of 4 cm^3 of an aqueous solution of 0.74% KCl was added to each sample of lipid extract. After 24 h, the upper phase containing hydrophobic peptides was removed with a water pump, and the lower phase containing lipids was filtered (deashed filter, blue ribbon). Lipid extracts were evaporated to dryness, weighed on an analytical balance, and calculated in mg/g.

Separation of lipids into classes

Separation of lipids into classes was carried out by the method of thin-layer chromatography on silica gel (silica gel L 5/40μ, LSL 5/40μ, *Chemapol*, Czech Republic), the mobile phase was hexane-diethyl ether-glacial acetic acid in a ratio of 70 : 30 : 1 (v/v/v). Lipid classes were shown in crystalline iodine vapors. Rf values identified lipids. Quantitative analysis and calculation of the content of individual classes of lipids were performed by computer processing of phorograms using *TotalLab TL120* software (Nonlinear Dynamics Limited, UK) and expressed as a percentage of the total amount.

Determination of lipid peroxidation products

To prepare a homogenate of tissues of the entire body of honey bees of the control and experimental groups, they were ground and formed into three parallel samples. A group of bees weighing 0.5 g was homogenized with physiological saline in a ratio of 1 : 5 using a homogenizer (*Homogenizer Type 302*, Poland) on ice. The samples were centrifuged at 3000 g for 5 minutes. The supernatant was used to measure the content of lipid peroxidation products further [35] in bee tissues on the 34th day of SS, Ge citrate, and probiotic use.

Determination of TBA reactive substances (MDA)

The basis of the method is the reaction between MDA and thiobarbituric acid (TBA), which at high temperatures and in an acidic environment forms a trimethine complex containing one MDA molecule and two TBA molecules. 5 cm^3 of 20% phosphotungstic acid was added to 0.5 cm^3 of the prepared homogenate. The tubes were closed, mixed, and left in the cold for 15 min, then centrifuged at *t* 4 C for 15 min at 2500 rpm. The supernatant liquid was drained, and 2 cm^3 of H_2O and 1 cm^3 of 0.8% TBA were added to the precipitate, mixed, covered, and incubated for 1 h in a heated bath at 100°C, then cooled in running water and centrifuged for 10 min at 6000 rpm. In the centrifuge, the optical density was measured on a spectrophotometer at 535 and 580 nm to prevent the absorption of stained complexes by TBA substances of non-lipid origin.

Determination of lipid hydroperoxide content

The precipitation of proteins determines lipid hydroperoxides' content in biological material with a solution of trichloroacetic acid and extraction of lipids with ethanol, followed by the interaction of the studied extracts with ammonium thiocyanate. 2.8 cm^3 of ethanol and 0.05 cm^3 of a 50% TChA solution were added to 0.2 cm^3 of the homogenate. The test tube was closed and shaken for 5–6 min. The resulting protein precipitate was isolated by centrifugation for 10 min at 3000 rpm. 1.5 cm^3 of the ethanol extract was taken and brought up to 2.7 cm^3 with ethanol, shaken, and 0.02 cm^3 of conc. HCl and 0.03 cm^3 of a 1% solution of Mohr's salt in a 3% solution of HCl. It was shaken, and after 30 s, 0.2 cm^3 of 20% ammonium thiocyanate was added. The optical density was measured for 10 min after adding ammonium thiocyanate on a spectro-

photometer at a wavelength 480 nm. The control sample was placed as a test sample, but 0.2 cm^3 of bidistilled water was taken instead of the homogenate.

No vertebrate animals were used in the experiments.

Statistical analysis

All obtained digital data were processed using the *Statistica* computer program using the method of variational statistics and the *Excel* program from the *Microsoft Office* 2007 and 2010 service packages. Differences between groups were considered statistically significant at P<0.05.

Results and Discussion

The analysis of the obtained research results indicates that the content of total lipids and the relative ratio of lipid classes in homogenates of body tissues of bees of the experimental groups changed compared to both the control group and the preparatory period (fig. 1, table).

An increase in the content of total lipids in the R1 and R2 groups was found, respectively, by 11.14% (P<0.05) and 7.65% (P<0.05) compared to the preparatory period (fig. 1). A significant increase in total lipids may indicate the stimulating effect of applied doses of Ge citrate and *L. casei* B-7280 on their exchange and synthesis in the tissues of honey bees. However, the absence of potential differences in the content of total lipids may indicate a minor effect of Ge in the form of citrate and the pH of the probiotic *L. casei* B-7280 on the synthesis and deposition of lipids in the body of bees.

It has been proven that the central mass of lipids in the body of bees comes from the alimentary canal and is deposited in the fat body. The chemical composition of these reserve fats depends on both the feed's composition and the body's physiological state [6].

Our research revealed changes in the ratio of lipid classes in bees' body tissues. In particular, such changes concern phospholipids, mono- and diacylglycerol (MDAG), free cholesterol, non-esterified fatty acids (NEFA), triacylglycerol, and esterified cholesterol (table). Phospholipids make up 24–28% of the total amount of lipids and predominate in the bees' body tissues in the control and experimental groups. In bees' body tissues homogenates of R1 and R2 groups, an increase in the phospholipids relative content compared to bees of the preparatory period and the control group was established by 16.79% and 17.08% (P<0.05) and 15.73% and 16.02% (P<0.05), respectively.

This class of lipids may be more synthesized in the body of bees under the action of NTC Ge and *L. casei* to enhance the functions of lipid membranes. It is known that the fatty acid composition of phospholipids of cell membranes is the main factor affecting the intensity of the transition of fatty acid nutritional components, through their active and passive transport, into bee tissues. In turn, the functioning of their nervous, immune, and reproductive systems and the oxidation process depends on the content of phospholipids and their fatty acid composition in bee tissues.

Table. Fractional composition of total lipids in bee body, % (M±SE, n=5)

Lipid classes	Groups			
	P	K	R1	R2
Phospholipids	24.12± ±0.74	24.34± ±0.38	28.17± ±0.51*#	28.24± ±0.57*#
Mono- and triacylglycerols	16.84± ±0,74	15.76± ±0.49	15.45± ±0.61	19.69± ±1.01*##
Free cholesterol	16.44± ±0.27	16.64± ±0.50	11.77± ±0.62*#	11.55± ±0.43***###
Non-esterified fatty acids	16.14± ±0.60	14.56± ±0.57	11.33± ±0.38*#	11.27± ±0.82*#
Triacylglycerols	13.98± ±0.31	16.46± ±0.53	14.33± ±0.37#	15.89± ±0.37*
Esterified cholesterol	12.49± ±0.86	12.24± ±0.57	18.95± ±0.55*#	13.36± ±0.87

Note. In the table and the fig. 1: * — P<0.05, ** — P<0.01, *** — P<0.001: significant differences between the preparatory and experimental periods by groups. # — P<0.05, ## — P<0.01, ### — P<0.001: significant differences between control and experimental groups.

It should be noted that membrane phospholipids are necessary to stabilize the aggregation and conformation of individual components in enzymatic protein complexes and create a hydrophobic environment to form a continuous structure with all the properties inherent to them [16].

An increase in the MDAG fraction in the R2 group by 16.92% (P<0.05) concerning the preparatory period and by 24.94% (P<0.01) in the control group was also established. It is known that the lipid transport system is a feature of fat metabolism in bees. The main feed lipids in the body of bees are transformed into diacylglycerols, performing, like glucose, the function of energy supply. Therefore, the increase in the level of MDA in the tissues of the body of bees of the R2 group may indicate a more intensive energy supply of their tissues due to the addition of 0.2 μg of Ge in the form of citrate and the pH probiotic *L. casei* B-7280 at a concentration of 10^6 cell/cm^3 to the sugar syrup.

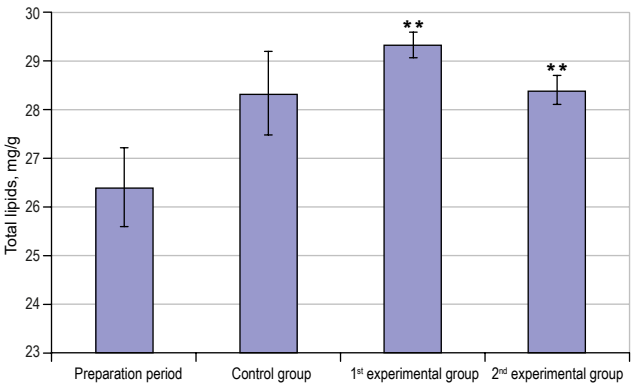

Fig. 1. Content of total lipids in homogenates of bee body tissues

The content of free cholesterol decreased in bees of R1 and R2 groups by 28.41% (P<0.05) and 29.74% (P<0.001) concerning the preparatory period and by 29.27% (P<0.05) and 30.59% (P<0.001) relative to the control group. The supply of Ge citrate in the body of bees contributes to the reduction of free cholesterol by increasing its use in metabolic reactions. Perhaps cholesterol is used to synthesize vitellogenin in the cholesterol-hydroxyecdysone-Vg pathway in trophocytes and enocytes of worker bees [12, 26].

A decrease in the content of NEFA in bees of R1 and R2 groups was established by 29.80% and 30.17% (P<0.05) concerning the preparatory period and by 22.18% and 22.60% (P<0.05) relative to the control group. The obtained data on the content of non-esterified fatty acids in the lipids of the tissues of bees of the experimental groups indicate the activation of lipolysis processes in the body of bees of these groups since a significant decrease in the relative content of non-esterified fatty acids, as precursors of lipid synthesis, was established compared to the control. It is known that lipolysis is physiologically reduced to maintaining the homeostatic concentrations of individual lipid components necessary for aerobic cellular respiration and the formation of PUFA to compensate for the energy needs of tissues in bees [31].

The content of esterified cholesterol increased only in R1 group by 51.72% (P<0.05) during the preparatory period and by 54.82% (P<0.05) following the control group. The increase in the content of cholesterol ethers in the tissues of bees in the first research group may indicate a higher antilipolytic activity of enzymes that regulate the process of its esterification under the action of SS and 0.1 μg of Ge citrate and the pH of the probiotic *L. casei* B-7280 at a concentration of 10^6 cell/cm^3 and no such effect at a higher dose of Ge citrate.

An increase in the content of triacylglycerols in the R2 group by 15.89% (P<0.05) concerning the preparatory period and a decrease by 12.94% (P<0.05) compared to the control group was established. This indicates the optimizing effect of complex feeding of bees with SS and a dose of 0.2 μg of Ge citrate and pH probiotic *L. casei* B-7280 at a 10^6 cell/cm^3 concentration and the absence of such an effect with a Ge citrate lower dose.

It is known that active forms of oxygen are formed due to aerobic respiration and oxidation of substrates. In body cells exposed to various stresses, the production of reactive oxygen species increases, which directly affect enzymes and damage cells [34]. At the same time, an analysis of the literature shows that Germanium promotes the removal of toxins from the body and neutralizes the negative impact of environmental factors, has a wide range of biological effects, which confirm our results [10], and prevents aging and cell death. This element is essential in forming the body's resistance and can restore and prevent many diseases [10].

Malondialdehyde is one of the end products of the peroxidation of polyunsaturated fatty acids in cells. An increase in the content of free radicals causes excessive production of MDA. The malondialdehyde level is a marker of oxidative stress and the body's antioxidant status [30].

Excessive activation of LPO processes with reduced activity of the body's antioxidant system can lead to significant pathological changes, primarily accompanied by damage to subcellular and cellular membranes. LPO products cause disruption of not only lipid bonds in biomembranes and their protein component — due to binding with amine groups, which leads to disruption of protein-lipid interaction. Free radical oxidation of lipids causes changes in fiber elasticity and initiates fibroplastic processes and collagen aging [2, 15].

As a result of the conducted studies, it was established that in the homogenates of bee body tissues, the concentration of lipid hydroperoxides in the R2 experimental group decreased by 16.67% (P<0.05) and TBARS by 41.85% (P<0.001) compared to the control group (fig. 2, 3).

These results indicate the antioxidant effect of Ge citrate in the body of bees in the applied doses, which was accompanied by a decrease in the content of TBARS (MDA) and lipid hydroperoxides in homogenates of bee body tissues of all experimental groups, which is consistent with the data of other authors [5, 9, 28].

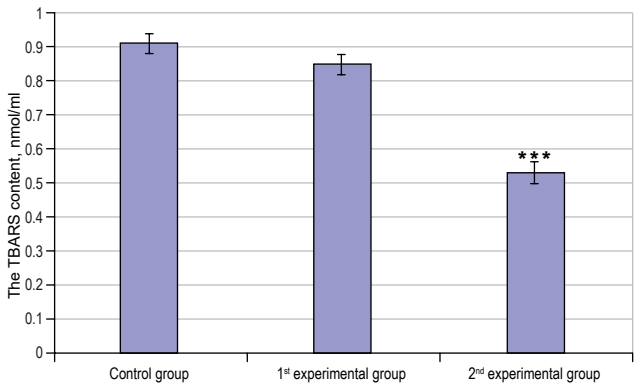

Fig. 2. Content of TBARS in homogenates of bee body tissues

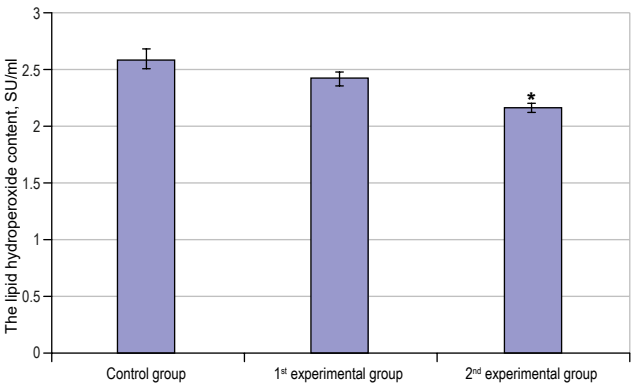

Fig. 3. Content of lipid hydroperoxides in homogenates of bee body tissues

Note. In these figures: * — P<0.05, ** — P<0.01, *** — P<0.001 — significant differences between the control and experimental periods by groups.

Conclusions

Supplementation of bees with NTC Ge at a dose of 0.1 and 0.2 μg/ml sugar syrup and 10^6 cell/cm^3 sugar syrup of *L. casei* was characterized by differences in the distribution of individual classes of lipids in homogenates of body tissues with a higher relative content of phospholipids, mono- and diacylglycerols (only in R2 group), of esterified cholesterol (R1), but a decrease in free cholesterol, NEFA compared to the control group and the experimental period, which indicates a dose-dependent effect of NTC Ge on lipid metabolism. An increase in the level of triacylglycerols in the lipids of bee tissues of all groups during the experimental period was noted.

The biological effect of nanotechnological Ge citrate and *L. casei* led to a decrease in the lipid peroxidation processes (lipid hydroperoxides, TBARS) in the body tissues of the bees of the experimental groups compared to the control group under the action of a higher dose of Ge citrate.

References

1. Almasri H, Tavares DA, Diogon M, Pioz M, Alamil M, Sené D, Tchamitchian S, Cousin M, Brunet JL, Belzunces LP. Physiological effects of the interaction between *Nosema ceranae* and sequential and overlapping exposure to glyphosate and difenoconazole in the honey bee *Apis mellifera*. *Ecotoxicol. Environ. Saf*. 2021; 217: 112258. DOI: 10.1016/j.ecoenv.2021.112258.
2. Briganti S, Picardo M. Antioxidant activity, lipid peroxidation and skin diseases. What's new. *J. Eur. Acad. Dermatol. Venereol.* 2003; 17 (6): 663–669. DOI: 10.1046/j.1468-3083.2003.00751.x.
3. Cho JM, Chae J, Jeong SR, Moon MJ, Shin DY, Lee JH. Immune activation of Bio-Germanium in a randomized, double-blind, placebo-controlled clinical trial with 130 human subjects: Therapeutic opportunities from new insights. *PLoS ONE*. 2020; 15 (10): e0240358. DOI: 10.1371/journal.pone.0240358.
4. Daisley BA, Chmiel JA, Pitek AP, Thompson GJ, Reid G. Missing microbes in bees: How systematic depletion of key symbionts erodes immunity. *Trends Microbiol*. 2020; 28 (12): 1010–1021. DOI: 10.1016/j.tim.2020.06.006.
5. Dolaychuk OP, Fedoruk RS, Kovalchuk II, Kropyvka SY. Physiological and biochemical processes in the organisms of rats that were fed with different amounts of germanium citrate. *Biol. Tvarin*. 2015; 17 (2): 50–56. DOI: 10.15407/animbiol17.02.050. (in Ukrainian)
6. Dvylyuk I. Mineral and lipid composition the body of the honeybees organism and the biological value of honey in the summer-autumn period under the conditions of feeding honey bees by citrate-capped silver and copper nanoparticles. *Sci. Mess. LNUVMBT. Ser. Agricult. Sci*. 2018; 20 (89): 89–94. DOI: 10.32718/nvlvet8917.
7. Dvylyuk II, Kovalchuk II. Reproductive ability of bee queens at the conditions of feeding citrates of Argentum and Cuprum. *Biol. Tvarin*. 2017; 19 (2): 30–36. DOI: 10.15407/animbiol19.02.030.
8. Falalyeyeva TM, Leschenko IV, Beregova TV, Lazarenko LM, Savchuk OM, Sichel LM, Tsyryuk OI, Vovk TB, Spivak MY. Probiotic strains of lactobacilli and bifidobacteria alter pro- and anti-inflammatory cytokines production in rats with monosodium glutamate-induced obesity. *Fiziol. Zh*. 2017; 63 (1): 17–25. DOI: 10.15407/fz63.01.017.
9. Fedoruk RS, Kovalchuk II, Mezentseva LM, Tesarivska UI, Pylypets AZ, Kaplunenko VH. Germanium compounds and their role in animal body. *Biol. Tvarin*. 2022; 24 (1): 50–60. DOI: 10.15407/animbiol24.01.050. (in Ukrainian)
10. Fedoruk RS, Kovalchuk II, Romaniv LI, Xrabko MI. Influence of germanium citrate and selenium on lipid and heavy metals content in melliferous bees' organism. *Biol. Tvarin*. 2014; 16 (2): 141–149. Available at: http://aminbiol.com.ua/index.php/archive/100-archive/bt-16-2-2014/1487 (in Ukrainian)
11. Fedoruk RS, Tesarivska UI, Kovalchuk II, Tsap MM, Kaplunenko VH, Koleschuk OI, Khrabko MI. Biological effects of iodine, selenium, sulfur citrates in broiler chickens. *Reg. Mech. Biosys*. 2021; 12 (3): 523−530. DOI: 10.15421/022172.
12. Feldlaufer MF, Harrison DJ. Neutral sterols in honey bee (*Apis mellifera*) feces. *J. Apicult. Res.* 2020; 59 (5): 1033–1036. DOI: 10.1080/00218839.2020.1753917.
13. Folch J, Lees M, Stanley GH. A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem.* 1957; 226 (1): 497–509. DOI: 10.1016/S0021-9258(18)64849-5.
14. Frias BED, Barbosa CD, Lourenço AP. Pollen nutrition in honey bees (*Apis mellifera*): impact on adult health. *Apidologie*. 2016; 47 (1): 15–25. DOI: 10.1007/s13592-015-0373-y.
15. Galiniak S, Mołoń M, Biesiadecki M, Bożek A, Rachel M. The role of oxidative stress in atopic dermatitis and chronic urticaria. *Antioxidants*. 2022; 11 (8): 1590. DOI: 10.3390/antiox11081590.
16. Hartfelder K, Bitondi MMG, Brent CS, Guidugli-Lazzarini KR, Simões ZLP, Stabentheiner A, Tanaka ÉD, Wang Y. Standard methods for physiology and biochemistry research in *Apis mellifera*. *J. Apicult. Res*. 2013; 52 (1): 1−48. DOI: 10.3896/IBRA.1.52.1.06.
17. Karavan VV, Kachmaryk DY, Cherevatov VF, Yazlovytska LS. Influence of wintering temperature on the state of the antioxidative system in *Apis mellifera* L. *Biol. Tvarin*. 2021; 23 (4): 32–42. DOI: 10.15407/animbiol23.04.032. (in Ukrainian)
18. Kosinov MV, Kaplunenko VH. Method of obtaining metal carboxylates "Nanotechnology of obtaining metal carboxylates". Patent UA no 38391. from 12.01.2009. Available at: https://base.uipv.org/searchINV/search.php?action=viewdetails&IdClaim=128062 (in Ukrainian)
19. Kovalchuk II, Fedoruk RS. Content of heavy metals in the bees tissues and products depending on agroecological conditions of the Carpathians region. *Biol. Tvarin*. 2013; 15 (4): 54–65. Available at: http://aminbiol.com.ua/index.php/archive/94-archive/bt4-15-2013/1536 (in Ukrainian)
20. Kovalchuk II, Fedoruk RS, Rivis YF, Romaniv LI. Lipid and fatty acid composition of body tissues of honey bees and pollen under conditions of supplementation with germanium and selenium nanoaquacitrates. *Sci. Tech. Bull. SRCIVMFA IAB*. 2014; 15 (2−3): 31−36. Available at: http://nbuv.gov.ua/UJRN/Ntbibt_2014_15_2-3_7 (in Ukrainian)
21. Kovalchuk II, Fedoruk RS, Spivak MY, Romanovych MM, Iskra RY. *Lactobacillus casei* IMV B-7280 immunobiotic strain influence on the viability of honey bees and the content of microelements in the organism. *Mikrobiol. Z.* 2021; 83 (2): 42–50. DOI: 10.15407/microbiolj83.02.042.
22. Kovalchuk II, Kykish IB, Kaplunenko VH. Influence of citrate microelements on the reproductive capacity of queen bees. In: *Actual problems of natural sciences: modern scientific discussions*. A collective monograph. Riga, Latvia, Baltija Publ., 2020; 87–110. DOI: 10.30525/978-9934-26-025-4-6.
23. Lazarenko LM, Babenko LP, Gichka SG, Sakhno LO, Demchenko OM, Bubnov RV, Sichel LM, Spivak MY. Assessment of the safety of *Lactobacillus casei* IMV B-7280 probiotic strain on a mouse model. *Probiot. Antimicr. Prot.* 2021; 13 (6): 1644–1657. DOI: 10.1007/s12602-021-09789-1.
24. Lazarenko LM, Babenko LP, Mokrozub VV, Demchenko OM, Bila VV, Spivak MY. Effects of oral and vaginal administration of probiotic bacteria on the vaginal microbiota and cytokines production in the case of experimental staphylococcosis in mice. *Mikrobiol Z.* 2017; 79 (6): 105–119. DOI: 10.15407/microbiolj79.06.105.

25. Li Z, Hou M, Qiu Y, Zhao B, Nie H, Su S. Changes in antioxidant enzymes activity and metabolomic profiles in the guts of honey bee (*Apis mellifera*) larvae infected with *Ascosphaera apis*. *Insects*. 2020; 11 (7): 419. DOI: 10.3390/insects11070419.

26. Lu CY, Huang PJ, Hsu CY. The cholesterol-hydroxyecdysone-vitellogenin pathway is involved in the longevity of trophocytes and oenocytes of queen honey bees (*Apis mellifera*). *Apidologie*. 2018; 49: 721–733. DOI: 10.1007/s13592-018-0596-9.

27. Mucci CA, Ramirez L, Giffoni RS, Lamattina L. Cold stress induces specific antioxidant responses in honey bee brood. *Apidologie*. 2021; 52: 596–607. DOI: 10.1007/s13592-021-00846-w.

28. Mylostiva D. Influence of germanium citrate on the defensive antioxidative system of rats organism. *Sci. Tech. Bull. SRCIVMFA IAB*. 2017; 18 (2): 34–37. Available at: http://nbuv.gov.ua/UJRN/Ntbibt_2017_18_2_7 (in Ukrainian)

29. Neov B, Georgieva A, Shumkova R, Radoslavov G, Hristov P. Biotic and abiotic factors associated with colonies mortalities of managed honey bee (*Apis mellifera*). *Diversity*. 2019; 11 (12): 237. DOI: 10.3390/d11120237.

30. Prezenská M, Sobeková A, Sabová L. Antioxidant enzymes of honeybee larvae exposed to oxamyl. *Folia Vet*. 2019; 63 (4): 9–14. DOI: 10.2478/fv-2019-0032.

31. Romaniv LI, Kovalchuk II, Pashchenko AG, Fedoruk RS. Content of lipids in tissues of the melliferous bees additionally fed with soybean meal, sugar syrup and citrates of Co and Ni. *Biol. Tvarin*. 2018; 20 (3): 84–92. DOI: 10.15407/animbiol20.03.084. (in Ukrainian)

32. Tauber JP, Collins WR, Schwarz RS, Chen Y, Grubbs K, Huang Q, Lopez D, Peterson R, Evans JD. Natural product medicines for honey bees: Perspective and protocols. *Insects*. 2019; 10 (10): 356. DOI: 10.3390/insects10100356.

33. Tawfik AI, Ahmed ZH, Abdel-Rahman MF, Moustafa AM. Effect of some bee bread quality on protein content and antioxidant system of honeybee workers. *Int. J. Trop. Insect. Sci.* 2022; 43: 93–105. DOI: 10.1007/s42690-022-00888-2.

34. Tezuka T, Higashino A, Akiba M, Nakamura T. Organogermanium (Ge-132) suppresses activities of stress enzymes responsible for active oxygen species in monkey liver preparation. *Adv. Enz. Res*. 2017; 5 (2): 13–23. DOI: 10.4236/aer.2017.52002.

35. Vlizlo VV. (ed.). *Laboratory Methods in Biology, Stockbreeding and Veterinary Medicine*. Lviv, Spolom. 2012: 764 p. (in Ukrainian)

36. Yefimenko T, Odnosum H, Vorobiy O. Flow of sacbrood disease in creation of infertile period at bee colonies in comparison with bee colonies treatment with eucalyptus and hypericum extracts and analogue means. *Beekeep. Ukr*. 2021; 1 (6): 18–23. DOI: 10.46913/beekeepingjournal.2021.6.03.

Ліпідний склад та продукти перекисного окиснення тканин організму бджіл за впливу різних доз нанотехнологічного цитрату Ge та пробіотика *Lactobacillus casei* B-7280

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Застосування сучасних засобів збереження медоносних бджіл спрямоване на підвищення їх життєздатності, рівня живлення та продуктивності у різні періоди розвитку. Відзначено тенденцію до використання нових ефективних засобів натурального походження, механізми дії яких відрізняються від синтетичних речовин і препаратів за рахунок активації захисних реакцій організму на фізіологічному рівні. Пробіотик *Lactobacillus casei* IMV B-7280 має ефективну стимулювальну дію на фізіологічні процеси за різних екологічних та експериментальних умов життєдіяльності бджіл. Фізіологічний вплив цього пробіотика пов'язаний з нормалізацією кишкової бактеріальної мікрофлори та участю в модуляції захисних реакцій організму. Опірність медоносних бджіл також залежить від мінерального живлення, що впливає на обмінні процеси на рівні тканин, органів і систем та визначає життєздатність і резистентність організму. Мінеральні елементи беруть участь у білковому, ліпідному, вуглеводному та енергетичному обмінах, активують ферментні системи. Тому метою досліджень було визначення впливу пробіотичного препарату класу *L. casei* B-7280 у поєднанні з різними дозами нанотехнологічного цитрату (НТЦ) Ge на ліпідний склад та вміст продуктів перекисного окиснення у тканинах організму бджіл. Бджоли контрольної групи отримували підгодівлю з 60% цукрового сиропу (ЦС) в кількості 1 мл/групу/добу. Перша дослідна група (Е1) бджіл додатково до 1 мл цукрового сиропу отримувала 0,1 мкг Ge у вигляді нанотехнологічного цитрату та розчин пробіотика *L. casei* B-7280 у концентрації 10^6 КУО/мл; друга дослідна (Е2) — 0,2 мкг Ge у вигляді цитрату та пробіотик *L. casei* B-7280 у концентрації 10^6 КУО/мл. Тривалість випоювання цукрового сиропу, Ge цитрату та пробіотика — 34 дні. Встановлено, що підгодівля бджіл цукровим сиропом, *L. casei* 10^6 КУО/мл та різними дозами Ge цитрату характеризувалась вищим відносним вмістом фосфоліпідів, моно- і диацилгліцеролів в Е2 групі та етерифікованого холестеролу — в Е1, але зниженням вільного холестеролу, неетерифікованих жирних кислот стосовно контрольної групи і дослідного періоду. Ці результати вказують на дозозалежний вплив нанотехнологічного цитрату Ge на обмін ліпідів в гомогенатах тканин організму. Відзначено підвищення рівня триацилгліцеролів у ліпідах тканин бджіл всіх груп у дослідний період. Біологічний вплив нанотехнологічного цитрату Ge і *L. casei* зумовлював у тканинах організму бджіл дослідних груп зниження рівня процесів пероксидації ліпідів за дії вищої дози цитрату Ge.

Ключові слова: бджоли**,** Ge цитрат, пробіотик, ліпіди, продукти перекисного окиснення

Pylypets AZ, Spivak MY, Fedoruk RS, Tsap MM, Kovalchuk II, Romanovych MM. Lipid composition and peroxidation products in the body tissues in bees under the action of different doses of nanotechnological Ge citrate and the probiotic *Lactobacillus casei* B-7280. *Biol. Tvarin*. 2023; 25 (1): 20–26. DOI: 10.15407/animbiol25.01.020.

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Productive qualities of young pigs of the Large White breed of diverse genealogical lines and interbreed differentiation according to some integrated indicators

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The purpose of the work was to investigate the fattening and meat qualities in young pigs of the Large White breed of diverse genealogical lines and interbreed differentiation according to some integrated indicators and to calculate the economic efficiency of the experimental results. The fattening and meat qualities in young pigs were evaluated by the quantitative characteristics such as average daily live weight gain during the control fattening period (g), the age of reaching 100 kg live weight (days), thickness of lard at the level of 6–7 thoracic vertebrae (mm), length of the chilled carcass (cm), length of the bacon half of the chilled half-carcass (cm). Comprehensive evaluation of the animals in the experimental groups was carried out according to the Tyler and Wangen indices. Biometric processing of research results was conducted according to the methods of V. P. Kovalenko et al. (2010). The research was performed in agricultural formations of the Dnipropetrovsk region, the *Jazz* meat processing plant, and the animal husbandry laboratory of the Institute of Grain Crops NAAS of Ukraine. It was established that in terms of fattening and meat qualities, the young pigs of the genealogical lines Tafftus C61203 UA 8819345 and Azuro UA 8800557 of the Large White breed correspond to the elite class. Young pigs of the genealogical line Tafftus C61203 UA 8819345 outperform peers of the Azuro line UA 8800557 by 3.25% in the age of reaching a live weight of 100 kg, in fat thickness at the level of 6–7 thoracic vertebrae by 5.74%, in chilled carcass length by 0.93%. Animals of the Azuro UA 8800557 line are characterized by a longer length of the chilled carcass and the length of the bacon half of the chilled carcass. The number of significant correlations between the fattening and meat qualities of the Large White breed young pigs, the CI selection index, and the Tyler index is 80%. The maximum increase in additional production was obtained from young pigs of the genealogical line Tafftus C61203 UA 8819345 (+2.52%), then I experimental group according to the Tyler index (+3.98%) and the selection index CI (+4.30%). The criteria for selecting highly productive animals due to the CI breeding index are 57.69–78.57 points, and the Tyler index is 214.89–242.85 points. The economic efficiency of the use of young pigs from the specified groups provides additional production at the level of +3.98–4.30%.

Key words: young pigs, breed, fattening and meat qualities, index, correlation, economic efficiency

Introduction

Evaluation of young pigs for fattening and meat qualities in agroformations of Ukraine is carried out following the requirements of the current Instructions for growing pigs [8] and "Methods for evaluating boars and sows according to the quality of the offspring in the conditions of breeding farms and breeders" [3]. However, the work experience of specialists and the research of domestic scientists testify to the following:

— the use of foreign-bred animals has a positive effect on improving the fattening and meat qualities of young pigs under the conditions of using different breeding methods [1, 2, 4–6, 15–18, 22];

— according to the requirements of the specified regulatory documents, the animals of the controlled herds correspond to the elite class. How to carry out further selection and breeding work to improve the main quantitative traits, namely age of reaching a live weight of 100 kg (days), fat thickness at the level of 6–7 thoracic vertebrae (mm), length of the chilled carcass (cm).

Therefore, the issue of finding effective methods for the comprehensive evaluation of the productive qualities of pigs taking into account their origin and interbreed differentiation according to some integrated indicators or markers is relevant [23, 24].

Research by domestic scientists indicates that young pigs obtained from a combination of cross-bred sows (½ Large White breed of Hungarian origin × ½ Landrace) with boars of the genotype (½ Duroc × ½ Piétrain), as well as cross-bred sows (½ Large White breed of Hungarian origin × ½ Landrace) with boars of the Duroc breed of Ukrainian selection [10]. They reach a live weight of 100 kg at the age of 178 and 180 days (P<0.001) with average daily gains of 769 and 751 g and feed consumption of 3.42 (P<0.001) and 3.47 (P<0.001) unit for 1 kg of gain. The author reports that the young pigs obtained from the combination of cross-bred sows (½ Large White breed of Hungarian origin × ½ Landrace) with boars of the genotype (½ Duroc × ½ Piétrain) exceeded the peers of the control group (Large White breed of Hungarian origin) in terms of half-carcass length by 6 cm, the thickness of the bacon by 1.33 mm, the area of the "muscle eye" by 8.81 cm^2. This group also had a high slaughter yield 75.66%, while the control group had 73.07%. A greater weight of the rear third of the half-carcass and meat yield characterized animals of the specified genotypes.

Comprehensive studies conducted by O. O. Krasnoshchok testify that the best fattening qualities are characterized by the young pigs of the combination of Great White and Landrace, which proves the effectiveness for the first hybridization stage; the effect of heterosis is 111.58% [13]. The author notes that the influence of combinations on average daily growth is 24.56% (P≤0.05), and the intensity of formation is 26.67 (P≤0.05); according to precocity, respectively, 26.85 and 16.97% (P≤0.05), according to feed consumption — 25.10 and 23.74% (P≤0.05). It was established that the use of Landrace breeders and terminal boars improved the meat quality of crossbred and hybrid pigs: the slaughter yield increased by 2.6% (P≤0.001); 1.6% (P≤0.05); 3.2% (P≤0.001), the area of the "muscle eye" — by 10.2 cm^2 (P≤0.001); 7.2 cm^2 (P≤0.001); 13.9 cm^2 (P≤0.001), the mass of the bone — by 0.8 kg (P≤0.01); 0.7 kg (P≤0.05); 0.7 kg (P≤0.01), fat thickness decreased by 6.8 mm (P≤0.001); 7.5 mm (P≤0.01); 7.8 mm (P≤0.001). The correlation between the genotypes of the LEP 2845 gene with high average daily gain, a younger age of reaching 100 kg live weight, and lower feed consumption during fattening was revealed.

The works of scientists [21, 20, 14, 19, 7] testify to the effectiveness of using pigs of foreign origin and methods of index selection. **The work aims** to investigate the fattening and meat qualities of young pigs of the Large White breed of different genealogical lines and interbreed differentiation according to some integrated indicators, as well as to calculate the economic efficiency of the experimental results.

Materials and Methods

The experimental part of the work was carried out at the "Druzhba-Kaznacheivka" dairy farm of the Dnipropetrovsk region, the "Jazz" meat processing plant, and the animal husbandry laboratory of the Institute of Grain Crops NAAS. The object of research was young pigs of the Large White breed of genealogical lines Tafftus C61203 UA 8819345 and Azuro UA 8800557.

Control fattening of young pigs of the Large White breed was carried out following the requirements of the "Methods for evaluating boars and sows according to the quality of the offspring in the conditions of breeding farms and breeding breeders" [3].

Selection indexes of CI (1) and Tyler (2) and the value of additional products (3) were calculated according to the following formulas:

$$CI = 0.18 \times X_1 - 4.46 \times X_2 \quad (1),$$

where CI — selection index, points;
X_1 — an average daily gain of live weight during the period of control fattening, g;
X_2 — thickness of fat at the level of 6–7 thoracic vertebrae, mm [19];

$$I_в = 100 + (242 \times K) - (4{,}13 \times L) \quad (2),$$

where Iв — complex index of fattening and meat qualities;
K — an average daily gain of live weight, kg;
L — fat thickness at 6–7 thoracic vertebrae, mm;
242; 4.13 are constant coefficients [21].

The formation of experimental groups of young pigs was carried out by taking into account their origin and based on the calculation of the average value of CI and Tyler indices. The deviation from the average value of the indices was equal to ± (0.67×σ).

The cost of additional products was calculated based on the following data: the purchase price of a product unit, under the current prices, which is valid in Ukraine; average productivity of animals; the average premium of the primary production, which is expressed as a percentage

per 1 animal when applying a new and improved breeding achievement compared to the productivity of animals of primary use; the constant ratio of reduction of the result, which is associated with additional costs for profitable products (0.75); the number of livestock of agricultural animals of a new or improved breeding achievement.

Variational statistics processed the research results according to the methods of V. P. Kovalenko and others [11].

Results and Discussion

It was established that the average daily live weight gain in young pigs of the experimental group (n=45) during the period of control fattening is 781.0±5.78 g (Cv=4.97%), the age of reaching 100 kg live weight is 177.3±0.77 days (Cv=2.93%), lard thickness at the level of 6–7 thoracic vertebrae — 20.7±0.32 mm (Cv=10.36%), chilled carcass length — 96.5±0.31 cm (Cv=1.71%), the length of the bacon half of the cooled carcass is 85.5±0.58 cm (Cv=3.54%). Selection index CI ranges from 19.16 to 78.57, Tyler index — from 126.13 to 182.36 points. The study results of the fattening and meat qualities of young pigs of the Large White breed of different origins and interbreed differentiation according to the Tyler index. The CI selection index is shown in tables 1–3.

It was established that the young pigs of the II group (genealogical line Tafftus C61203 UA 8819345) prevailed over peers I (genealogical line Azuro UA 8800557) in terms of the average daily gain of live weight during the period of control fattening by 25.3 g (td=2.67; P<0,05), the age of reaching a live weight of 100 kg by 5.8 days (td=3.64; P<0.001), the fat thickness at the level of 6–7 thoracic vertebrae by 1.2 mm (td=1.18; P>0,05). The animals were characterized by a longer length of the chilled carcass (by 0.9 cm; td=1.09; P>0.05) and the length of the bacon half of the chilled carcass (by 1.7 cm; td=1.24; P>0.05) lines Azuro UA 8800557 (I experimental group).

The difference between animals of different genealogical lines, according to the Tyler index, is equal to 8.95 points (td=2.28; P<0.05), according to the CI selection index — 8.89 points (td=2.35; P<0.05).

A comprehensive evaluation of young pigs for fattening and meat qualities using the CI selection index and the Tyler index showed that the young pigs of the I group (CI=57.69–78.57 points, Iv=214.89–242.85 points) prevailed age group III (CI=19.16–38.75 points, Iv=178.89–192.72 points) according to the average daily increase in live weight during the period of control fattening by 72.8 (td=8.02; P<0.001) and 70.7 g (td=6.77; P<0.001), the age of reaching a live weight of 100 kg by 8.3 (td=5.28; P<0.001) and 8.9 days (td=5.63; P<0.001), the thickness of lard at the level of 6–7 thoracic vertebrae by 4.2 (td=6.56; P<0.001) and 4.6 mm (td=6.76; P<0.001), the length of the chilled carcass by 1.6 (td=1.86; P>0.05) and 2.0 cm (td=4.16; P>0.001), the length of the bacon half of the cooled carcass by 1.8 (td=1.21; P>0.05) and 2.7 cm (td=2.57; P<0.05).

The results of the calculation of pairwise correlation coefficients between the fattening and meat qualities of young

Table 1. Fattening and meat qualities of young pigs of diverse genealogical lines of the large white breed

Indexes	Biometric indicators	Young pigs of the genealogical line	
		Azuro UA 8800557	Tafftus C61203 UA 8819345
		Group	
		I	II
1	*n*	*35*	*10*
	X±*Sx*	775.9±6.26	801.2±7.12
	σ±$X_σ$	37.59±4.496	38.89±8.700
	Cv±Sc_v, %	4.84±0.578	4.85±1.085
2	*X*±*Sx*	178.3±0.83	172.5±1.37
	σ±$X_σ$	5.02±0.600	4.12±0.921
	Cv±Sc_v, %	2.81±0.336	2.38±0.532
3	*X*±*Sx*	20.9±0.31	19.7±0.97
	σ±$X_σ$	1.91±0.228	2.91±0.651
	Cv±Sc_v, %	9.13±1.092	14.58±3.261
4	*n*	*23*	*4*
	X±*Sx*	96.6±0.34	95.7±0.75
	σ±$X_σ$	1.67±0.246	1.50±0.531
	Cv±Sc_v, %	1.72±0.253	1.57±0.556
5	*X*±*Sx*	85.7±0.64	84.0±1.22
	σ±$X_σ$	3.08±0.454	2.44±0.865
	Cv±Sc_v, %	3.60±0.530	2.92±1.035
6	*n*	*35*	*10*
	X±*Sx*	46.14±2.258	55.03±3.038
	σ±$X_σ$	13.55±1.620	12.11±2.709
	Cv±Sc_v, %	29.36±3.511	22.01±4.923
7	*X*±*Sx*	147.67±1.872	156.62±3.452
	σ±$X_σ$	11.23±1.343	12.59±2.816
	Cv±Sc_v, %	7.60±0.909	8.04±1.798

Note: in this and the following tables, 1 is the average daily increase in live weight during the period of control fattening, g; 2 — age of reaching 100 kg live weight, days; 3 — fat thickness at the level of 6–7 thoracic vertebrae, mm; 4 — length of the cooled carcass, cm; 5 — length of the bacon half of the cooled carcass, cm; 6 — CI, points; 7 — Iv, scored.

Table 2. Feeding and meat qualities of young pigs of the large white breed of diverse interbreed differentiation according to the Tyler index

Indexes	Biometric indicators	Gradations of the Tyler index		
		214.89–242.85	195.52–213.54	178.89–192.72
		Group		
		I	II	III
1	*n*	*11*	*21*	*13*
	X±*Sx*	813.4±9.28	788.0±7.19	742.7±4.78
	σ±$X_σ$	30.78±6.562	32.95±5.084	17.26±3.390
	Cv±Sc_v, %	3.79±0.808	4.18±0.645	2.32±0.499
2	*X*±*Sx*	172.5±1.08	177.4±0.94	181.4±1.16
	σ±$X_σ$	3.58±0.763	4.33±0.668	4.18±0.821
	Cv±Sc_v, %	2.08±0.443	2.45±0.378	2.31±0.453
3	*X*±*Sx*	18.3±0.63	20.7±0.23	22.9±0.28
	σ±$X_σ$	2.11±0.449	1.05±0.162	1.03±0.202
	Cv±Sc_v, %	11.49±2.449	5.10±0.787	4.53±0.889
4	n	4	16	7
	X±*Sx*	97.7±0.25	96.5±0.46	95.7±0.42
	σ±$X_σ$	0.50±0.177	1.85±0.327	1.11±0.296
	Cv±Sc_v, %	0.51±0.180	1.92±0.339	1.16±0.310
5	*X*±*Sx*	87.0±0.81	85.7±0.89	84.3±0.68
	σ±$X_σ$	1.63±0.578	3.57±0.631	1.79±0.478
	Cv±Sc_v, %	1.88±0.667	4.17±0.738	2.13±0.569

Table 3. Fattening and meat qualities of young pigs of large white breed of diverse interbreed differentiation according to the selection index CI

Indexes	Biometric indicators	Gradations of the CI selection index		
		57.69–78.57	43.84–56.12	19.16–38.75
		Group		
		I	II	III
1	*n*	*12*	*18*	*15*
	X±*Sx*	816.1±8.00	789.1±7.35	743.3±4.29
	σ±$X_σ$	27.72±5.668	31,19±5.198	16.63±3.040
	Cv±Sc_v, %	3.40±0.695	3.95±0.658	2.24±0.409
2	*X*±*Sx*	172.6±1.04	177.5±0.97	180.9±1.18
	σ±$X_σ$	3.62±0.740	4.15±0.691	4.60±0.840
	Cv±Sc_v, %	2.10±0.429	2.34±0.390	2.54±0.464
3	*X*±*Sx*	18.5±0.59	20.7±0.25	22.7±0.28
	σ±$X_σ$	2.06±0.421	1.08±0.180	1.09±0.199
	Cv±Sc_v, %	11.17±2.284	5.25±0.875	4.84±0.884
4	n	5	14	8
	X±*Sx*	97.2±0.80	96.8±0.46	95.6±0.34
	σ±$X_σ$	1.78±0.563	1.74±0.328	1.06±0.265
	Cv±Sc_v, %	1.84±0.582	1.80±0.340	1.11±0.277
5	*X*±*Sx*	85.8±1.35	86.2±0.91	84.0±0.65
	σ±$X_σ$	3.03±0.958	3.40±0.642	1.85±0.462
	Cv±Sc_v, %	3.54±1.120	3.95±0.746	2.20±0.550

Table 4. Coefficients of paired correlation between fattening and meat qualities of young pigs of the large white breed, CI selection index, and Tyler index

Sign			Biometric indicators	
	x	*y*	*r*±*Sr*	tr
Index, points	*CI*	1	0.748±0.0656***	11.39
		2	–0.628±0.0903***	6.96
		3	–0.876±0.0347***	25.27
		4	0.283±0.1371*	2.06
		5	0.128±0.1466	0.87
	Iв	1	0.595±0.0963***	6.18
		2	–0.677±0.0807***	8.39
		3	–0.923±0.0221***	41.83
		4	0.298±0.1358*	2.19
		5	0.155±0.1455	1.07

Note. * — P<0.05; *** — P<0.001.

Table 5. Economical efficiency of using sows of different breeding value

Group	n	Average daily gain of live weight during the control fattening, g	Increase in additional products, %	Cost of additional products, UAH/animal*
General sample	45	781.0±5.78	—	—
intrabreed differentiation along the genealogical line				
I	35	775.9±6.26	–0.65	–-32.38
II	10	801.2±7.12	+2.52	+121.45
intrabreed differentiation according to the Tyler index				
III	13	742.7±4.78	–4.90	–248.34
II	21	788.0±7.19	+0.88	+43.61
I	11	813.4±9.28	+3.98	+191.82
intrabreed differentiation according to the SI selection index				
III	15	743.3±4.29	–4.82	–243.62
II	18	789.1±7.35	+1.02	+50.58
I	12	816.1±8.00	+4.30	+207.36

Note. * — the selling price of young pigs at the time of the research was UAH 47.7. for 1 kg of live weight.

pigs of the Large White breed and indices are shown in table 4. Studies have proven that the number of significant correlation coefficients between the fattening and meat qualities of young pigs of the Large White breed of the general sample (n=45), the CI breeding index, and the Tyler index is equal to 80%. The significant relationships were established between the following pairs of traits: CI selection index × average daily live weight gain during the control fattening period (r = +0.748); CI selection index × age of reaching 100 kg live weight (r = –0.628); selection index CI × fat thickness at the level of 6–7 thoracic vertebrae (r = –0.876); selection index CI × length of the chilled carcass (r = +0.283); Tyler's index × average daily gain of live weight during the control feeding period (+0.595); Tyler's index × age of reaching 100 kg live weight (r = –0.677); Tyler's index × fat thickness at the level of 6–7 thoracic vertebrae (r = –0.923); Tyler index × length of the chilled carcass (r = +0.293).

Calculations of the economic efficiency of the research results show that the maximum increase in additional production was obtained from young pigs of the genealogical line Tafftus C61203 UA 8819345 (+2.52%), I experimental group according to the Tyler index (+3.98%) and the CI selection index (+4.30%) (table 5). The cost of additional animal products in the specified groups is +121.45, +191.82, and +207.36 UAH/animal, respectively.

Conclusions

The fattening and meat qualities of young pigs of the genealogical lines Tafftus C61203 UA 8819345 and Azuro UA 8800557 of the Large White breed correspond to the elite class. It was established that the young pigs of the genealogical line Tafftus C61203 UA 8819345 outperform peers of the Azuro line UA 8800557 in terms of the age of reaching a live weight of 100 kg, the thickness of lard at the level of 6–7 thoracic vertebrae and the length of the chilled carcass by an average of 3.3%. Animals of the Azuro line UA 8800557 are characterized by a longer length of the chilled carcass and the length of the bacon half of the chilled carcass.

The criteria for selecting highly productive animals according to the CI breeding index are 57.69–78.57 points, and the Tyler index is 214.89–242.85 points. The number of significant correlations between the fattening and meat qualities of young pigs of the Large White breed, the CI breeding index and the Tyler index is 80%. Therefore, the above testifies to the effectiveness of using these indices in selection and breeding work. It was established that the maximum increase in additional production was obtained from young pigs of the genealogical line Tafftus C61203 UA 8819345 (+2.52%), I experimental group according to the Tyler index (+3.98%) and the CI selection index (+4.30%).

References

1. Bagnell CA, Bartol FF. Review: Maternal programming of development in the pig and the lactocrine hypothesis. *Animal*. 2019; 13 (12): 2978–2985. DOI: 10.1017/S1751731119001654.

2. Balatsky V. Polymorphism of leptin (LEP) and leptin receptor (LEPR) genes and their association with meat and back fat quality in Ukrainian Large White pigs. *CRIB Annual Meeting 2017*. University of West of England, 2017: 25.
3. Berezovskyi MD., Khatko IV. Methods of evaluation of boars and sows according to the quality of the offspring in the conditions of breeding farms and breeding breeders. *Modern methods of research in pig breeding*. Poltava, 2005: 32–37. (in Ukrainian)
4. Buslyk TV, Ilchenko MO, Oliinychenko YK, Bankovska IB, Balatskyi VM. The influence of the polymorphism of cathepsin F gene on the meat quality of Ukrainian large white pigs. *Sci. Tech. Bull. SRCIVMFA IAB.* Lviv, 2018; 19 (2): 280–285. Available at: https://www.scivp.lviv.ua/wp-content/uploads/2021/09/44.pdf (in Ukrainian)
5. Hryshyna LP, Krasnoshchok OO. Feeding qualities of purebred, crossbred and hybrid young pigs. *Swine Breed.* Poltava, 2018; 71: 35–41. (in Ukrainian)
6. Hryshyna LP, Krasnoshchok OO. Meat qualities of purebred, crossbred and hybrid young pigs of different growth intensities. *Ukr. Black Sea Reg. Agr. Sci*. Mykolaiv, 2019; 3 (103): 98–106. DOI: 10.31521/2313-092X/2019-3(103)-12. (in Ukrainian**)**
7. Hugo A., Osthoff G., Jooste P. J. Effect of slaughter weight on the intramuscular fat composition of pigs. *Proc. 45th International Congress Meat Sci. Tech*. 1–6 August 1999, Yokohama, Japan; 1999: 496–497.
8. *Instructions for the growing pigs. Instructions for keeping pedigree records in pig breeding*. Kyiv, Kyiv University, 2003: 64 p. (in Ukrainian)
9. Kemp B, Da Silva CLA, Soede NM. Recent advances in pig reproduction: Focus on impact of genetic selection for female fertility. *Reprod. Dom. Anim*. 2018; 53 (2): 28–36. DOI: 10.1111/rda.13264.
10. Kodak TS. The effectiveness of the use of foreign and domestic boars in combination with purebred and cross-breed sows in the conditions of commercial breeder. Abstract. PhD agr. sci. 06.02.01 Breeding and selection of animals. Poltava, 2015: 21 p. (in Ukrainian)
11. Kovalenko VP, Khalak VI, Nezhlukchenko TI, Papakina NS. *Biometric analysis of the variability of traits of farm animals and birds*. A Textbook on genetics of farm animals. Kherson, Oldie, 2010: 160 p. (in Ukrainian)
12. Krasnoshchok OO. Formation of productivity of pigs depending on methods of cultivation and intensity of growth. Abstract. PhD agr. sci. 06.02.01 Breeding and selection of animals. Poltava, 2020: 23 p. (in Ukrainian)
13. Naryzhna OL. The efficiency of using purebred and terminal boars when combining them with large white sows in farm conditions. Abstract PhD agr. sci. 06.02.01 Breeding and selection of animals. Poltava, 2017: 22 p. (in Ukrainian)
14. Pelykh VH., Ushakova SV. Pig productivity's increase through the compatibility of cross parental pairs in two-way crossing. *Ukr. Black Sea Reg. Agr. Sci*. Mykolaiv, 2015; 4 (87): 145–152. Available at: https://visnyk.mnau.edu.ua/n87v4r2015pelykh (in Ukrainian)
15. Pogodaev VA, Komlatskyi GV. Reproductive, fattening and meat qualities of Danish breeding pigs. *Zootechnics*, 2014; 6: 5–7.
16. Povod M, Mykhalko O, Korzh O, Gutyj B, Mironenko O, Verbelchuk S, Koberniuk V, Tkachuk O. Dependence of the microclimate parameters of the pig house on different frequency of manure pits emptying and outdoor temperature. *Sci. Pap. Ser. Managem. Econ. Engineer. Agricult. Rural Dev.* 2022; 22 (4): 603–615
17. Rauw WM, Rydhmer L, Kyriazakis I, Øverland M, Gilbert H, Dekkers JCM, Hermesch S, Bouquet A, Gómez Izquierdo E, Louveau I, Gomez-Raya L. Prospects for sustainability of pig production in relation to climate change and novel feed resources. *J. Sci. Food Agricult.* 2020; 100 (9): 3575–3586. DOI: 10.1002/jsfa.10338.
18. Saienko AM, Hryshyna LP, Oliinychenko YK, Voloshchuk OV. Relationship of genotypes at loci RYR1. LEP 3469 T>C with fattening and meat qualities of pigs. *Swine Breed.* Poltava, 2019; 72: 70–75. (in Ukrainian)
19. Susol RL. Feeding and meat qualities of young pigs of the Piétrain breed taking into account DNA markers. *Agr. Bull. Black Sea*. Odesa, 2013; 70: 91–97. (in Ukrainian)
20. Tserenyuk OM. The effect of heterosis in the reciprocal crossing of Large white and Landrace breeds. *Ukr. Black Sea Reg. Agr. Sci*. Mykolaiv, 2010; 1 (52/2): 66–70. (in Ukrainian)
21. Vashchenko PA. Prediction of breeding value of pigs based on linear models of selection indices and DNA markers. Thes. Doc. Agr. Sci. 06.02.01 Breeding and selection of animals. Mykolaiv, 2019: 43 p. (in Ukrainian)
22. Voloshchuk VM, Floka LV. Feeding and meat qualities of pigs depending on phenotypic and genotypic factors. *Swine Breed*. Poltava, 2016; 68: 47–52. (in Ukrainian)
23. Wang G, Shen Y, Li C, Zhu Q, ZhanBota A. The regulatory effect of herd structure on pig production under the environmental regulation. *PLoS One*. 2022; 17 (4): e0266687. DOI: 10.1371/journal.pone.0266687.
24. Wu Y, Zhao J, Xu C, Ma N, He T, Zhao J, Ma X, Thacker PA. Progress towards pig nutrition in the last 27 years. *J. Sci. Food Agricult.* 2020; 100 (14): 5102–5110. DOI: 10.1002/jsfa.9095.

Продуктивні якості молодняку свиней великої білої породи різних генеалогічних ліній та внутрішньопородної диференціації за деякими інтегрованими показниками

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Мета роботи — дослідити відгодівельні та м'ясні якості молодняку свиней великої білої породи різних генеалогічних ліній та внутрішньопородної диференціаціації за деякими інтегрованими показниками, а також розрахувати економічну ефективність результатів експерименту. Оцінку молодняку свиней за відгодівельними та м'ясними якостями проводили з урахуванням таких кількісних ознак: середньодобовий приріст живої маси за період контрольної відгодівлі, г; вік досягнення живої маси 100 кг (діб); товщина шпику на рівні 6–7 грудних хребців (мм); довжина охолодженої туші (см); довжина беконної половини охолодженої півтуші (см). Комплексну оцінку тварин піддослідних груп проводили за індексами Тайлера і Вангена. Біометричну обробку результатів досліджень проводили за методиками В. П. Коваленка та ін. (2010). Дослідження проведено в агроформуваннях Дніпропетровської області, м'ясокомбінаті "Джаз" та лабораторії тваринництва Інституту зернових культур НААН України. Установлено, що за відгодівельними і м'ясними якостями молодняк свиней генеалогічних ліній Tafftus C61203 UA 8819345 і Azuro UA 8800557 великої білої породи відповідають класу еліта. Молодняк свиней генеалогічної лінії Tafftus C61203 UA 8819345 переважає ровесників лінії Azuro UA 8800557 за віком досягнення живої маси 100 кг на 3,25%, товщиною шпику на рівні 6–7 грудних хребців — на 5,74%, довжиною охолодженої туші — на 0,93%. Більша довжина охолодженої туші та довжина беконної половини охолодженої туші характерні для тварин лінії Azuro UA 8800557. Кількість вірогідних кореляційних зв'язків між відгодівельними і м'ясним якостями молодняку свиней великої білої породи, селекційним індексом СІ та індексом Тайлера становить 80%. Установлено, що максимальну прибавку додаткової продукції одержано від молодняку свиней генеалогічної лінії Tafftus C61203 UA 8819345 (+2,52%), І піддослідної групи за індексом Тайлера (+3,98%) та селекційним індексом СІ (+4,30%). Критерієм відбору високопродуктивних тварин за селекційним індексом СІ є показники 57,69–78,57 бала, за індексом Тайлера — 214,89–242,85 бала. Економічна ефективність використання молодняку свиней зазначених груп забезпечує одержання додаткової продукції на рівні +3,98–4,30%.

Ключові слова: молодняк свиней, порода, відгодівельні і мясні якості, індекс, кореляція, економічна ефективність

Khalak VI, Gutyj BV. Productive qualities of young pigs of the Large White breed of diverse genealogical lines and interbreed differentiation according to some integrated indicators. *Bìol. Tvarin*. 2023; 25 (1): 27–31. DOI: 10.15407/animbiol25.01.027.

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Effect of ethylthiosulfanylate in combination with vitamin E on certain biochemical blood parameters and hematological indicators in rats under the influence of Cr(VI)

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BIK: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Writing — review & editing.

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The aim of our study was to investigate the effect of ethylthiosulfanylate, a representative of the class of thiosulfonate compounds, in combination with vitamin E on certain biochemical blood parameters, hematological indicators and total Chromium content in liver of rats exposed to Cr(VI). Laboratory rats were divided into 8 groups of 5 animals each. Animals of group I (intact control) were injected daily intraperitoneally with 150 µl of physiological saline solution for 7 days. Rats of III/IV groups received intraperitoneal daily administration of $K_2Cr_2O_7$ (diluted in physiological saline solution at a dose of 2.5 mg Cr(VI)/kg) for 7/14 days. Animals of the II experimental group were injected daily intragastrically with 1000 µl of sunflower oil for 14 days. Rats of V/VI experimental groups were administrated daily intragastrically with 1000 µl of an oil solution of vitamin E (20 mg/kg)/ vitamin E (20 mg/kg) in combination with ethylthiosulfanylate (100 mg/kg) for 14 days. Animals of VII/VIII experimental groups were injected daily intragastrically with 1000 µl of an oil solution of vitamin E (20 mg/kg) in combination with ethylthiosulfanylate (100 mg/kg) for 14 days, after which a 7-day/14-day period of intraperitoneal $K_2Cr_2O_7$ administration was performed. Exposure to Cr(VI) led to a decrease in the number of erythrocytes, leukocytes, content of hemoglobin, phospholipids, total protein against the background of the accumulation of total lipids, mono- and diglycerides, non-esterified fatty acids, and creatinine in blood of rats. Chromium concentration significantly increased in the liver of rats after administration of Cr(VI). The combined effect of vitamin E and ethylthiosulfanylate contributed to the partial compensation of Cr(VI)-induced disturbances of the number of leukocytes and content of total proteins, phospholipids, non-esterified fatty acids in blood of rats. Vitamin E and ethylthiosulfanylate pretreatment also contributed to the reduction of the percentage accumulation of Chromium in liver of rats injected with Cr(VI).

Key words: ethylthiosulfanylate, hexavalent chromium, hematological parameters, lipids, lipid classes, creatinine

Introduction

Cr(VI) is a common heavy metal and is classified as a global environmental pollutant that increases the risk of several types of cancer and is increasingly recognized as a neurotoxicant [18]. The United States Environmental Protection Agency (USEPA) has included Cr(VI) as a priority pollutant due to its persistent toxic properties and

largely irreversible nature of adverse effects [39, 13]. However, Cr(VI) is an integral component in such technological processes as: paint production, leather tanning, magnetic tape production, hydrocarbon production (the role of a catalyst), metal processing, chromate production, stainless steel welding [3, 4]. Violation of production leads to uncontrolled emissions of Cr(VI) compounds into the environment. In particular, more than 20% of Cr compounds used in the process of industrial leather tanning are released in the form of wastewater and pollute the surrounding soils and water bodies with toxic Cr(VI), which in turn creates serious risks for poisoning of animals and human [28]. Cr(VI) compounds accumulate in cells of living organisms that inhabit polluted areas of ecosystems, and thus the toxic heavy metal is included in the food chain [38]. Cr(VI) from natural and industrial sources is mostly presented in the form of chromate and dichromate oxyanion (CrO_4^{2-}; $Cr_2O_7^{2-}$), which easily penetrates the cell membrane. The main pathways of Cr(VI)-induced toxicity are the activation of oxidative stress mechanisms, damage to the DNA structure, epigenetic disorders, which in turn leads to cytotoxicity, cellular mutagenesis, carcinogenesis, apoptosis.

Biologically active substances with antioxidant, detoxifying and cytoprotective properties are good candidates for the prevention and reduction of the negative effects of Cr(VI)-induced oxidative stress [29, 30, 36]. Ethylthiosulfanylate (ETS) belongs to the class of thiosulfonate compounds, which are synthetic analogues of natural biologically active organosulfur compounds isolated from garlic, onion, broccoli, cauliflower and sea urchin. Thiosulfonates are more stable than their natural counterparts, exhibit a wide range of biological properties and are characterized by low toxicity. Recent studies have shown that ETS is characterized by antioxidant, cytoprotective and hypolipidemic properties [23, 31]. Our previous studies established that 14-day exposure to ETS (100 mg/kg) contributed to only partial normalization of certain blood biochemical parameters of rats exposed to Cr(VI) [20]. Literature data report that the combined action of antioxidant compounds is often more effective in preventing Cr(VI)-induced disorders. In particular, vitamin E significantly complements the protective effect of Selenium, melatonin, atorvastatin under the conditions of Cr(VI)-induced toxicity [29, 30, 36]. Considering the good effectiveness of the combined application of vitamin E, it is important to evaluate the complex effect of ETS with the corresponding vitamin under the action of Cr(VI). The purpose of our work was to evaluate the specifics of the combined vitamin E and ETS action on certain biochemical blood parameters, hematological indicators and total Chromium content in liver of rats exposed to Cr(VI).

Materials and Methods

The research was conducted on male Wistar rats with mean body weight 135±5 g. Laboratory rats were kept in normal vivarium conditions with 12/12 hours lighting cycle, room temperature (22°C), air humidity 50±20%, standard feed and free access to drinking water. All manipulations with animals were conducted in accordance with European Convention "For the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes" (Strasbourg, 1986) and laws of Ukraine "Common Ethical Principles for Animal Experiments" (Ukraine, 2001). The animals were divided into 8 groups of 5 animals each (1 control and 7 experimental groups):

group I (intact control): daily intraperitoneally administered physiological saline solution (150 µl) for 7 days;

group III/IV: daily intraperitoneally administered $K_2Cr_2O_7$ solute in 150 µl of physiological saline (in terms of 2.5 mg Cr(VI) per kg of body weight) for 7/14 days;

group II (oil control): daily intragastrically treatment with 1000 µl of sunflower oil ("Oleina", ISO 14024: DSTU 4492) during 14-day period by the next 7-day period of physiological saline solution (150 µl) administration;

group V: daily intragastrically treated with vitamin E solute in 1000 µl of sunflower oil (in terms of 20 mg of vitamin E per kg of body weight) during 14-day period by the next 7-day period of physiological saline solution (150 µl) administration;

group VI: daily intragastrically treated with vitamin E and ethylthiosulfanylate (ETS) solute in 1000 µl of sunflower oil (in terms of 20 mg of vitamin E and 100 mg of ETS per kg of body weight) during 14-day period by the next 7-day period of physiological saline solution (150 µl) administration;

group VII/VIII: daily intragastrically treated with vitamin E and ETS solute in 1000 µl of sunflower oil during 14-day period by the next 7-/14-day period of $K_2Cr_2O_7$ administration.

In our research we used organosulfur compound — ETS (ethylthiosulfanylate), which was synthesized at the department of technology of biologically active compounds, pharmacy and biotechnology of National University "Lviv Polytechnic" according to the method as described previously [26].

After the thiopental anesthesia rats were decapitated and then we collected blood and liver. The research material was whole blood, blood plasma and liver of rats. In whole blood we counted the number of erythrocytes, leukocytes and determined the hemoglobin content. In blood plasma we determined total lipids, proteins and creatinine level, as well as measured the percentage content of individual lipid classes. In liver tissue we measured the total Chromium content.

Counting of erythrocytes and leukocytes number was performed by use of the Goryaev's chamber and at low microscope magnification (lens — 8x, eyepiece — 10x or 15x) with covered diaphragm or lowered condenser (in the dark field of view) [37]. To represent the number of erythrocytes and leukocytes per liter, the unit of measurement was given in 10^{12}/L and g/L respectively (SI units).

Determination of hemoglobin concentration was performed by hemoglobin-cyanide method [37]. The optical density of the obtained hemoglobin-cyanide solution was determined spectrophotometrically at λ 540 nm against

the transforming solution ($NaHCO_3$ — 1 g; $K_3Fe(CN)_6$ — 0.2 g; KCN or NaCN — 0.05 g; distillated water in order to obtain a total volume of 1 L). The hemoglobin content was expressed in g/L (SI units).

Blood plasma lipids were extracted according to Folch's method with the addition of a chloroform-methanol mixture in a ratio of 2:1 (v/v) [10]. To purify the lipid extract, a 0.74 M KCl solution was added. Determination of the content of total lipids was carried out by the gravimetric method by weighing the dry residue [17].

Determination of the percentage content of individual lipid classes was carried out according to the method of thin-layer chromatography on silica gel in the presence of a solvent complex of hexane — diethyl ether — glacial acetic acid in a ratio 70: 30: 1 (v/v/v). The plates with silica gel were processed using the crystalline iodine vapor [17]. The processed plates underwent scanning using an *HP Scanjet G2710* (China). The lipid classes were quantitatively analyzed and counted from obtained scans by using the *TotalLab TL120* (*Nonlinear Dynamics Ltd.*, UK). The results were then expressed as a percentage of the total lipids pool.

Total protein plasma level was determined by the Lowry Method [25] using the biochemical kit *Simko LTD* (Lviv, Ukraine) and expressed in g/L (SI units).

Determination of creatinine level was performed at biochemical analyzer *Humalyzer 2000* (*Human*; automatic type) by using the biochemical kit *Creatinine liquicolor (10051)* (Wiesbaden, Germany). The creatinine content was expressed in μmol/L (SI units).

Determination of Chromium content in liver tissues was performed by the method of atomic absorption spectrophotometry, which is based on absorption of electromagnetic radiation by free atoms in an unexcited state [37]. Liver tissue sample with a weight of 5 g was mineralized by the method of dry ashing in a muffle furnace stove according to GOST 286-87-85. Determination of the Chromium content was carried out after acid extraction (3N HCl) of sample. The Chromium content was expressed in mg/kg of tissue weight.

Statistical processing of data was carried out by the ANOVA method (with Tukey's *post hoc* test) and only P values ≤0.05 were statistically significant. All numerical values of indicators were presented as mean values (M) ± standard error (S.E.M.).

Results and Discussion

The main task of our work was to evaluate the potentially protective effects of vitamin E in combination with ETS against Cr(VI)-induced toxicity. As a result of research was established the multidirectional effect of the studied compounds on some hematological and biochemical parameters of rat blood.

We observed a statistically significant decrease of hemoglobin content, erythrocytes and leukocytes count after Cr(VI) intoxication in blood of animals of group III by 19, 16 and 19% and in group IV by 31, 25 and 35% compared to the group I (intact control) (table 1). This indicates about Cr(VI)-induced suppression of hemoglobin biosynthesis [35] and inhibition of erythrocyte and leukocyte differentiation processes by damaging hematopoietic stem cells of the bone marrow [12].

Table 1. Indicators of hematological parameters of rat blood (M±S.E.M., n=5)

Groups of animals	Hemoglobin, g/L	Erythrocytes, 10^{12}/L	Leukocytes, g/L
I — control	126.61±7.86	8.16±0.29	9.67±0.27
II — oil	123.35±5.73	8.32±0.3	9.92±0.30
III — Cr(VI) 7 days	102.43±2.88*	6.89±0.26*	7.89±0.38*
IV — Cr(VI) 14 days	87.41±2.45*	6.11±0.20*	6.27±0.17*
V — vitamin E	121.28±7.12	8.55±0.36	9.85±0.22
VI — vitamin E + ETS	121.75±5.78	8.83±0.41	9.71±0.26
VII — vitamin E + + ETS + Cr 7 days	123.31±5.08	8.28±0.44	8.97±0.32
VIII — vitamin E + + ETS + Cr 14 days	112.25±4.46	7.87±0.38	8.29±0.33*#

Note. Here and in the following tables: the statistically significant difference II, III, IV, V, VI, VII, VIII groups compared to the group I (control) is: * (P<0.001–0.05); the statistically significant difference V, VI, VII, VIII groups compared to the group II is: # (P<0.001–0.05).

We did not find statistically significant changes of hemoglobin level and erythrocytes number under the combined effect of vitamin E and ETS followed by Cr(VI) intoxication (experimental groups VII, VIII). The combined effect of vitamin E and ETS followed by Cr(VI) administration for 14 days led to decrease of leukocytes count in the blood of rats of group VIII by 16% compared to the group II. However, the percentage decrease of leukocytes number in blood of rats of group VIII (16%) compared with the group II was twice lower than the percentage decrease of leukocyte counts in blood of animals of group IV (35%) compared to the group I. Literature sources report that antioxidant and cytoprotective effects of vitamin E contributes to the prevention of Cr(VI)-induced decrease in the number of leukocytes [7].

Cr(VI) administration during 7-day and 14-day periods led to significant accumulation of the total lipids content in blood of rats by 38 and 44% relative to the group I (fig. 1).

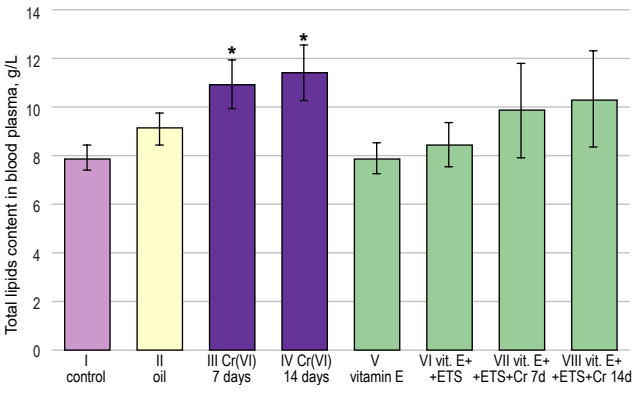

Fig. 1. Total lipids content in blood plasma of rats (M±m, n=5)
Note. * — P<0.05, the statistically significant difference II, III, IV, V, VI, VII, VIII groups compared to the group I (control).

Table 2. Indicators of the percentage content of individual lipid classes in blood of rats (M±S.E.M., n=5)

Class of lipids, % / Groups of animals	Phospho-lipids	Mono- and diglycerides	Non-esterified fatty acids	Non-esterified cholesterol	Triglycerides	Esterified cholesterol
I — control	32.33±1.61	9.78±0.95	13.39±1.75	12.94±0.57	17.81±1.07	13.75±3.42
II — oil	32.75±1.15	10.17±1.16	13.02±0.58	12.99±0.29	18.52±1.69	12.57±2.69
III — Cr(VI) 7 days	26.04±1.60*	12.94±0.16*	16.27±0.60	12.23±0.20	17.33±0.66	16.19±0.25
IV — Cr(VI) 14 days	23.00±2.31*	12.67±0.50*	17.82±0.53*	11.39±0.29	17.57±2.68	17.56±3.87
V — vitamin E	33.61±1.12	10.38±0.66	11.73±0.76	12.73±1.86	17.39±1.42	14.16±1.28
VI — vitamin E + ETS	38.46±1.28#	11.48±0.56	10.29±0.83#	11.23±0.84	16.56±1.10	11.98±1.94
VII — vitamin E + ETS + Cr 7 days	32.47±1.82	11.81±0.44	10.84±0.78	14.96±1.51	16.84±1.09	13.08±0.90
VIII — vitamin E + ETS + Cr 14 days	38.68±1.42*#	11.46±0.34	10.26±0.35#	12.68±0.47	15.60±3.23	11.33±2.17

The cause of hyperlipidemia by Cr(VI)-intoxicated rats may be SREBP-1 protein hyperexpression by the next accumulation of lipids, cholesterol, and triglycerides in blood and tissues [21]. Exposure to vitamin E in particular (group V) and in combination with ETS (groups VI, VII, VIII) did not cause statistically significant changes of total lipid level in blood of rats.

The analysis of individual classes of blood plasma lipids showed that the 7-day and 14-day exposure to Cr(VI) led to a significant decrease in the content of phospholipids by 19 and 27%, respectively, compared to the group I (table 2). Cr(VI) induces activation of phospholipids hydrolysis due to stimulation of phospholipase A2 [24].

In turn, the combined effect of vitamin E and ETS in particular (VI group) and by the next 14-day exposure to Cr(VI) (VIII group) caused an increase in the content of blood phospholipids by 17 and 18%, respectively, compared to the indicators of group II. Corresponding changes may indicate the need for the use of appropriate lipids in the adaptive rearrangements of cell membranes under the action of ETS [31] or inhibition of phospholipid hydrolysis processes due to phospholipase A2 suppression by vitamin E [32].

It is known that the toxic effect of heavy metals and oxidative stress are accompanied by the inactivation of the enzymes monoacylglycerol lipase and diacylglycerol kinase, which in turn contributes to the accumulation of mono- and diglycerides due to inhibiting the processes of splitting and conversion of the latter [2, 11]. It was established that mono- and diglycerides level increased under the influence of Cr(VI) in blood plasma of animals of groups III and IV by 32 and 30%, respectively, compared to the group I (table 2). We did not register statistically significant changes in the content of mono- and diglycerides under the combined effect of vitamin E and ETS (VI, VII, VIII groups).

We observed an increase in the level of non-esterified fatty acids (NEFA) in blood plasma of rats exposed to Cr(VI) during 14 days by 33% compared to the group I, which may be a consequence of the inhibition of fatty acids β-oxidation processes under the conditions of Cr(VI) intoxication [22]. However, the combined effect of vitamin E and ETS in particular (VI group) and by the next 14-day Cr(VI) exposure (VIII group) was accompanied by a significant decrease in the content of blood NEFA by 21% compared to the group II. Vitamin E and natural analogues of thiosulfonates contribute to the acceleration of the liver fatty acids breakdown [6, 14], which may be the reason for the decrease in the concentration of NEFA in rat blood.

As for the indicators of triglycerides, non-esterified and esterified cholesterol in blood of rats, no significant changes were found between all experimental groups.

Exposure to Cr(VI) for 14 days was accompanied by a decrease in the total protein content in blood plasma of rats by 28% compared to the indicators of group I (table 3), which may indicate Cr(VI)-induced damage to the filtering apparatus of kidneys with subsequent development of proteinuria [33]. Proteins are an important structural component of cells and at the same time are very sensitive to free radical damage. Literature data indicate that the decrease in blood total protein content under the conditions of Cr(VI) toxicity may be associated with nephrosis, as well as with a disruption of anabolic and catabolic balance of protein metabolism [8, 35].

The combined effect of vitamin E and ETS followed by the next 14-day exposure to Cr(VI) (group VIII) was also contribute to a decrease of blood total protein content by 12% compared to group II (table 3). However, the percentage

Table 3. Indicators of the total protein and creatinine content in blood of rats (M±S.E.M., n=5)

Groups of animals	Total protein, g/L	Creatinine, μmol/L
I — control	43.91±1.68	74.94±2.52
II — oil	44.28±0.71	74.70±2.26
III — Cr(VI) 7 days	36.97±3.50	134.41±2.82 *
IV — Cr(VI) 14 days	33.94±1.60 *	182.93±22.9 *
V — vitamin E	46.20±1.81	67.96±2.76
VI — vitamin E + ETS	45.46±1.44	71.64±2.03
VII — vitamin E + + ETS + Cr 7 days	41.30±1.17	100.42±5.50
VIII — vitamin E + + ETS + Cr 14 days	38.83±1.10 #	148.20±6.38 * #

decrease of total protein content in this case was twice lower than in blood of animals injected with Cr(VI) without vitamin E and ETS pretreatment (group IV). Vitamin E is an important natural antioxidant and provides protection of protein molecules due to the effective neutralization of reactive oxygen species (ROS) and free radicals [16]. Thiosulfonates and ETS in particular are also characterized by antiradical properties [23, 27]. It is possible that the radical scavenging and antioxidant properties of vitamin E and ETS may be the cause of attenuation of Cr(VI)-induced total protein content decreasing in blood of rats.

Cr(VI) stimulates the processes of protein catabolism and degradation, followed by the accumulation of urea and creatinine in blood plasma, which are the end products of amino acid metabolism [9]. The level of creatinine significantly increased in the blood plasma of rats after 7 and 14 days of Cr(VI) exposure by 79 and 144%, respectively, compared to the group I (table 3). Creatinine accumulation in this case may indicate a violation of renal filtration processes under the influence of Cr(VI) as a result of inflammation, fibrosis, renal tubular necrosis [33].

Creatinine content similarly increased after exposure to vitamin E and ETS by the subsequent 14-day Cr(VI) injection in blood of animals of group VIII by 98% compared to the group II. However, the percentage accumulation of creatinine in the blood of animals of group VIII (98%) compared to the II group was by 46% lower than the percentage increase of creatinine content in blood of rats of group IV (144%) compared to the indicators of group I. Vitamin E and organosulfur natural analogues of thiosulfonates are characterized by nephroprotective properties. These compounds reduce the intensity of lipids and proteins oxidation, ROS formation, reduced glutathione (GSH) depletion in kidneys under the conditions of oxidative stress, which in turn contributes to normalization of blood creatinine level [1, 15]. It is possible that the antioxidant properties of vitamin E and ETS may be the reason for the decrease in the intensity of creatinine accumulation in blood of rats injected with Cr(VI).

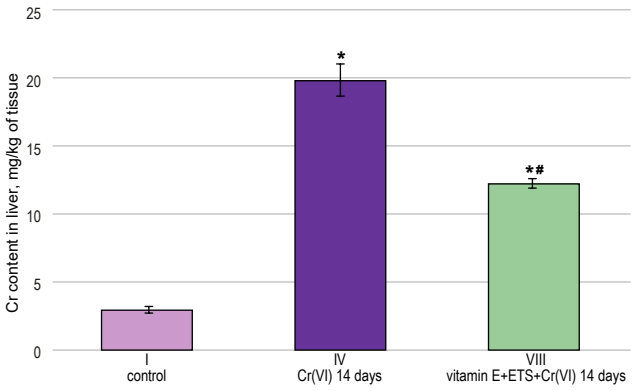

Fig. 2. Total Chromium content in liver of rats (M±m, n=5)
Note. * — P<0.05, the statistically significant difference IV, VIII groups compared to the group I (control); # — P<0.001–0.05, the statistically significant difference of group VIII compared to the group IV.

An important parameter that reflects the degree of Cr(VI) intoxication is the level of corresponding heavy metal accumulation in tissues and organs. The liver is one of the organs that intensively accumulates Cr(VI) from the blood circulatory system [40, 41]. Cr(VI) enters the liver cells through the capillary network and is accumulated by hepatocytes, which subsequently leads to hepatotoxicity, hyperplasia, fibrosis, necrosis and apoptosis [34]. Therefore, we determined the content of total Chromium in the liver of rats after 14-day exposure to Cr(VI) in order to assess the level of the corresponding heavy metal accumulation in the liver tissue of animals. It was established that exposure to Cr(VI) for 14 days (group IV) caused a significant increase in total Chromium content in liver of rats by 6.6 times compared to the control (fig. 2). Exposure to vitamin E in combination with ETS by the following 14-day injection of Cr(VI) was also accompanied with a significant increase in Chromium content by 4.1 times in the liver of rats compared to the control.

However, the percentage of Chromium accumulation in the liver tissue of rats of group VIII was by 38% lower compared to the group IV, which indicates a decrease in the percentage accumulation of Cr(VI) in the liver of rats pretreated with vitamin E and ETS. The literature data and our previous research report that exposure to vitamin E and ETS promotes the accumulation of GSH pool in liver of rats [14, 19]. Non-enzymatic antioxidant GSH reduces the intensity of Cr(VI) accumulation in liver by binding to the corresponding heavy metal with subsequent formation of biologically inert complexes [42]. GSH-Cr(VI) complexes are reduced to GSH-Cr(III), which are subsequently excreted from the body through the kidneys [5].

Conclusions

Cr(VI) causes a violation of the homeostasis of hematological blood parameters due to a decrease of erythrocytes, leukocytes count and hemoglobin content after both periods of administration. The combined effect of vitamin E and ETS lowered the percentage decrease of leukocytes number in blood of animals.

The toxic effect of Cr(VI) led to an increase in the level of blood total lipids, mono- and diglycerides during both periods of administration and caused also blood NEFA accumulation after 14-day period of Cr(VI) action. In turn, phospholipids content decreased after both periods of Cr(VI) exposure in blood plasma of rats.

The combined effect of vitamin E and ETS partially compensated for 14-day Cr(VI)-induced disturbances of blood lipid parameters by preventing an increase of NEFA content and decrease of phospholipids level in blood of rats. In turn, vitamin E and ETS in particular contributed to accumulation of the content of phospholipid fraction and to reduction of NEFA level in blood plasma of rats.

Cr(VI) caused a decrease of total protein level and led to an increase of creatinine content in blood plasma of animals. The combined effect of vitamin E and ETS

attenuated the percentage accumulation of creatinine and lowered the percentage decrease of total protein in blood of rats under conditions of 14-day Cr(VI) toxicity.

The combined effect of vitamin E and ETS attenuated the percentage accumulation of Chromium in liver tissue of rats exposed to Cr(VI) during 14-day period.

References

1. Abdel-Daim, MM, Abushouk AI, Donia T, Alarifi S, Alkahtani S, Aleya L, Bungau SG. The nephroprotective effects of allicin and ascorbic acid against cisplatin-induced toxicity in rats. *Env. Sci. Pollut. Res*. 2019; 26: 13502–13509. DOI: 10.1007/s11356-019-04780-4.
2. Atsumi H, Kitada M, Kanasaki K, Koya D. Reversal of redox-dependent inhibition of diacylglycerol kinase by antioxidants in mesangial cells exposed to high glucose. *Mol. Med. Rep*. 2011; 4 (5): 923–927. DOI: 10.3892/mmr.2011.524.
3. Bashandy SA, Salama A, Fayed AM, Omara EA, El-Toumy, SA, Salib JY. Protective effect of mandarin (Citrus reticulata) peel extract on potassium dichromate induced hepatotoxicity and nephrotoxicity in rats. *Plant Arch*. 2020; 20 (1): 2231–2242.
4. Boşgelmez İİ. An overview on the potential mechanisms of action of N-acetyl-l-cysteine in hexavalent chromium-induced toxicity. *Toxicol*. 2021; 397–408. DOI: 10.1016/B978-0-12-819092-0.00039-X.
5. Boşgelmez İİ, Güvendik G. N-acetyl-L-cysteine protects liver and kidney against Chromium(VI)-induced oxidative stress in mice. *Biol. Trace El. Res*. 2017; 178: 44–53. DOI: 10.1007/s12011-016-0901-2.
6. Cheng B, Li T, Li F. Use of network pharmacology to investigate the mechanism by which allicin ameliorates lipid metabolism disorder in HepG2 cells. *Evid. Bas. Compl. Alt. Med*. 2021; 2021: 3956504. DOI: 10.1155/2021/3956504.
7. DesMarias TL, Costa M. Mechanisms of chromium-induced toxicity. *Curr. Op. Toxicol*. 2019; 14: 1–7. DOI: 10.1016/j.cotox.2019.05.003.
8. El-Demerdash FM, El-Sayed RA, Abdel-Daim MM. Hepatoprotective potential of Rosmarinus officinalis essential oil against hexavalent chromium-induced hematotoxicity, biochemical, histological, and immunohistochemical changes in male rats. *Environmental Science and Pollution Research*. 2021; 28: 17445–17456. DOI: 10.1007/s11356-020-12126-8.
9. Feng H, Feng Q, Xiao T, Liu T, Guan B, Firdous SM, Huang J. *Ipomoea staphylina* attenuates potassium dichromate-induced nephrotoxicity in Wistar rats via antioxidant and antiapoptotic effects. *Dokl. Biochem. Biophys*. 2021; 499: 289–295. DOI: 10.1134/S1607672921040074.
10. Folch J, Lees M, Stanley GH. A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem*. 1957; 226 (1): 497–509. DOI: 10.1016/S0021-9258(18)64849-5.
11. Gkini E, Anagnostopoulos D, Mavri-Vavayianni M, Siafaka-Kapadai A. Metabolism of 2-acylglycerol in rabbit and human platelets. Involvement of monoacylglycerol lipase and fatty acid amide hydrolase. *Platelets*. 2009; 20 (6): 376–385. DOI: 10.1080/09537100903121813.
12. Haney J Jr. Consideration of non-linear, non-threshold and threshold approaches for assessing the carcinogenicity of oral exposure to hexavalent chromium. *Reg. Toxicol. Pharmacol*. 2015; 73 (3): 834–852. DOI: 10.1016/j.yrtph.2015.10.011.
13. Hassan M, Abd-Elwahab W, Megahed R, Mohammed A. An evaluation of hepatotoxicity, nephrotoxicity, and genotoxicity induced by acute toxicity of hexavalent chromium and comparison of the possible protective role of selenium and vitamin E on these effects. *Ain Shams J. Forensic Med. Clin. Toxicol*. 2019; 33 (2): 48–58. DOI: 10.21608/ajfm.2019.36574.
14. He W, Xu Y, Ren X, Xiang D, Lei K, Zhang C, Liu D. Vitamin E ameliorates lipid metabolism in mice with nonalcoholic fatty liver disease via Nrf2/CES1 signaling pathway. *Digest. Diseases Sci*. 2019; 64: 3182–3191. DOI: 10.1007/s10620-019-05657-9.
15. Kandpal V, Kumar D. Ameliorative role of vitamin E against hexavalent chromium induced hepato-nephrotoxicity in laboratory chicks: a histopathological study. *J. Adv. Sci. Res*. 2020; 11 (1): 132–138. Available at: https://www.sciensage.info/index.php/JASR/article/view/420
16. Kandpal V, Kumar D, Bisht R. Protective effect of vitamin E on haematological parameters in chronic toxicity of hexavalent chromium in laboratory chicks. *J. Drug Deliv. Therapeut*. 2019; 9 (3): 388–392. DOI: 10.22270/jddt.v9i3.2889.
17. Kates M. *Techniques of Lipidology. Isolation, Analysis and Identification of Lipids*. Amsterdam, Elsevier, 1986: 464 p.
18. Kim JJ, Kim YS, Kumar V. Heavy metal toxicity: An update of chelating therapeutic strategies. *J. Trace El. Med. Biol*. 2019; 54: 226–231. DOI: 10.1016/j.jtemb.2019.05.003.
19. Kotyk, BI, Iskra RY, Slivinska OM, Liubas NM, Pylypets AZ, Lubenets VI, Pryimych VI. Effects of ethylthiosulfanylate and chromium(VI) on the state of pro/antioxidant system in rat liver. *Ukr. Biochem. J*. 2020; 92 (5): 78–86. DOI: 10.15407/ubj92.05.078.
20. Kotyk B, Iskra R, Sushko O, Slivinska O, Klymets G, Buchko O, Pylypets A, Pryimych V. Effect of ethylthiosulfanylate and chrome(VI) on the pro/antioxidant system in rats blood. *Bìol. Tvarin*. 2019; 21 (4): 38–45. DOI: 10.15407/animbiol21.04.038.
21. Li X, He S, Zhou J, Yu X, Li L, Liu Y, Li W. Cr(VI) induces abnormalities in glucose and lipid metabolism through ROS/Nrf2 signaling. *Ecotoxicol. Environm. Saf*. 2021; 219: 112320. DOI: 10.1016/j.ecoenv.2021.112320.
22. Li Y, Zhao Y, Deng H, Chen A, Chai L. Endocrine disruption, oxidative stress and lipometabolic disturbance of *Bufo gargarizans* embryos exposed to hexavalent chromium. *Ecotoxicol. Environm. Saf*. 2018; 166: 242–250. DOI: 10.1016/j.ecoenv.2018.09.100.
23. Liubas N, Iskra R, Stadnytska N, Monka N, Havryliak V, Lubenets V. Antioxidant activity of thiosulfonate compounds in experiments *in vitro* and *in vivo*. *Biointerface Res. Appl. Chem*. 2022; 12 (3): 3106–3116. DOI: 10.33263/BRIAC123.31063116.
24. Long C, Hu G, Zheng P, Chen T, Su Z, Zhang Y, Ding C, Peng F, Yu S, Wang T, Jia G. Analysis of serum metabolome of workers occupationally exposed to hexavalent chromium: a preliminary study. *Toxicol. Lett*. 2021; 349: 92–100. DOI: 10.1016/j.toxlet.2021.06.007.
25. Lowry OH, Rosebrough NJ, Farr AL, Randall RJ. Protein measurement with the Folin phenol reagent. *J. Biol. Chem*. 1951; 193 (1): 265–275. DOI: 10.1016/S0021-9258(19)52451-6.
26. Lubenets VI, Havryliak VV, Pylypets AZ, Nakonechna AV. Changes in the spectrum of proteins and phospholipids in tissues of rats exposed to thiosulfonates. *Reg. Mech. Biosys*. 2018; 9 (4); 495–500. DOI: 10.15421/021874.
27. Lubenets V, Stadnytska N, Baranovych D, Vasylyuk S, Karpenko O, Havryliak V, Novikov V. Thiosulfonates: The Prospective Substances against Fungal Infections. In: Silva de Loreto É, Simoni Moraes Tondolo J (eds). *Fungal Infection*. IntechOpen, 2019. DOI: 10.5772/intechopen.84436.
28. Ma Y, Li S, Tang S, Ye S, Liang N, Liang Y, Xiao F. Clusterin protects against Cr(VI)-induced oxidative stress-associated hepatotoxicity by mediating the Akt-Keap1-Nrf2 signaling pathway. *Environm. Sci. Pollut. Res*. 2022; 29 (34): 52289–52301. DOI: 10.1007/s11356-022-19118-w.
29. Mehany HA, Abo-youssef AM, Ahmed LA, Arafa SA, Abd El-Latif HA. Protective effect of vitamin E and atorvastatin against potassium dichromate-induced nephrotoxicity in rats. *Beni-Suef Univer. J. Basic Appl. Sci*. 2013; 2 (2): 96–102. DOI: 10.1016/j.bjbas.2013.02.002.
30. Ozkan A, Fiskin K, Ayhan AG. Effect of vitamin E and selenium on antioxidant enzymes in brain, kidney and liver of cigarette smoke-exposed mice. *Biologia*. 2007; 62 (3): 360–364. DOI: 10.2478/s11756-007-0060-1.
31. Pylypets AZ, Iskra RY, Havryliak VV, Nakonechna AV, Novikov VP, Lubenets VI. Effects of thiosulfonates on the lipid composition of rat tissues. *Ukr. Biochem. J*. 2017; 89 (6): 56–62. DOI: 10.15407/ubj89.06.056.

32. Rhee SJ, Jeong YC, Choi JH. Effects of vitamin E on phospholipase A_2 activity and oxidative damage to the liver in streptozotocin-induced diabetic rats. *Annals Nutr. Metab*. 2005; 49 (6): 392–396. DOI: 10.1159/000088930.
33. Saidi M, Aouacheri O, Saka S, Tebboub I, Ailane L. Nephron-protective effects of curcuma on oxidative damage and oxidative stress in rat under sub-chronic poisoning of chromium. *Int. J. Biosci*. 2019; 15 (1): 242–251. DOI: 10.12692/ijb/15.1.242-251.
34. Shaw P, Mondal P, Bandyopadhyay A, Chattopadhyay A. Environmentally relevant concentration of chromium activates Nrf2 and alters transcription of related XME genes in liver of zebrafish. *Chemosphere*. 2019; 214: 35–46. DOI: 10.1016/j.chemosphere.2018.09.104.
35. Suljević D, Sulejmanović J, Fočak M, Halilović E, Pupalović D, Hasić A, Alijagic A. Assessing hexavalent chromium tissue-specific accumulation patterns and induced physiological responses to probe chromium toxicity in *Coturnix japonica* quail. *Chemosphere*. 2021; 266: 129005. DOI: 10.1016/j.chemosphere.2020.129005.
36. Temiz MA, Temur A, Oguz EK. Antioxidant and hepatoprotective effects of vitamin E and melatonin against copper-induced toxicity in rats. *Trop. J. Pharm. Res*. 2018; 17 (6): 1025–1031. DOI: 10.4314/tjpr.v17i6.7.
37. Vlizlo VV, Fedoruk RS, Ratych IB. *Laboratory methods of investigation in biology, stock-breeding and veterinary medicine*. Lviv, Spolom, 2012: 761p. ISBN 976-966-665-677-6. (in Ukrainian)
38. Wani PA, Wani JA, Wahid S. Recent advances in the mechanism of detoxification of genotoxic and cytotoxic Cr(VI) by microbes. *J. Environm. Chem. Eng*. 2018; 6 (4), 3798–3807. DOI: 10.1016/j.jece.2018.05.042.
39. Wise JP Jr, Young JL, Cai J, Cai L. Current understanding of hexavalent chromium [Cr(VI)] neurotoxicity and new perspectives. *Environm. Intern*. 2022; 158: 106877. DOI: 10.1016/j.envint.2021.106877.
40. Yan J, Huang H, Liu Z, Shen J, Ni J, Han J, Wang R, Lin D, Hu B, Jin, L. Hedgehog signaling pathway regulates hexavalent chromium-induced liver fibrosis by activation of hepatic stellate cells. *Toxicol. Lett*. 2020; 320: 1–8. DOI: 10.1016/j.toxlet.2019.11.017.
41. Zhao Y, Yan J, Li AP, Zhang ZL, Li ZR, Guo KJ, Zhao KC, Ruan Q, Guo L. Bone marrow mesenchymal stem cells could reduce the toxic effects of hexavalent chromium on the liver by decreasing endoplasmic reticulum stress-mediated apoptosis via SIRT1/HIF-1α signaling pathway in rats. *Toxicol. Lett*. 2019; 310: 31–38. DOI: 10.1016/j.toxlet.2019.04.007.
42. Zhao Y, Zhang H, Hao D, Wang J, Zhang D, Sun Z, Liu C. Selenium alleviates chromium(VI)-induced ileum damage and cecal microbial disturbances in mice. *Biol. Trace El. Res*. 2022; 200: 4750–4761. DOI: 10.1007/s12011-021-03061-x.

Вплив етилтіосульфанілату у поєднанні з вітаміном Е на окремі біохімічні параметри крові та гематологічні показники щурів за дії Cr(VI)

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Метою роботи було з'ясувати вплив етилтіосульфанілату, представника класу сполук тіосульфонатів, у поєднанні з вітаміном Е на стан окремих гематологічних показників, біохімічних параметрів крові та вміст Хрому у печінці щурів за впливу Cr(VI). Лабораторних щурів розділили на 8 груп по 5 тварин у кожній. Тваринам І групи (інтактний контроль) вводили 150 мкл фізрозчину щоденно внутрішньоочеревинно впродовж 7-ми діб. Щури III/IV груп отримували внутрішньоочеревинне щоденне введення $K_2Cr_2O_7$ (розведений у фізіологічному розчині у дозі 2,5 мг Cr(VI)/кг) впродовж 7-ми/14-ти діб. Тваринам ІІ дослідної групи вводили 1000 мкл соняшникової олії внутрішньошлунково щоденно протягом 14-ти діб. Щури V/VI дослідних груп отримували щоденне внутрішньошлункове введення 1000 мкл олійного розчину вітаміну Е (20 мг/кг)/вітаміну Е (20 мг/кг) у поєднанні з етилтіосульфанілатом (100 мг/кг) протягом 14-ти діб. Тваринам VII/VIII дослідних груп внутрішньошлунково щоденно вводили 1000 мкл олійного розчину вітаміну Е (20 мг/кг) у поєднанні з етилтіосульфанілатом (100 мг/кг) протягом 14-ти діб, після чого проводили 7-/14-добовий цикл внутрішньоочеревинного щоденного введення $K_2Cr_2O_7$. Вплив Cr(VI) призводив до зниження числа еритроцитів, лейкоцитів, вмісту гемоглобіну, фосфоліпідів, загального протеїну на фоні накопичення вмісту загальних ліпідів, моно- та диацилгліцеролів, неестерифікованих жирних кислот, креатиніну крові щурів. Концентрація Хрому значно зростала у печінці щурів після введення Cr(VI). Поєднаний ефект вітаміну Е та етилтіосульфанілату сприяв частковій стабілізації Cr(VI)-індукованого порушення кількості лейкоцитів, вмісту фосфоліпідів, неестерифікованих жирних кислот, загального протеїну у крові та зниженню відсоткового накопичення Хрому у печінці щурів, яким вводили Cr(VI).

Ключові слова: етилтіосульфанілат, хром шестивалентний, гематологічні показники, ліпіди, класи ліпідів, креатинін

Kotyk BI. Effect of ethylthiosulfanylate in combination with vitamin E on certain biochemical blood parameters and hematological indicators in rats under the influence of Cr(VI). *Biol. Tvarin*. 2023; 25 (1): 32–38. DOI: 10.15407/animbiol25.01.032.

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Вплив лікувально-профілактичної кормової добавки на рубцеву ферментацію хворих на кетоз корів

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SRS: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Supervision; Writing — review & editing.

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Іонофорні антибіотики регулюють рубцеву ферментацію, покращують використання протеїну корму, запобігають кетозу та стеатозу. Вони і β-кислоти хмелю пригнічують активність більшості грампозитивних мікроорганізмів рубця. Бактерії потребують вітаміну Е як активного антиоксиданта клітинних мембран. Токсичність токоферолу дуже низька, тому додавання його до раціону жуйних у кількості, більшій за рекомендовану, може стимулювати целюлозолітичні бактерії рубця і зменшити негативний вплив іонофорів на гідроліз клітковини. Бактерії рубця розщеплюють значну частину кормового холіну, метіоніну та карнітину, тому жуйним варто отримувати їх у захищеній формі. Сформовано три групи корів української молочної чорно-рябої породи (>5 тис. кг за попередню лактацію): з симптомами клінічного кетозу (n=4), з субклінічним кетозом (n=5) і клінічно здорові (n=5). Коровам з кетозом протягом місяця згодовували добавку з подрібненими гранулами шишок хмелю (20 г), вітаміном Е (3 г) і захищеними від розщеплення в рубці холіном (50 г), метіоніном (20 г) і карнітином (1 г). Здорові корови слугували контролем. У крові корів з субклінічним кетозом добавка збільшила рівень глюкози і зменшила рівень β-гідроксибутирату до клінічної норми. У корів з симптомами клінічного кетозу концентрація β-гідроксибутирату теж знизилася (P<0,01), проте перевищувала норму. У хворих корів амілолітична та ліполітична активності були нижчими, ніж у здорових (P<0,05–0,01). Целюлозолілітична активність була нижчою лише за клінічного кетозу. Протеолітична активність за кетозу була вищою (P<0,05–0,01) як наслідок зростання в рубці кількості та активності бактерій-гіперпродуцентів аміаку. Після лікування субклінічного кетозу целюлозолітична і амілолітична активності рубцевої рідини дорівнювали контрольним показникам, а протеолітична активність була навіть дещо нижчою (P<0,05). Лікування клінічної форми кетозу було менш ефективне, хоча тенденції зберігались. За обох форм кетозу у вмісті рубця виявлено більшу кількість аміаку (P<0,05–0,01) як наслідок вищої протеолітичної активності; концентрація летких жирних кислот в рубці знижувалась, а концентрація лактату зростала (P<0,05–0,01). Після згодовування добавки вказані показники за субклінічного кетозу наблизились до контролю, тоді як за клінічного кетозу стан покращувався, але концентрація аміаку і далі відрізнялась від норми.

Ключові слова: корови, кетоз, рубець, шишки хмелю, вітамін Е

Відомо, що іонофорні антибіотики впливають на рубцеву ферментацію, покращують використання протеїну корму. Вони здатні зменшувати інтенсивність наслідків негативного енергетичного балансу у високопродуктивних корів [5, 8]. У більшості досліджень виявлено зниження концентрації кетонових тіл у їхній крові [6, 13, 8]. Іонофори збільшують утворення в рубці попередника глюкози — пропіонату, а також зменшують розщеплення амінокислот [20]. За застосування іонофорів знижується ймовірність виникнення у корів субклінічного і клінічного кетозу [7, 4, 27, 19].

У високопродуктивних корів часто спостерігається жирове переродження печінки, зумовлене надмірним депонуванням триацилгліцеролів у гепатоцитах. Під впливом іонофорів стимулюється синтез гепатоцитами карнітин-пальмітоїл трансферази, яка транспортує жирні кислоти у мітохондрії для подальшого бета-окислення [24], внаслідок чого відбувається зменшення накопичення триацилгліцеролів у печінці [21, 36].

Іонофорні антибіотики і β-кислоти хмелю проявляють подібний спектр біологічної активності, вони пригнічують активність більшості грампозитивних мікроорганізмів рубця [10, 11]. Зокрема, β-кислоти інгібують активність грампозитивних бактерій *S. bovis*, які є одним з основних продуцентів лактату в рубці жуйних. Разом з тим, деякі грампозитивні бактерії нечутливі до β-кислот — наприклад, бактерії класу *Negativicutes* [10]. Представник цього класу *M. elsdenii* є важливим продуцентом пропіонату в рубці. Отже, за дії біологічно активних кислот суплідь хмелю у вмісті рубця знижується продукція молочної кислоти. Продукція пропіонової кислоти кількісно переважно не змінюється, проте внаслідок деякого зниження кількості ацетату частка пропіонату у рубцевій рідині стає більшою [10]. Як й іонофорні антибіотики, β-кислоти шишок хмелю знижують протеолітичну активність та пригнічують утворення аміаку і метаногенез у рубці [39, 12, 2].

Шишки хмелю містять низку біологічно активних компонентів, подібних за дією до антибіотиків-іонофорів — це пренільовані флавоноїди: гумулон (α-кислоти), лупулон (β-кислоти) та їхні похідні [35, 11]. Вказані компоненти шишок хмелю можна розглядати як потенційний замінник іонофорних антибіотиків [37, 9]. Основними й найчисленнішими біологічно активними компонентами шишок хмелю є гідрофобні α- і β-кислоти або, як їх ще називають, «гіркі кислоти». α-кислоти представлені шістьма сполуками, серед яких хумулон (35–70%), кохумулон (20–55%), адхумулон (10–15%), а також мінорні компоненти: постхумулон, прехумулон та адпрехумулон [17]. До β-кислот належать лупулон (30–55%), колупулон (20–55%), адлупулон (5–10%), прелупулон і постлупулон [17].

Шишки хмелю містять поліфенольні компоненти, кількість яких відносно невелика (3–6%), проте вони проявляють значну біологічну активність [18, 29]. Як і β-кислоти, поліфенольні сполуки діють переважно на грампозитивні бактерії [32]. Відносно висока активність характерна для поліфенолів групи пренілфлавоноїдів, які діють на грампозитивні бактерії та деякі гриби і протисти [23].

Інша велика група біологічно активних речовин шишок хмелю — це ефірні олії, які також продукуються лупуліновими залозами [3]. Протимікробна активність притаманна ефірним оліям хмелю, проте вона менша порівняно з дією гірких кислот і поліфенолів [17].

Наявні у шишках хмелю сполуки мають значні антиоксидантні властивості [1, 40]. Найвища антиоксидантна дія характерна для поліфенолів хмелю, які ефективно нейтралізують активні форми Оксигену [25, 31]. Крім того, поліфеноли інгібують ензими, задіяні у генеруванні активних форм Оксигену [17]. Антиоксидантна дія притаманна також α- і β-кислотам [17].

Бактерії, як й інші живі організми, потребують наявності вітаміну Е як активного антиоксиданта клітинних мембран. Причому мікроорганізми потребують більших доз вітаміну Е, ніж сама тварина [14]. За згодовування або парентерального введення жуйним токоферолу враховують потребу саме тварини, тоді як мікроорганізмам рубця цієї кількості недостатньо. Токсичність токоферолу дуже низька, тому додавання його до раціону жуйних у підвищених кількостях стимулює целюлолітичні бактерії рубця та компенсує пригнічення іонофорами розщеплення клітковини раціону [30].

Карнітин необхідний для транспортування довголанцюгових жирних кислот з цитоплазми в мітохондрії, ацетил-КоА з пероксисом в цитоплазму, також він регулює співвідношення ацил-КоА/КоА-SH [28]. За надмірного надходження жирних кислот до печінки карнітин посилює їх окислення, зменшуючи цим накопичення триацилгліцеролів у гепатоцитах [22].

Холін є компонентом фосфатидилхоліну і відомий як гепатопротектор [16]. Холін бере участь у регуляції секреції інсуліну і розглядається як попередник ацетилхоліну [33, 15].

Метіонін — незамінна амінокислота, яка широко застовується для захисту печінки [38]. Метаболізм метіоніну та холіну тісно взаємопов'язаний, їх часто вважають взаємозамінними з точки зору гепатопротекції, проте нещодавно виявлено, що вказані сполуки по-різному впливають на стан печінки і молочну продуктивність корів [38].

Оскільки бактерії рубця розщеплюють значну частину кормового холіну, метіоніну та карнітину, жуйні повинні отримувати їх у захищеній формі [16, 33, 38, 26], тому їхній вплив на рубцеву ферментацію незначний.

Матеріали і методи

У корів української молочної чорно-рябої породи з продуктивністю 5 і більше тис. кг молока за попередню лактацію після отелення взяли зразки венозної крові для визначення концентрації глюкози і β-гідроксибутирату. Для досліду підібрано 3 групи корів: з ознаками клінічного кетозу (концентрація β-гідроксибутирату у крові >3,0 ммоль/л) —

4 тварини; з субклінічним кетозом (концентрація β-гідроксибутирату 1,3–2,2 ммоль/л) — 5 тварин та клінічно здорові (концентрація β-гідроксибутирату 0,2–1,1 ммоль/л) — 5 тварин.

Хворим на кетоз коровам протягом місяця до комбікорму додавали лікувально-профілактичну добавку, яка містить: подрібнені гранули шишок хмелю — 20 г, вітамін Е — 3 г, та захищені від розщеплення у рубці холін — 50 г, метіонін — 20 г, карнітин — 1 г. Клінічно здорові корови слугували контролем.

Для лабораторних досліджень використовували вміст рубця і кров. Матеріал для аналізу брали через тиждень та через місяць після отелення. У рубцевій рідині визначали протеїн методом К'єльдаля, вміст аміаку за Конвеєм, молочної кислоти — за Баркером-Саммерсоном, загальний вміст летких жирних кислот — методом парової дистиляції в апараті Маркгама, pH згідно з методами, викладеними у довіднику [34]. У крові визначали концентрацію глюкози і β-гідроксибутирату за допомогою глюкокетометра *CareSens Dual* (*i-Sens*, Південна Корея).

Результати та їх обговорення

Лікувально-профілактична добавка, яка містить подрібнені гранули шишок хмелю, вітамін Е та захищені від розщеплення у рубці холін, метіонін і карнітин, знижує концентрацію β-гідроксибутирату та збільшує концентрацію глюкози в крові корів. У корів з субклінічною формою кетозу спостерігають нормалізацію показників крові, а у хворих на клінічний кетоз корів захворювання переходить у субклінічну форму (табл. 1).

У корів із симптомами клінічного кетозу згодовування кормової добавки знизило концентрацію β-гідроксибутирату в крові — з 4,08 ммоль/л на початку до 2,78 ммоль/л наприкінці досліду (P<0,01). Добавка суттєво зменшила кількість кетонових тіл, проте їхня концентрація залишалась на відносно високому рівні; це свідчить, що інтенсивність перебігу патологічного процесу хоч і знизилась, але недостатньо для повного одужання, тобто захворювання перейшло у легшу субклінічну форму. Концентрація глюкози у сироватці крові цих корів зросла на 50% — з 1,95 до 2,93 ммоль/л (P<0,01).

Різниця між показниками концентрації глюкози в крові здорових і хворих на субклінічний кетоз корів становила 15,3% (P<0,05). Вміст β-гідроксибутирату у крові корів із субклінічним кетозом у 2,6 раза перевищував показник здорових корів (P<0,001). Лікувально-профілактична добавка збільшила концентрацію глюкози та зменшила концентрацію β-гідроксибутирату; ці показники увійшли в межі норми, проте залишались вищими від показників здорових корів.

У клінічно здорових корів протягом дослідного періоду також виникли певні зміни метаболічного профілю крові. За порівняння показників на початку

Таблиця 1. Концентрація глюкози та β-гідроксибутирату у крові корів
Table 1. Glucose and β-hydroxybutyrate concentrations in the cows blood

Показники Parameters	Групи корів / Groups of cows		
	клінічно здорові healthy	субклінічний кетоз subclinical ketosis	клінічний кетоз clinical ketosis
Початок досліду / The beginning of the experiment			
Глюкоза, ммоль/л Glucose, mmol/L	2,42± ±0,13	2,05± ±0,08*	1,95± ±0,17*
β-Гідроксибутират, ммоль/л β-Hydroxybutyrate, mmol/L	0,64± ±0,10	1,65± ±0,09***	4,08± ±0,26***
Кінець досліду / The end of the experiment			
Глюкоза, ммоль/л Glucose, mmol/L	2,87± ±0,08#	2,69± ±0,12##	2,93± ±0,11##
β-Гідроксибутират, ммоль/л β-Hydroxybutyrate, mmol/L	0,56± ±0,07	1,06± ±0,12*##	2,78± ±0,30**##

Примітка. Тут і далі: * — ступінь вірогідності різниць у показниках хворих корів порівняно з здоровими; * — P<0,05; ** — P<0,01; *** — P<0,001; # — ступінь вірогідності різниць у показниках до і після лікування; # — P<0,05; ## — P<0,01; ### — P<0,001.
Note. Here and further: * — statistical significance between sick and healthy cows; * — P<0.05; ** — P<0.01; *** — P<0.001; # — statistical significance in each group before and after treatment; # — P<0.05; ## — P<0.01; ### — P<0.001.

Таблиця 2. Азотовий та вуглеводний обмін у вмісті рубця
Table 2. Nitrogen and carbohydrate metabolism in rumen contents

Показники / Parameters	Групи корів / Groups of cows		
	клінічно здорові healthy	субклінічний кетоз subclinical ketosis	клінічний кетоз clinical ketosis
Початок досліду / The beginning of the experiment			
Білковий азот, ммоль/л Protein nitrogen, mmol/L	58,45± ±4,76	52,33± ±5,11	45,27± ±3,18*
Мікробний азот, ммоль/л Microbial nitrogen, mmol/L	38,37± ±2,65	39,62± ±1,97	31,24± ±2,03*
ЛЖК, ммоль/л VFA, mmol/L	122,67± ±9,75	108,69± ±6,14	89,36± ±7,32**
Азот аміаку, ммоль/л Ammonia nitrogen, mmol/L	5,71± ±0,52	6,41± ±0,40*	7,63± ±0,29**
Лактат, ммоль/л Lactate, mmol/L	4,02± ±0,13	4,59± ±0,10*	5,27± ±0,06**
pH	6,70± ±0,11	6,79± ±0,15	6,78± ±0,17
Кінець досліду / The end of the experiment			
Білковий азот, ммоль/л Protein nitrogen, mmol/L	57,28± ±3,98	55,81± ±3,14	50,42± ±2,81
Мікробний азот, ммоль/л Microbial nitrogen, mmol/L	36,83± ±1,77	37,55± ±2,05	35,89± ±3,12
ЛЖК, ммоль/л VFA, mmol/L	121,39± ±5,87	123,13± ±7,34#	107,75± ±4,67**#
Азот аміаку, ммоль/л Ammonia nitrogen, mmol/L	5,24± ±0,43	5,11± ±0,29#	6,09± ±0,32*#
Лактат, ммоль/л Lactate, mmol/L	4,32± ±0,27	4,65± ±0,19	4,96± ±0,06*
pH	6,63± ±0,07	6,67± ±0,09	6,73± ±0,12

і наприкінці досліду виявлено збільшення концентрації глюкози на 18,6% (P<0,05).

Як видно з результатів, наведених у табл. 2, захворювання на кетоз змінює перебіг рубцевої ферментації у корів. Виявлено зміни у інтенсивності розщеплення клітковини, крохмалю, протеїну та ліпідів. Зокрема, порівняно з коровами контрольної групи, амілолітична активність рубцевої рідини корів з субклінічним кетозом знизилась на 6,5% (P<0,05), а у хворих на клінічний кетоз корів цей показник був нижчим на 16,5% (P<0,01). Подібну тенденцію спостерігали для целюлозолітичної активності, проте для цієї групи ензимів меншу активність виявили лише в корів, хворих на клінічний кетоз, у яких зниження становило 11,4% (P<0,05). У корів з субклінічним кетозом змін целюлозолітичної активності у рубцевій рідині не виявлено, тобто у цій групі вказана активність не відрізнялась від показника рубцевої рідини здорових корів. У хворих корів значно знизилась ліполітична активність: за субклінічного кетозу — на 12,9% (P<0,05), а за клінічної форми цього захворювання — на 21,5% (P<0,01). Такі зміни можуть бути наслідком меншого споживання корму хворими коровами, а також змін чисельності та функціонування мікроорганізмів рубця внаслідок порушень метаболізму і погіршення загального стану хворих тварин. Протеолітична активність вмісту рубця змінювалась протилежно, тобто у хворих корів вона зростала. Зокрема, в рубці корів із субклінічним кетозом протеолітична активність була вищою на 12,5% (P<0,05), а в рубці корів з клінічною формою кетозу — на 22,4% (P<0,01) порівняно зі здоровими коровами. Це є наслідком характерного для кетозу корів зростання у рубці чисельності та активності бактерій гіперпродуцентів аміаку.

У результаті додавання до комбікорму корів протикетозної добавки встановлено позитивний вплив на рубцеву ферментацію. Після лікування корів із субклінічним кетозом целюлозолітична й амілолітична активності рубцевої рідини вирівнялась з відповідними показниками здорових корів, а протеолітична активність була навіть дещо нижчою (P<0,05), ніж у контрольній групі.

Проте лікування корів з клінічною формою кетозу було не таким ефективним. Амілолітична активність в рубцевій рідині цих корів залишалась нижчою порівняно зі здоровими тваринами (P<0,05), хоча була більшою, ніж до лікування (P<0,05). Целюлозолітична активність рубцевої рідини після лікування клінічного кетозу була дещо меншою, ніж у корів контрольної групи, хоча ця різниця не була статистично вірогідною. Після лікування протеолітична активність рубцевої рідини корів, хворих на субклінічний кетоз, знизилась на 15,0% (P<0,05), а в корів з клінічним кетозом — навпаки, зросла на 5,5%, хоча й статистично невірогідно порівняно з контрольною групою. На ліполітичну активність досліджувана добавка не вплинула, цей показник залишався нижчим після лікування як субклінічного (P<0,05), так і клінічного кетозу (P<0,01).

Таким чином, за порівняння показників рубцевої ферментації до і після лікування виявлено зниження протеолітичної активності в рубці корів, які мали субклінічний кетоз (P<0,01), та зростання амілолітичної (P<0,05) і зменшення протеолітичної активності (P<0,01) в рубці корів, яких лікували від клінічної форми кетозу. Інші показники в рубці корів кожної з груп після лікування суттєво не змінювались.

Таку дію можна пояснити пригніченням життєдіяльності бактерій-гіперпродуцентів аміаку біологічно активними сполуками хмелю, насамперед лупулоном і його похідними. Менш інтенсивне зниження целюлозолітичної активності, очевидно, спричинене частковою її компенсацією внаслідок стимулювальної дії вітаміну Е на цю групу рубцевих бактерій. З дією вітаміну Е може бути пов'язане і зниження ліполітичної активності.

Згідно з наведеними у табл. 3 даними, захворювання на кетоз впливає на інтенсивність і спрямованість рубцевої ферментації, причому за клінічного перебігу цього захворювання зміни виражені значно суттєвіше, ніж за субклінічної форми. За субклінічного кетозу основні особливості обміну азотових сполук стосувались збільшення концентрації аміаку в рубцевій рідині, яка перевищувала відповідний показник в рубці здорових корів на 12,3% (P<0,05). Клінічна форма кетозу суттєвіше впливала на ферментацію протеїну та утворення продуктів його розпаду. Концентрація аміаку в цьому випадку зростала на 33,6% (P<0,01). При цьому, на відміну від корів з субклінічним кето-

Таблиця 3. Азотовий та вуглеводний обмін у вмісті рубця
Table 3. Nitrogen and carbohydrate metabolism in rumen content

Показники Parameters	Групи корів / Groups of cows		
	клінічно здорові healthy	субклінічний кетоз subclinical ketosis	клінічний кетоз clinical ketosis
Початок досліду / The beginning of the experiment			
Білковий азот, ммоль/л Protein nitrogen, mmol/l	58,45± ±4,76	52,33± ±5,11	45,27± ±3,18*
Мікробний азот, ммоль/л Microbial nitrogen, mmol/l	38,37± ±2,65	39,62± ±1,97	31,24± ±2,03*
ЛЖК, ммоль/л VFA, mmol/l	122,67± ±9,75	108,69± ±6,14	89,36± ±7,32**
Азот аміаку, ммоль/л Ammonia nitrogen, mmol/l	5,71± ±0,52	6,41± ±0,40*	7,63± ±0,29**
Лактат, ммоль/л Lactate, mmol/l	4,02± ±0,13	4,59± ±0,10*	5,27± ±0,06**
pH	6,70± ±0,11	6,79± ±0,15	6,78± ±0,17
Кінець досліду / The end of the experiment			
Білковий азот, ммоль/л Protein nitrogen, mmol/l	57,28± ±3,98	55,81± ±3,14	50,42± ±2,81
Мікробний азот, ммоль/л Microbial nitrogen, mmol/l	36,83± ±1,77	37,55± ±2,05	35,89± ±3,12
ЛЖК, ммоль/л VFA, mmol/l	121,39± ±5,87	123,13± ±7,34#	107,75± ±4,67**#
Азот аміаку, ммоль/л Ammonia nitrogen, mmol/l	5,24± ±0,43	5,11± ±0,29#	6,09± ±0,32*#
Лактат, ммоль/л Lactate, mmol/l	4,32± ±0,27	4,65± ±0,19	4,96± ±0,06*
pH	6,63± ±0,07	6,67± ±0,09	6,73± ±0,12

зом, за клінічного кетозу в рубці зменшувався вміст білкового азоту (P<0,05), що відбувалося за рахунок меншої кількості азоту клітин мікроорганізмів, тобто зменшення чисельності мікробіоти рубця. Враховуючи наведені у попередній таблиці дані про зростання в рубці протеолітичної активності, можна припустити, що це зменшення не стосувалося протеолітичних бактерій. Проте, з іншого боку, зростання протеолітичної активності може бути спричинене бактеріями гіперпродуцентами аміаку, для яких характерна невелика чисельність за дуже високої гідролітичної активності.

Відхилення виявили й у показниках вуглеводного обміну: вони проявились у меншій кількості летких жирних кислот та зростанні концентрації молочної кислоти. За субклінічного та клінічного кетозу концентрація летких жирних кислот у рубці знижувалась, відповідно, на 11,4% та 27,2%. Хоча статистично вірогідними ці зміни були лише у випадку клінічного кетозу (P<0,01), кількісно зміни за субклінічної форми достатньо суттєві, що дозволяє стверджувати про певну тенденцію. На жаль, ми не мали змоги визначити концентрації окремих летких жирних кислот, що дало б детальнішу інформацію про вплив кетозу на ферментацію вуглеводів. Проте, з огляду на особливості ферментативної активності в рубці, можна зробити висновок, що у хворих на субклінічний кетоз корів пригнічувалось насамперед розщеплення крохмалю та цукрів, а в корів, хворих на клінічний кетоз, — крім крохмалю та цукрів, також і целюлози та геміцелюлози.

Концентрація лактату зросла за обох форм кетозу; за субклінічної форми вона була більшою на 14,2% (P<0,05), а за клінічної — на 31,1% (P<0,01), ніж у здорових тварин. Отже, незважаючи на зниження загальної амілолітичної активності в рубці хворих корів, молочнокисле бродіння у них посилювалось.

Згодовування лікувально-профілактичної добавки вплинуло на перебіг бродильних процесів у рубці. У хворих на кетоз корів, порівняно з коровами контрольної групи, виявлено більшу концентрацію аміаку та меншу кількість білкового азоту у вмісті рубця (P<0,05). При цьому важливо, що в корів з клінічним кетозом відсутня різниця за вмістом мікробного азоту, тобто популяція бактерій у їхньому рубці вирівнялась зі значенням у здорових корів. Після згодовування лікувальної добавки показники рубцевої ферментації у хворих на субклінічний кетоз корів наблизились до показників здорових тварин, тоді як у корів з клінічним кетозом концентрація аміаку та білкового азоту відрізнялась від показників здорових тварин. Те саме стосується й лактату: його концентрація після лікування зменшувалась (P<0,05), але надалі була вищою, ніж у здорових корів (P<0,05).

Ми не виявили вірогідних різниць показників pH вмісту рубця хворих і здорових корів до та після лікування. Вочевидь, це зумовлено взаємнокомпенсаційними змінами концентрацій летких жирних кислот і лактату в рубці.

Висновки

Лікувально-профілактична добавка, яка містить подрібнені гранули шишок хмелю, вітамін Е та захищені від розщеплення у рубці холін, метіонін і карнітин, знижує концентрацію β-гідроксибутирату і збільшує концентрацію глюкози в крові корів. У корів із субклінічною формою кетозу нормалізувалися показники крові, а у хворих на клінічний кетоз корів захворювання перейшло в субклінічну форму.

У рубці хворих на кетоз корів виявлено пригнічення амілотітичної і ліполітичної та посилення протеолітичної активності. Досліджувана добавка пригнічує протеолітичну та посилює амілолітичну і целюлозолітичну активності в рубці корів.

За кетозу в рубці корів спостерігали зниження загальної концентрації летких жирних кислот та зростання концентрації аміаку і лактату. Лікувальна добавка нормалізує вказані показники у корів, хворих на субклінічний кетоз, та покращує стан корів з клінічною формою кетозу.

References

1. Almeida ADR, Maciel MVDOB, Machado MH, Bazzo GC, de Armas RD, Vitorino VB, Vitali L, Block JM, Barreto PLM. Bioactive compounds and antioxidant activities of Brazilian hop (*Humulus lupulus* L.) extracts. *Int. J. Food Sci. Technol.* 2020; 55 (1): 340–347. DOI: 10.1111/ijfs.14311.
2. Blaxland JA, Watkins AJ, Baillie LWJ. The ability of hop extracts to reduce the methane production of *Methanobrevibacter ruminantium*. *Archaea.* 2021; 2021: 5510063. DOI: 10.1155/2021/5510063.
3. Briggs DE, Boulton CA, Brookes PA, Stevens RC. *Brewing Science and Practice*. London, CRC Press. 2004: 900 p. DOI: 10.1201/9780203024195.
4. Compton C, Young L, McDougall S. Efficacy of controlled-release capsules containing monensin for the prevention of subclinical ketosis in pasture-fed dairy cows. *New Zealand Vet. J.* 2015; 63 (5): 249–253. DOI: 10.1080/00480169.2014.999842.
5. Duffield TF, Merrill JK, Bagg RN. Meta-analysis of the effects of monensin in beef cattle on feed efficiency, body weight gain, and dry matter intake. *J. Anim. Sci.* 2012; 90 (12): 4583–4592. DOI: 10.2527/jas.2011-5018.
6. Duffield TF, Rabiee AR, Lean IJ. A meta-analysis of the impact of monensin in lactating dairy cattle. Part 1. Metabolic effects. *J. Dairy Sci.* 2008; 91 (4): 1334–1346. DOI: 10.3168/jds.2007-0607.
7. Duffield TF, Rabiee AR, Lean IJ. A meta-analysis of the impact of monensin in lactating dairy cattle. Part 3. Health and reproduction. *J. Dairy Sci.* 2008; 91 (6): 2328–2341. DOI: 10.3168/jds.2007-0801.
8. Fiore E, Perillo L, Gianesella M, Giannetto C, Giudice E, Piccione G, Morgante M. Comparison between two preventive treatments for hyperketonaemia carried out *pre-partum*: Effects on non-esterified fatty acids, β-hydroxybutyrate and some biochemical parameters during peripartum and early lactation. *J. Dairy Res.* 2021; 88 (1): 38–44. DOI: 10.1017/S0022029921000108.
9. Flythe MD. The antimicrobial effects of hops (*Humulus lupulus L.*) on ruminal hyper ammonia-producing bacteria. *Lett. Appl. Microbiol.* 2009; 48 (6): 712–717. DOI: 10.1111/j.1472-765X.2009.02600.x.

10. Flythe MD, Aiken GE. Effects of hops (*Humulus lupulus L.*) extract on volatile fatty acid production by rumen bacteria. *J. Appl. Microbiol.* 2010; 109 (4): 1169–1176. DOI: 10.1111/j.1365-2672.2010.04739.x.

11. Flythe MD, Kagan IA, Wang Y, Narvaez N. Hops (*Humulus lupulus L.*) bitter acids: Modulation of rumen fermentation and potential as an alternative growth promoter. *Front. Vet. Sci.* 2017; 4: 131. DOI: 10.3389/fvets.2017.00131.

12. Harlow BE, Bryant RW, Cohen SD, O'Connell SP, Flythe MD. Degradation of spent craft brewer's yeast by caprine rumen hyper ammonia-producing bacteria. *Lett. Appl. Microbiol.* 2016; 63 (4): 307–312. DOI: 10.1111/lam.12623.

13. Hausmann J, Deiner C, Patra AK, Immig I, Starke A, Aschenbach JR. Effects of a combination of plant bioactive lipid compounds and biotin compared with monensin on body condition, energy metabolism and milk performance in transition dairy cows. *PLoS ONE*. 2018; 13 (3): e0193685. DOI: 10.1371/journal.pone.0193685.

14. Hernández-Mendo O, Ramírez-Mella M, Ramírez-Bribiesca JE, Crosby-Galván MM, Burgueño-Ferreira JA. Effect of vitamin E on ruminal fermentation and nutrient digestion in steers supplemented with microencapsulated conjugated linoleic acid. *Anim. Nutr. Feed Techn*. 2017; 17 (2): 293–301. DOI: 10.5958/0974-181X.2017.00028.2.

15. Humer E, Bruggeman G, Zebeli Q. A meta-analysis on the impact of the supplementation of rumen-protected choline on the metabolic health and performance of dairy cattle. *Animals (Basel).* 2019; 9 (8): E566. DOI: 10.3390/ani9080566.

16. Jayaprakash G, Sathiyabarathi M, Robert MA, Tamilmani T. Rumen-protected choline: A significance effect on dairy cattle nutrition. *Vet. World*. 2016; 9 (8): 837–841. DOI: 10.14202/vetworld.2016.837-841.

17. Karabín M, Hudcová T, Jelínek L, Dostálek P. Biologically active compounds from hops and prospects for their use. *Compr. Rev. Food Sci. Food Saf.* 2016; 15 (3): 542–567. DOI: 10.1111/1541-4337.12201.

18. Karabin M, Hudcova T, Jelinek L, Dostalek P. Biotransformations and biological activities of hop flavonoids. *Biotech. Adv.* 2015; 33 (6/2): 1063–1090. DOI: 10.1016/j.biotechadv.2015.02.009.

19. Mammi LME, Guadagnini M, Mechor G, Cainzos JM, Fusaro I, Palmonari A, Formigoni A. The use of monensin for ketosis prevention in dairy cows during the transition period: a systematic review. *Animals (Basel).* 2021; 11 (7): 1988. DOI: 10.3390/ani11071988.

20. Markantonatos X, Varga GA. Effects of monensin on glucose metabolism in transition dairy cows. *J. Dairy Sci.* 2017; 100 (11): 9020–9035. DOI: 10.3168/jds.2016-12007.

21. McCarthy MM, Yasui T, Ryan CM, Mechor GD, Overton TR. Performance of early-lactation dairy cows as affected by dietary starch and monensin supplementation. *J. Dairy Sci.* 2015; 98 (5): 3335–3350. DOI: 10.3168/jds.2014-8820.

22. Meyer J, Daniels SU, Grindler S, Tröscher-Mußotter J, Alaedin M, Frahm J, Hüther L, Kluess J, Kersten S, von Soosten D, Meyer U, Most E, Eder K, Sauerwein H, Seifert J, Huber K, Rehage J, Dänicke S. Effects of a dietary L-carnitine supplementation on performance, energy metabolism and recovery from calving in dairy cows. *Animals (Basel).* 2020; 10 (2): E342. DOI: 10.3390/ani10020342.

23. Mukai R. Prenylation enhances the biological activity of dietary flavonoids by altering their bioavailability. *Biosci. Biotechnol. Biochem.* 2018; 82 (2): 207–215. DOI: 10.1080/09168451.2017.1415750.

24. Mullins CR, Mamedova LK, Brouk MJ, Moore CE, Green HB, Perfield KL, Smith JF, Harner JP, Bradford BJ. Effects of monensin on metabolic parameters, feeding behavior, and productivity of transition dairy cows. *J. Dairy Sci.* 2012; 95 (3): 1323–1336. DOI: 10.3168/jds.2011-4744.

25. Nemzer BV, Rodriguez LC, Hammond L, DiSilvestro R, Hunter JM, Pietrzkowski Z. Acute reduction of serum 8-iso-PGF2-alpha and advanced oxidation protein products *in vivo* by a polyphenol-rich beverage; a pilot clinical study with phytochemical and *in vitro* antioxidant characterization. *Nutr. J*. 2011; 10 (1): 67. DOI: 10.1186/1475-2891-10-67.

26. Pirestani A, Aghakhani M. The effects of rumen-protected choline and L-carnitine supplementation in the transition period on reproduction, production, and some metabolic diseases of dairy cattle. *J. Appl. Anim. Res.* 2018; 46 (1): 435–440. DOI: 10.1080/09712119.2017.1332632.

27. Raboisson D, Barbier M. Economic synergy between dry cow diet improvement and monensin bolus use to prevent subclinical ketosis: An experimental demonstration based on available literature. *Front. Vet. Sci.* 2017; 4: 35. DOI: 10.3389/fvets.2017.00035.

28. Ringseis R, Keller J, Eder K. Regulation of carnitine status in ruminants and efficacy of carnitine supplementation on performance and health aspects of ruminant livestock: a review. *Arch. Anim. Nutr.* 2018; 72 (1): 1–30. DOI: 10.1080/1745039X.2017.1421340.

29. Roehrer S, Behr J, Stork V, Ramires M, Médard G, Frank O, Kleigrewe K, Hofmann T, Minceva M. Xanthohumol C, a minor bioactive hop compound: Production, purification strategies and antimicrobial test. *J. Chromatogr. B*. 2018; 1095: 39–49. DOI: 10.1016/j.jchromb.2018.07.018.

30. Sachko S, Vudmaska I. Use of hop cones and vitamin E to prevent metabolic disorders in transition dairy cows. Proceedings of the XIX Middle-European Buiatrics Congress, May 22–25, 2019, Lviv, Ukraine. *Bìol. Tvarin*. 2019; 21 (2): 132.

31. Sandoval-Acuña C, Ferreira J, Speisky H. Polyphenols and mitochondria: an update on their increasingly emerging ROS-scavenging independent actions. *Arch. Biochem. Biophys.* 2014; 559: 75–90. DOI: 10.1016/j.abb.2014.05.017.

32. Sendamangalam V, Choi OK, Kim D, Seo Y. The anti-biofouling effect of polyphenols against *Streptococcus mutans*. *Biofouling*. 2011; 27 (1): 13–19. DOI: 10.1080/08927014.2010.535897.

33. Shahsavari A, D'Occhio MJ, Al Jassim R. The role of rumen-protected choline in hepatic function and performance of transition dairy cows. *Brit. J. Nutr.* 2016; 116 (1): 35–44. DOI: 10.1017/S0007114516001641.

34. Vlizlo VV, Fedoruk RS, Ratych IB. *Laboratory Research Methods in Biology, Stockbreeding and Veterinary Medicine*. A handbook. Lviv, Spolom publ., 2012: 355–368.

35. Weiskirchen R, Mahli A, Weiskirchen S, Hellerbrand C. The hop constituent xanthohumol exhibits hepatoprotective effects and inhibits the activation of hepatic stellate cells at different levels. *Front. Physiol.* 2015; 6: 140. DOI: 10.3389/fphys.2015.00140.

36. Zahra LC, Duffield TF, Leslie KE, Overton TR, Putnam D, LeBlanc SJ. Effects of rumen-protected choline and monensin on milk production and metabolism of periparturient dairy cows. *J. Dairy Sci.* 2006; 89 (12): 4808–4818. DOI: 10.3168/jds.S0022-0302(06)72530-9.

37. Zanoli P, Zavatti M. Pharmacognostic and pharmacological profile of *Humulus lupulus* L. *J. Ethnopharmacol.* 2008; 116 (3): 383–396. DOI: 10.1016/j.jep.2008.01.011.

38. Zhou Z, Vailati-Riboni M, Trevisi E, Drackley JK, Luchini DN, Loor JJ. Better postpartal performance in dairy cows supplemented with rumen-protected methionine compared with choline during the peripartal period. *J. Dairy Sci.* 2016; 99 (11): 8716–8732. DOI: 10.3168/jds.2015-10525.

39. Zmora P, Cieslak A, Jedrejek D, Stochmal A, Pers-Kamczyc E, Oleszek W, Nowak A, Szczechowiak J, Lechniak D, Szumacher-Strabel M. Preliminary *in vitro* study on the effect of xanthohumol on rumen methanogenesis. *Arch. Anim. Nutr.* 2012; 66 (1): 66–71. DOI: 10.1080/1745039X.2011.644917.

40. Zugravu CA, Bohiltea RE, Salmen T, Pogurschi E, Otelea MR. Antioxidants in hops: bioavailability, health effects and perspectives for new products. *Antiox. (Basel).* 2022; 11 (2): 241. DOI: 10.3390/antiox11020241.

The effect of therapeutic feed additive on rumen fermentation in cows with ketosis

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It is known that ionophoric antibiotics regulate ruminal fermentation, improve the utilization of feed protein, and prevent the occurrence of ketosis and steatosis in ruminants. Ionophoric antibiotics and β-acids of hops have a similar spectrum of biological activity, that is, they inhibit the vital activity of most gram-positive microorganisms of the rumen. Bacteria, like other living organisms, need vitamin E as an active antioxidant for cell membranes. The toxicity of tocopherol is very low, so adding it to the diet of ruminants in larger quantities can stimulate celluloselytic rumen bacteria and compensate for the negative effect of ionophores on fiber breakdown. Since rumen bacteria break down a significant part of dietary choline, methionine and carnitine, ruminants must receive them in a protected form, so their influence on rumen fermentation is insignificant. Three groups of cows of the Ukrainian dairy black-spotted breed with milk yields of 5 or more thousand kg during the previous lactation were formed: with signs of clinical ketosis — 4 animals; with subclinical ketosis — 5 animals and clinically healthy — 5 animals. For a month, cows with ketosis were given a treatment supplement containing crushed granules of hop cones (20 g), vitamin E (3 g), and rumen protected choline (50 g), methionine (20 g) and carnitine (1 g). Clinically healthy cows were used as control. In the blood of cows with subclinical ketosis, the additive increased the concentration of glucose and decreased the concentration of β-hydroxybutyrate, these indicators were within the normal range. In cows with symptoms of clinical ketosis, using of the feed additive also reduced the concentration of β-hydroxybutyrate ($P<0.01$), but it was still higher than normal. In sick cows, amylolytic and lipolytic activity was lower than in healthy cows ($P<0.05–0.01$). Celluloselytic activity was lower only in cows with clinical ketosis. The proteolytic activity of rumen content changed in the opposite way; it was higher in sick cows ($P<0.05–0.01$). This is a consequence of the increase in the number and activity of hyper producing ammonia bacteria in the rumen, what is characteristic for ketosis. After treatment of cows with subclinical ketosis, the celluloselytic and amylolytic activities in the rumen fluid were equal to the corresponding indicators of healthy cows, and the proteolytic activity was even slightly lower ($P<0.05$) than in the control group. Treatment of cows with clinical form of ketosis was not as effective, although the general trends remained. During subclinical and clinical ketosis, a greater amount of ammonia was found in the rumen fluid ($P<0.05–0.01$), because of higher proteolytic activity. In both forms of ketosis, the concentration of volatile fatty acids in the rumen decreased, and the concentration of lactate increased ($P<0.05–0.01$). After the treatment, these indicators in cows with subclinical ketosis approached the healthy animals, while the condition of cows with clinical ketosis improved, but the concentration of ammonia continued to differ from healthy animals.

Key words: cows, ketosis, rumen, hop cones, vitamin E

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Review article

Biological features of meat productivity formation in sheep

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The data from literature and our own research on the chemical and biochemical composition of muscle tissue, its biological functions and nutritional value are summarized in the article. The data on the chemical composition and nutritional value of meat of different animal species, including beef, veal, pork and lamb are generalized. It is shown that sheep meat is characterized by nutritional, taste and dietary properties. In terms of biological value, it is not inferior to beef and pork, and even superior in other respects. For example, lamb contains the same amount of protein and amino acids as beef and pork, and it contains more fat than beef, which makes it higher in calories. Lamb is a good source of vitamins and minerals (Calcium, Phosphorus, and Iron), and its content of Copper and Zinc is significantly higher than that of other meats. On the global market, lamb is valued higher than other types of meat. Carcasses of young lambs weighing 13–16 kg are in particularly high demand. The dietary value of young lamb is due to its protein composition, high content of vitamins A and E and group B, lipids, in particular phospholipids. However, although sheep meat is characterized by high nutritional and biological properties, its disadvantage is a significant content of saturated fatty acids, which is associated with the processes of rumen biohydrogenation. Thus, the problem of increasing the proportion of polyunsaturated fatty acids in lamb is extremely important for human health. With this aim, various biologically active additives are widely used in animal feeding, which can directly or indirectly increase the content of polyunsaturated fatty acids in their products. In particular, antioxidants are widely used to prevent double bond peroxidation and there by increase the content of polyunsaturated fatty acids in products. Rearing and fattening lambs is biologically feasible and economically profitable until they reach a live weight of 40–50 kg, as during this period the growth of muscle tissue is the largest compared to fat deposition, and feed consumption is the lowest.

Key words: sheep, meet productivity, biochemical composition, biological value, feeding, breed, crossing

Biological characteristics of muscle tissue composition

One of the main economic characteristics of farm animals is meatiness. Meat is an important food product that includes muscle, connective, fat, bone and cartilage tissue, blood and other substances. The biological structure of meat varies depending on the species, sex, breed, fatness, feeding and housing conditions. The organoleptic characteristics of meat include color, tenderness, aroma, taste, juiciness and appearance.

First of all, meat is one of the main sources of protein in the body, as muscle tissue proteins contain highly valuable essential amino acids. The most valuable part of meat is muscle tissue. The yield of muscle tissue is as follows (%): in cattle — 51–57; calves — 51–61; sheep — 55–56; pigs — up to 44% [9, 26].

On the one hand, the protein content of sheeps largely characterizes their morphological, functional and metabolic characteristics, and on the other hand, their nutritional value. Proteins of muscle tissue are different in physicochemical functions and biological properties and are characterized by a complex structure. In the study of muscle tissue proteins, the most important proteins are myofibrils, nuclei, sarcoplasm and sarcolemma.

The group of **sarcoplasmic** proteins (soluble proteins) includes myoalbumin, myoglobin, myogen, and globulin γ, which are heterogeneous systems with similar biological and physicochemical properties. Thus, the myogen fraction makes up about 20% of all muscle tissue proteins. Myogen is identical to albumin in its physicochemical properties, but has a globular shape and aldolase activity. These proteins mainly perform enzymatic functions related to the oxidative conversion of carbohydrates into other compounds. Myogen contains all the essential amino acid, i.e., myogen is a complete protein.

Approximately 1% of all muscle cell proteins is myoglobin, a muscle protein. Its main function is to transport oxygen delivered by blood cells to the enzyme systems of cells. Myoglobin is essentially a pigment — a chromoprotein that contains a heme complex of ferric porphyrin, which gives muscle tissue its characteristic red color. Myoglobin is characterized by a special property of easily combining with various gaseous substances: oxygen, nitric oxide, hydrogen sulfide, etc.

After slaughtering animals, myoglobin in the upper layers of meat is converted into a myoglobin-oxygen compound, oxymyoglobin, by adding oxygen (the reaction is reversed), which has a bright red color. The darker color in the deeper layers of muscle tissue is due to the presence of reduced myoglobin. During prolonged storage of meat, oxymyoglobin is oxidized and turns into metmyoglobin, and the meat becomes brownish-brown in color.

Globulin γ makes up about 20% of all proteins and is a mixture of proteins, some fractions of which perform enzymatic functions.

The structure of muscle tissue, in fact, in the water-soluble fraction of proteins, contains myoalbumin (1–2%). Myoalbumin is a typical albumin, but it differs from blood albumin both in its amino acid composition and physicochemical properties [32].

Sarcoplasmic proteins contain a small amount of nucleoproteins, which are mainly concentrated in ribosomes. Their special characteristic is the presence of the nucleic acid molecule ribose in the structure.

The biological and nutritional value of sarcoplasmic proteins is quite high and is due to the presence of sulfur-containing amino acids, which are known to perform various biological functions in the human body [29].

Myofibrillar proteins consist of myosin, actin, actomyosin, tropomyosin, etc. In fact, myofibrillar proteins determine the nutritional and biological value of meat due to their high content of essential amino acids [32, 47].

Myosin is the most valuable protein in muscle tissue in terms of biological properties (40% of all proteins). However, it is difficult to isolate this protein from muscle tissue because it interacts with other structural myofibrillar proteins and with various ions: in particular, Calcium, Potassium, and Magnesium, and also interacts with ADP and ATP. The structure of the myosin molecule contains approximately 5000 residues of essential amino acids. One myosin molecule can bind three molecules of ADP or two molecules of pyrophosphate.

Myosin is located in the cell in a complex with lipids — with cholesterol. As an enzyme, myosin catalyzes the conversion of adenosine triphosphoric acid to adenosine phosphoric acid and phosphoric acid with the release of water and a large amount of energy, which is necessary for the functioning of muscle fibers [16].

Actins are proteins that form the cytoskeleton of cells. Actin exists in two forms: globular — G-actin (ball-shaped molecules) and fibrillar — F-actin (elongated molecules), which differ in their physical and chemical properties. In a living muscle fiber, at rest, actin is in a fibrillar form and it is possible for fibrillar actin to turn into globular actin, a reversible reaction. The amino acid composition of actin is characterized by a significant proline content, which prevents the formation of an α-helix. It is impossible to isolate actin by conventional methods, such as extraction with water or salt solutions, so actin is classified as a stromal protein.

A very important compound is actomyosin, a complex of actin and myosin proteins that form the basis of the contractile filaments of muscle fibers. The characteristic biological functions of actomyosin are its interaction with adenosine triphosphoric acid and magnesium ions.

About 10–12% of myofibril protein, or 2.5% of the total muscle tissue protein, is tropomyosin. This is a complicated structural protein complex of myofibrils consisting of two proteins: tropomyosin B and troponin, which is soluble in water but is released from muscle tissue only by salt solutions with high ionic strength. The tropomyosin B-troponin complex is bound to thin filaments of myofibrils by the protein actin. The main function of tropomyosin during muscle contraction is to transport calcium ions.

Other water-soluble proteins have been isolated from myofibrils, such as α- and β-actinins in small amounts, which are components of Z-membranes.

The **nuclei** of muscle cells are constructed mainly of nucleoproteins, which make up about 50% of dry matter. Nucleoproteins are extracted with alkalis or sodium chloride. The structure of nuclear nucleoproteins includes deoxyribonucleic acids.

Histones are protein components of nucleoproteins that contain diamino acid molecules, arginine and lysine, which create an alkaline character. In addition to nucleoproteins, the nuclei of muscle cells contain the so-called

"acidic protein" (about 30–50% of the dry matter of the nucleus), the molecular structure of which contains the essential amino acid tryptophan (2.5%) [6].

Thus, the nuclei of muscle cells contain at least three protein fractions — nucleoproteins, acidic and residual proteins.

The **sarcolemma** is a slim, elastic membrane that covers each muscle fiber and consists of membranes. In addition to proteins, the membranes contain phospholipids, which play a determinative function in the permeability of the membrane. Phospholipids consist of: sphingomyelin, phosphatidylethanolamine, phosphatidylcholine, phosphatidylinositol, lysophosphatide, and phosphatidylserine in approximately identical amounts. The surface of the sarcolemma is covered with connective tissue fibers, which consist of proteoids — connective tissue proteins: collagen, reticulin, and elastin, and in the intercellular space of muscle fibers there are mucoid proteins and mucins that perform protective functions and reduce friction of muscle bundles.

The muscles of young intensively growing animals contain more elastin and collagen. With an increased level of fattening, as well as with an increase in fat content in meat, the proportion of connective tissue proteins decreases [6, 22].

Stromal sarcolemmal proteins, unlike myofibrillar and sarcoplasmic proteins, contain mainly nonessential amino acids, so their nutritional and biological value, as well as digestibility, are low. With the age of animals, the content of stromal proteins increases, and the quality of meat decreases accordingly. The collagen molecule consists of about 50% glycine, proline and oxyproline, with small amounts of tyrosine and methionine, and does not contain cysteine, tryptophan and cystine. Elastin contains more glycine and much less proline and oxyproline [47]. The nutritional value of meat is determined by the amino acid index ("quality protein index"), the ratio of tryptophan (the most complete muscle tissue protein) to oxyproline (inferior connective tissue proteins) [15]. The higher index means higher quality of meat.

On the outside of the sarcolemma, as well as in the intermuscular spaces, there is a nervous apparatus of cells with nerve fibers, consisting of neurokeratins and lipoproteins.

The percentage composition of muscle tissue proteins is as follows: myosin — 35; myogen — 20 and globulin — 20; actin — 15; other proteins — 10 [29].

Lipids, along with proteins, play an important role in the structure of skeletal muscle, which, on the one hand, are structural units (cholesterol, phospholipids), and on the other hand, are depots of the necessary metabolic energy (triacylglycerols) [49].

Glycerophospholipids in myofibrils (sarcoplasmic reticulum) catalyze the activity of many enzymes. Sarcolemmal membranes also contain glycerophospholipids. Their qualitative composition does not differ from that of glycerophospholipids in subcellular structures. However, the total content of phospholipids in the membrane is lower than in mitochondria.

The main sources of polyunsaturated fatty acids are skeletal muscle phospholipids, which have a wide range of biological effects in the human body, and their quantitative content in meat affects its nutritional and biological value. In fact, lamb is the richest in phospholipids [26].

The sarcoplasm of muscle tissue contains reserve lipids at the mitochondrial poles in the form of small droplets. In addition, reserve lipids are found in significant amounts in intercellular spaces, between muscle fiber bundles in the connective tissue layers. The quantitative content of triacylglycerols in muscle fibers differs depending on the species of animal. During intense work, the content of reserve lipids in the intercellular spaces is reduced to a minimum.

In addition, ethanol glycerophosphatides, cholinesterase phospholipids, sphingomyelin plasmogens, etc. have been isolated from muscle tissue glycerophosphatides. In fact, these lipid fractions are characterized by a higher content of unsaturated fatty acids (65–75%) than glycerophosphatides of other tissues. The quantitative content of glycerophosphatides in muscle tissue is 0.2–1.0% [40].

Muscle tissue contains unesterified and esterified cholesterol from sterols (as a percentage of dry tissue): 0.8% in smooth muscle, 0.5% in cardiac muscle, and 0.3% in skeletal muscle. Attention should be paid to the unique feature of cholesterol-protein complexes in mammalian muscle tissue, due to the strong bond of cholesterol with proteins. Depending on the type of animal, age, sex, state, feeding and housing conditions, the total lipid content in muscle tissue, as well as their structural components, varies significantly.

Lipids provide high caloric value, tenderness, and flavor of meat, but excessive amounts of them in any meat lead to a decrease in the proportion of protein and, in fact, to a decrease in its nutritional and biological value. Fats from different animal species differ little in caloric content, but they differ in digestibility. Pig fat (96–98%) and beef fat (96–98%) have the highest digestibility, while lamb fat is less digestible (80–90%) [44].

An important energy component and one of the main carbohydrates in muscle tissue is glycogen, which is used during muscle work and stored at rest. During intense muscle work, glycogen is broken down anaerobically in glycolysis to form lactate. The quantitative content of glycogen in muscle tissue depends on the physiological state of the animals, age and fatness. The glycogen and glucose content in muscle tissue samples immediately after slaughter is as follows: 0.3–0.9% (sometimes 2.0%) and 0.05% glucose. In the subsequent post-slaughter period, muscle tissue glycogen conversion is the root cause of many further biochemical transformations [40].

Non-protein compounds of nitrogen-containing substances in muscle tissue also perform specific functions in the process of metabolism and energy: adenosine triphosphoric acid, carnitine, creatine, carnosine, anserine, creatine phosphate, purine bases, free amino acids (intermediate products of protein metabolism), as well as uric acid, urea and ammonium salts (which are their

final breakdown products). Extractive substances are important for characterizing the nutritional value of meat, as they have aromatic, flavor, and biologically active properties and actually give the meat broth a specific smell and taste [36]. The content of non-protein nitrogen in muscle tissue samples immediately after slaughter contains 0.3% of non-protein nitrogen, based on wet weight (1.2% on dry weight).

Muscle tissue performs its functions (locomotive, support, protective, heat exchange, blood and lymph circulation, respiratory movements, communication, and contraction of internal organs — gastrointestinal tract, bronchi, genitourinary system) due to the specific activity of enzyme systems. Skeletal muscle has high ATPase and glycolytic activity [43, 51].

The sarcoplasm (matrix) contains many enzymes for the synthesis of proteins, lipids, and polysaccharides. The mitochondria are responsible for the aerobic (oxygen) oxidation of metabolic products — the Krebs cycle and the chain of electrons transport. However, different muscle fibers, depending on their functional characteristics, are characterized by different concentrations of enzyme systems that catalyze anaerobic and aerobic conversion. Red muscle fibers are characterized by a higher content of mitochondria than white muscle fibers; this indicates that there are 6 times more active respiratory enzymes in red muscle fibers than in white ones.

The nuclei of muscle cells contain glycolytic, hydrolytic and oxidizing enzymes, as well as enzymes for programming the synthesis of nucleic acids (DNA polymerase and RNA polymerase).

The organoleptic characteristics of meat include appearance, color, tenderness, juiciness, aroma, and taste. The quality of lamb depends significantly on the age of the animal, sex, housing conditions and physiological state. Lamb, compared to mutton, contains more protein and water, less fat [46]. The difference in meat quality between a 5-month-old lamb and an adult sheep is much greater than between meat from pigs of the same age range. According to the age of the slaughtered animals, lamb is divided into three categories: lamb, young lamb (meat of animals up to one year old) and mutton. The first two categories are considered dietary meat, and all mutton must be processed.

There are the following generally accepted classifications of meat by animal type (beef, pork, lamb), sex, age, and thermal condition (steamed, chilled, frozen).

As noted below, depending on the type of animal, sex, housing conditions, and their fatness, the composition of meat varies significantly. The smallest changes are noticeable in the mass fraction of protein, which is the most valuable component of meat, as well as minerals, and the largest changes are in the mass fractions of water and fat. For example, meat from fattened pigs has more than 35% fat, while meat from underfed calves has about 1%, and sheep — up to 26%.

Although lamb is characterized by high nutritional and biological properties, its disadvantage is the high content

Table 1. Composition and nutritional value of meat of different animal species

Meat	Chemical compostion, %				Energetic value of 100 g	
	water	protein	fat	mineral	kCal	kJ
Beef	55–69	16.2–19.5	11–28	0.8–1.0	180–320	750–1340
Veal	68–70	19.1–19.4	5–12	1.0–1.3	140–190	580–790
Pork	49–58	13.5–16.4	25–37	0.7–0.9	300–390	1250–1630
Lamb	48–65	12.8–18.6	16–37	0.8–0.9	220–380	920–1590

of saturated fatty acids. Due to hydrogenation processes, less than 1.8% of polyunsaturated fatty acids reach the small intestines [33].

Plant feeds contain a large amount of polyunsaturated fatty acids, in particular, linoleic and linolenic acids, Cis-double bonds of these acids are toxic to rumen bacteria that hydrogenate them, as a result of which the organs and tissues of ruminants contain a large amount of stearic and oleic acids and a small amount of polyunsaturated fatty acids [13, 30, 48]. At the same time, some trans-isomers of oleic (trans-11) and linolenic (cis-9, trans-11) acids synthesized in the processes of rumen biohydrogenation have biological activity that partially compensates for the deficiency of polyunsaturated fatty acids of the ω-3 family [2, 11, 13, 30].

Thus, the problem of increasing the proportion of polyunsaturated fatty acids in sheep meat is quite important for human health. With this aim, various biologically active additives are widely used in animal feeding, in particular ruminants, which can directly or indirectly increase the content of polyunsaturated fatty acids in their products. In particular, antioxidants are widely used to prevent double bond peroxidation and thereby increase the content of fatty acids in products [21, 24, 48].

Lipids present in the diet of animals also affect the composition of fatty acids, as they reduce the processes of biohydrogenation, which increases the content of polyunsaturated fatty acids in the fat of these animals [27, 41].

For example, the introduction of high doses of α-tocopherol into the diet activates the synthesis of trans-11–18:1 and cis-9, trans-11–18:2 fatty acids in the rumen, and also leads to a decrease in the formation of trans-10–18:1 and trans-10, cis-12–18:2 fatty acids [3, 4, 12], and the addition of selenium salts and vitamin E (0.5 and 300 mg/kg in terms of dry matter of feed) changes the fatty acid composition of skeletal muscle by increasing the content of unpaired, polyunsaturated, branched and trans-11 fatty acids [3].

There are contradictory data in the literature regarding the influence of nutritional factors and breed characteristics of sheep on the content of total lipids and their individual components (phospholipids, sterols, fatty acids) in muscle and adipose tissue. In particular, Sosta R. G. et al. showed that the content of saturated (C12:0, C14:0, C18:0, C20:0) and monounsaturated fatty acids increased in the longest muscle of lambs fed a high energy diet compared to a low energy diet. Different genotypes were also characterized by different contents and ratios of saturated and unsaturated fatty acids. At the same time, diet

and genotype did not affect cholesterol levels [10]. Similar results were obtained by other researchers [25]. In particular, Auroussean B. et al. (2007) noted that lambs kept on pasture had a better fatty acid profile due to higher concentrations of conjugated linoleic acid (C18:2 — CLA), C18:3 n-3 and C18:2 n-6 [1]. However, Bonagurio S. et al. obtained the opposite effect in experiments on Texel lambs fed different diets [8].

The influence of various factors on the formation of sheep meat productivity

The meat productivity of sheep is determined by many factors, among which genetic and organizational and economic factors are the most important.

In particular, different sheep breeds differ significantly in terms of meat productivity. For example, Askanian crossbreds (early maturing meat and wool sheep) are significantly superior in meat quality to Tsygai and thin-fleshed sheep. Precos and Askanian fine fleece sheep produce wool of low tone. However, Precos sheep have a better meat productivity, characterized by higher slaughter yield, higher meat content, meat with higher moisture and fat content, which makes it juicier and fattier.

It is characteristic that in sheep, wool and meat productivity are interrelated, but have a significant opposite. If the result of the breeding process is high woolenness, the development of meat qualities is usually reduced and *vice versa*. At the same time, bred meat and wool sheep with crossbred wool (early maturing) combine high wool and meat productivity well [9].

Table 2. Amino acids composition of different animal species meat

Amino acids \ Meat	Beef	Pork	Lamb
Essential aminoacids, % to total protein			
Arginine	6.6	6.4	6.9
Valine	5.7	5.0	5.0
Histidine	2.9	3.2	2.7
Isoleucine	5.1	4.9	4.8
Leucine	8.4	7.5	7.4
Lysine	8.4	7.8	7.6
Methionine	2.3	2.5	2.3
Threonine	4.0	5.1	4.9
Phenylalanine	4.0	4.1	3.9
Tryptophan	1.1	1.4	1.3
Nonessential amino acids, % to total protein			
Alanine	6.4	6.3	6.3
Aspartic acid	8.8	8.9	8.5
Glycine	7.1	6.1	6.7
Glutamic acid	14.4	14.5	14.4
Proline	5.4	4.6	4.8
Serine	3.8	4.0	3.9
Tyrosine	3.2	3.0	3.2
Cystine	1.4	1.3	1.3

Crossbreeding methods (related and unrelated) are one of the most important factors in increasing the productivity (meat and wool) of sheep. Thus, in the case of unrelated crossbreeding (outbreeding) of ewes of fine-fleeced breeds with rams of semi-fine-fleeced breeds, the resulting offspring have 4–8% more live weight than the offspring from fine-fleeced ewes, a higher slaughter yield by 1–1.5% and a higher meat content by 0.4–1.0%. Even better results are obtained by crossing three or more breeds [15, 41, 44].

The type of animal constitution is one of the most important factors affecting the productive qualities of animals, including sheep. Animals of different constitutional types (strong, dense, coarse, delicate, loose) differ significantly in constitutional strength, exterior and interior indicators, productive and adaptive factors [31, 34]. Sheep of each type of constitution are characterized by peculiarities of wool and meat productivity and their reproductive capacity. The integral indicator is the meat productivity of sheep, in fact, the quality composition of meat. It has been established that when comparing the productivity (of different constitutional and productive types) of Askanian fine-fleece sheep, the most valuable in terms of biological indicators is the meat of lambs of coarse constitution type, due to the best protein-fat ratio (2.06 : 1.0), the highest content of total proteins (19.99%), in fact, the γ-globulin fraction, the lowest amount of unesterified cholesterol (10.52%), the optimal content of total lipids (9.72%), with a higher amount of phospholipids (24.21%) [38].

It is known that the biosynthesis of proteins plays a key role in the growth of animals, including sheep, with a content of up to 75% in terms of dry matter of skeletal muscle. Animal skeletal muscle consists of white and red muscle fibers. Static muscle is dominated by white muscle fibers, and dynamic muscle is dominated by red muscle fibers. Dynamic and statodynamic (shoulder, large round, pelvic, sacral) muscle fibers are thin slim-fiber, they contain more complete proteins and less incomplete proteins [22]. The skeletal muscles of sheep of different ages contain (based on raw weight): protein — 16.0–23.0%; lipids — 2.0–5.0%; carbohydrates — 0.5–3.5%; extractable nitrogenous substances — 1.0–1.7% and minerals — 0.8–1.8%.

High protein content and an optimal ratio between the content of essential and nonessential amino acids ensure high nutritional value of any type of meat. According to some authors, the amino acid composition of beef, pork and lamb meat is almost similar [15].

Mineral and vitamin composition of meat is important for its biological value. It is known [14] that lamb is a good source of B vitamins, in particular, biotin, thiamine and nicotinic acid, B_{12}, but is somewhat inferior to pork and beef in terms of pantothenic acid and vitamin B_6. Sheep meat contains (mg%): biotin — 5.9; nicotinic acid — 4.3–5.2; B_{12} — 2.5; pantothenic acid — 0.58; B_6 — 0.29; riboflavin — 0.18–0.22; thiamine (B_1) — 0.13–0.16; folic acid — 0.07–0.09. Meat vitamins are characterized by relative stability and are not destroyed during heat treatment. Boiled meat retains up to 75% and 45–60% of vitamin B_6. Vitamin B_{12} is the most resistant to heat treatment [14].

Meat contains virtually no vitamin C, and small amounts of fat-soluble vitamins A, D and partially vitamin E. There is a pattern that the more fat the meat contains, the higher content of fat-soluble vitamins and the lower content of water-soluble vitamins.

There are almost no differences in the content of Iron, Phosphorus and Calcium in meat samples from different animal species. Among the peculiarities, it can be noted that the hind part of lamb is the richest in Phosphorus, Copper and Zinc [14].

The color of meat directly depends on the presence of the pigments myoglobin and hemoglobin. However, the color of meat is also influenced by the sex of the animal, the type of feeding and housing conditions. Meat from young animals is pale pink in color, while meat from older animals is dark red. It should be noted that the meat of sheep is less intensely colored than that of rams. During the stall period, when the animal receives less green feed, its meat is lighter. When sheep are kept at pasture, they move nore, their meat is darker in color and has better flavor. If there is a deficiency of Fe in the feed, the meat has a less intense color.

The age and sex of animals, muscle load, fatness, the ratio of elastin to collagen, and marbling (connective tissue content, thickness of muscle fibers) affect the tenderness of meat. In fact, the specific flavor of lamb is given by hirsinic acid.

The influence of individual feed components on sheep productivity and quality

The cost of feed determines the unit cost of production by 58–60%, so the issue of reducing the cost of production is an urgent task in the sheep industry by taking into account the needs of animals for the necessary nutrients and biologically active substances, taking into account their availability in feed and the availability of eating, assimilation and transformation into products.

First of all, it is of particular importance to provide complete protein in animal feeding. The biosynthesis of proteins in the body is continuous, which makes it possible to renew the proteins of animal tissues. Proteins perform a number of vital functions: protective, energetic, catalytic, transport, hormonal and immune. It has been proven that protein deficiency leads to a decline in nutrient metabolism and an increase in feed costs per unit of production, delayed growth and development of animals, and a decrease in reproductive function [5, 7, 39, 44, 49].

Animal rearing conditions have a significant impact on the quality composition of fatty acids in meat. For example, lambs raised in pasture type of housing produce meat that is biologically healthier for the consumer than those raised in stall housing. This is manifested in higher concentrations of conjugated linoleic acid (C18:2 — CLA), linoleic acid (C18:3 n-3), long-chain fatty acids n-3 and higher ratios of C18: n-6: C18:3 n-3 [1].

Vegetable feed for ruminants is the main source of feed protein. For animals, their share in the total protein balance is 94–95%, of which 60–70% is accounted for by grain and forage crops and 25–30% by pasture, haylage, and crop processing products [17, 35, 50].

The literature shows that in different regions of Ukraine, the protein deficit in feed is 25–35%, which leads to a deficit of many macro- and microelements, vitamins, and amino acids [20, 23, 28].

Sheep are grazing animals that are well-adapted to eating large quantities of plant fodder, which is the main source of feed protein. However, vegetable feeds are not always able to provide the animal body with all the necessary biologically active nutrients. Of particular importance for sheep, as deficient nutrients, along with the general components of nutrition (protein, energy, carbohydrates), are the macronutrient Sulfur and sulfur-containing amino acids — methionine and cystine, which have a stimulating effect on the growth and development of animals, improve the quality of wool and meat products [37]. In our experiments, which were conducted on Askanian fine-fleshed lambs of the Taurian type, it was found that the longest back muscle of 4-month-old animals, compared to 5-month-old animals, contained a greater amount of total phospholipids due to a higher content of nitrogen-containing fractions, in particular, phosphatidylethanolamine and phosphatidylcholine, which are metabolically active components of cell membranes, which, in turn, may indicate an increase in the intensity of metabolic processes in them, as well as better nutritional and biological value of such meat [40]. The longest muscle of younger animals had a lower content of total fat (by 1.74%) and dry matter (by 1.08%), but contained a higher amount of soluble proteins due to a higher content of β- and γ-globulins. Nevertheless, the muscle tissue of 5-month-old lambs contained a significant amount of prealbumin and albumin fractions. Summarizing, it can be concluded that the nutritional and biological value of lambs meat of 4 months of age is better compared to the meat of lambs of 5 months of age [18, 40]. The addition of the essential amino acids methionine, lysine, and a salt of the macronutrient Sulfur to the diets of young sheep had a positive effect on the biological value and biochemical composition of muscle tissue by increasing the content of proteins, in particular, albumin and phospholipids [19]. It should also be noted that the differences in average daily live weight gain in animals of the experimental groups were 17.3–29.5% higher compared to the control group [42].

Conclusions

From the above review, it can be concluded that sheep meat is characterized by high nutritional, taste and dietary properties due to the balanced content of high-quality proteins, minerals and vitamins, and therefore lamb meat is valued higher on the world market than meat of other animal and poultry species.

Meat productivity of sheep is determined by many factors. Among them, genetic and nutritional factors are the most important. It is especially important to provide sheep with adequate protein, since its deficiency leads to a decrease in growth, reproductive function, and increased feed costs per unit of production.

References

1. Aurousseau B, Bauchart D, Faure X, Galot AL, Prache S, Micol D, Priolo A. Indoor fattening of lambs raised on pasture: (1) Influence of staff finishing duration on lipid classes and fat acids in the *longissimus thoracis* muscle. *Meat Sci.* 2007; 76 (2): 241–252. DOI: 10.1016/j.meatsci.2006.11.005.
2. Belury MA. Dietary conjugated linoleic acid in health: Physiological effects and mechanisms of action. *Annu. Rev. Nutr.* 2002; 22: 505–531. DOI: 10.1146/annurev.nutr.22.021302.121842.
3. Bilash YP, Didovych AP, Vudmaska IV, Golubets OV. Fatty acid composition lipids of skeletal muscle fedding steers with different levels of vitamin E and selenium in the diet. *Bìol. Tvarin.* 2013; 15 (1): 19–27. Available at: https://aminbiol.com.ua/index.php/archive/90-archive/bt1-15-2013/1592 (in Ukrainian)
4. Bilash YP, Golubets OV, Tsisaryk OY, Vudmaska IV. Effects of selenium and vitamin E on unsaturated fatty acids hydrogenation in the rumen of fattening cattle. *Bìol. Tvarin*. 2011; 13 (1–2): 187–192. Available at: https://aminbiol.com.ua/index.php/archive?catid=1:2013-02-15-09-09-13&id=36:2013-03-05-14-00-54 (in Ukrainian)
5. Bohdanov GA. *Feeding Farm Animals*. Moscow, Ahropromyzdat. 1990: 623 p.
6. Boisen S, Hvelplund T, Weisbjerg MR. Ideal amino acid profiles as a basis for feed protein evaluation. *Livestock Prod. Sci.* 2000; 64 (2–3): 239–251. DOI: 10.1016/S0301-6226(99)00146-3.
7. Bomko VS. The effect of different levels of protein nutrition on the digestibility of nutrients and the use of nitrogen in forage by cows in the dry period. *Sci. Bull. LNUVMBT S. Z. Gzhytsky.* 2002; 4 (2): 3–7. (in Ukrainian)
8. Bonagurio S, Pérez SRO, Garcia IFF, dos Santos CL, Lima AL. Meat centesimal composition of purebred Santa Ines lambs and its crosses with Texel, slaughtered at different weights. *Rev. Brasil. Zootecnia*. 2004; 33 (6/3): 2387–2393. DOI: 10.1590/S1516-35982004000900027. (in Portuguese)
9. Burkat VP. Sheep Breeding of UKRAINE. *The Agricultural Science.* 2006: 612 p. (in Ukrainian)
10. Costa RG, Batista ASM, de Azevedo PS, do Egypto Queiroga RCE, Madruga MS, de Araújo Filho JT. Lipid profile of lamb meat from different genotypes submitted to diets with different energy levels. *Ruminants. R. Bras. Zootec.* 2009; 38 (3): 532–538. DOI: 10.1590/S1516-35982009000300019.
11. Corl BA, Baumgard LH, Dwyer DA, Griinari JM, Phillips BS, Bauman DE. The role of Δ^9-disaturase in the production of cis-9, trans-11 CLA. *J. Nutr. Biochem*. 2001; 12 (11): 622–630. DOI: 10.1016/S0955-2863(01)00180-2.
12. Cristaldi LA, McDowell LR, Buergelt CD, Davis PA, Wilkinson NS, Martin FG. Tolerance of inorganic selenium in wether sheep. *Small Rum. Res*. 2005; 56 (1–3): 205–213. DOI: 10.1016/j.smallrumres.2004.06.001.
13. Daley CA, Abbott A, Doyle PS, Nader GA, Larson S. A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. *Nutr. J.* 2010; 9 (10). DOI: 10.1186/1475-2891-9-10.
14. Danylenko GK, Topikha IN, Kulyk VV. *Sheep Breeding*. Kyiv, Urozhay, 1989: 200 p. (in Ukrainian)
15. Gerasymenko VG. *Biochemistry of Animal Productivity and Resistance*. Kyiv, Vyshcha shkola, 1987: 224 p. (in Ukrainian)
16. Gonskyi YI, Maksymchuk TP, Kalynskyi MI. *Human Biochemistry*. Ternopil, Ukrmedknyga, 2002: 744 p. (in Ukrainian)
17. Gratylo OD, Zharuk LV, Smenov VF, Smenova GS, Myrza OV. Economic evaluation of feed production efficiency and their impact on the formation of expenses in sheep breeding. *Sci. Bull. Askania-Nova*. 2010; 3: 41–48. Available at: http://nbuv.gov.ua/UJRN/nvan_2010_3_9 (in Ukrainian)
18. Havrylyak VV, Stapay PV, Tkachuk VM. The content and composition of the longissimus muscle proteins in the lambs of different ages under the intensive fattening. *Sci. Bull. LNUVMBT S. Z. Gzhytsky*. 2018; 20 (89): 52–55. DOI: 10.32718/nvlvet8909. (in Ukrainian)
19. Havrylyak VV, Sydir NP, Paranyak NM, Druzhyna OS, Stapay PV. Protein and lipid composition of the longest back muscle of young sheep under conditions of use of lysine, methionine and sodium sulfate amino acid supplements in their diets. *Probl. Zooeng. Vet. Med. Digest Sci. Works*. 2014; 28 (1): 108–114. (in Ukrainian)
20. Kebko V. Raising dairy calves using a lysinoprotein-mineral premix. *Livestock Ukr*. 2002; 4: 25–28. (in Ukrainian)
21. Kozmiluk K, Gabryszuk M, Kowalczyk J, Crauderna M. Effect of diet supplementation with selenium, zinc and α-tocopherol on fatty acid composition in the liver and loin muscle of lambs. *Anim. Sci. Pap. Rep*. 2008; 26 (1): 59–70. (in Ukrainian)
22. Kozyr VS. *Biological Patterns of Growth and Development of Agricultural Animals*. A reference guide. Dnipropetrovsk, Oksamyt, 2004: 540 p. (in Ukrainian)
23. Kuyan N. The state of the compound feed industry in plants. *Effective Fodders Feeding*. 2011; 4: 5–10. (in Ukrainian)
24. Liu ZL, Yang DP, Chen P, Dong WX, Wang DM. Supplementation with selenium and vitamin E improves milk fat depression and fatty acid composition in dairy cows feat fat diet. *As. Australas. J. Anim. Sci.* 2008; 89 (2): 685–692.
25. Madruga MS, de Araújo MO, de Sousa WH, Cézar MF, Galvão MS; MGG Cunha MS. Effect of genotype and sex on chemical composition and fatty acid profile of sheep meat. *Rev. Brasil. Zootecn.* 2006; 35 (4): 1838–1844. DOI: 10.1590/S1516-35982006000600035. (in Portuguese)
26. Meshkhi AI. *Biochemistry of Meat and Poultry Products*. Moscow, Light and food industry, 1984: 280 p.
27. Palmquist DL, Mattos WRS. The lipid metabolism. In: Berchielli TT, Pires AV, Oliveira SG. *Nutrition of Ruminants* Jaboticabel, Funep, 2006: 287–310. (in Portuguese)
28. Petrychko A, Osadets Y, Vintonyak V, Zhupanin P. Peculiarities of metabolic processes in the rumen of steers with different sources of digestible protein supplementation. *Livestock Ukr*. 2002; 7: 26–27. (in Ukrainian)
29. Rennie MJ, Edwards RHT, Davies CTM, Krywawych S, Halliday D, WATERLOW JC, Millward DJ. Protein and amino acid turnnover during and after exercise. *Biochem. Soc. Trans*. 1980; 8 (5): 499–501. DOI: 10.1042/bst0080499.
30. Schmid A, Collomb M, Sieber R, Bee G. Conjugated linoleic acid in meat and meat products: A review. *Meat Sci*. 2006; 73 (1): 29–41. DOI: 10.1016/j.meatsci.2005.10.010.
31. Serbina VO. To the question about the constitution of animals. *Sheep breeding*. Nova Kakhovka, PYEL, 2007; 34: 41–45. (in Ukrainian)
32. Sevastyanov A, Kirovych N, Belenko V. Composition of the longest back muscle in calves of different origin. *Livestock Ukr*. 2009; 4: 19–21. (in Ukrainian)
33. Sinclaiz LL Nutritional manipulation of the fatty acid composition of sheep meat: A review. *J. Agr. Sci.* 2007; 145 (5): 419–434. DOI: 10.1017/S0021859607007186.
34. Siratsky MV, Fedorovych EI, Hopka BM. *Interior of Farm Animals*. Kyiv, Vyshcha osvita, 2009: 280 p. (in Ukrainian)
35. Skrypets VI, Demenska NM. Use of Celobacterin to increase the milk productivity of ewes. *Sheep Breed*. 2006; 33: 103–107. (in Ukrainian)

36. Sokrut VI, Sokrut AV, Gerasimov VI, B. Pron TN, Danilova TV, Donskikh TV. *Pork and Its Morphological Composition*. 2011: 245 p. (in Ukrainian)
37. Stapay PV, Havrylyak VV, Tkachuk VM. Protein nutrition of sheep. *Effective Fodders Feeding*. 2011; 2 (50): 24–29. (in Ukrainian)
38. Stapay PV, Paranyak NM, Havrylyak VV, Kochetov SV, Strogush NS, Iovenko VM, Serbina VO. Peculiarities of the lipid and protein composition of muscle tissue of sheep of the Tavrian type of the Askanian thin-wool breed of different constitutional types. *Sci. Bull. Askania-Nova*. 2010: 3: 152–156. Available at: http://nbuv.gov.ua/UJRN/nvan_2010_3_24 (in Ukrainian)
39. Stapay PV, Paranyak NM, Strogush NS, Kochetov SV, Polska PI, Kalashchuk HP, Atanovska-Maslyuk OI. Effect of low feeding level on productivity and chemical parameters of wool and fat sweat of Askanian meat-wool sheep. *Sci. Bull. Askanya-Nova*. 2010; 3: 122–129. Aailable at: http://nbuv.gov.ua/UJRN/nvan_2010_3_20 (in Ukrainian)
40. Stapay PV, Paranyak NM, Tkachuk VM, Stakhiv NP. The content and composition of lipids of the longest back muscle in young sheep of different age under conditions of intensive fattening. *Biol. Tvarin*. 2018; 20 (2): 71–76. DOI: 10.15407/animbiol20.02.071. (in Ukrainian)
41. Stapay PV, Stakhiv NP, Havrylyak VV, Smolyaninova OO, Tyutyunnyk OS. Lipid nutrition of sheep. *Biol. Tvarin.* 2020; 22 (2): 3–7. DOI: 10.15407/animbiol22.02.003. (in Ukrainian)
42. Stapay PV, Tkachuk VM, Sydir NP, Havrylyak VV, Paranyak NM, Skorokhid AV. Effect of amino acids lysine, methionine and sulfur on meat and wool productivity of young sheep. *Probl. Zooeng. Vet. Med. Digest Sci. Works*. 2014; 28 (1): 105–108. (in Ukrainian)
43. Staron RS, Pette D. Correlation between myofibrillar ATPase activity and myosin heavy chain composition in rabbit muscle fibers. *Histochem*. 1986; 86: 19–23. DOI: 10.1007/BF00492341.
44. Suharlyov VO, Yakrovlev KI. *Sheep of Ukraine*. A monograph. Ed. by. V. O. Sukharlyova. Kharkiv, Espada, 2011: 352 p. (in Ukrainian)
45. Svystula MM, Efremov DV, Horb SV. *Scientific and Practical Basis of Standardized Feeding of Sheep and Feed Production*. Kherson, OLDI-PLYUS, 2022: 300 p. (in Ukrainian)
46. Tarig MM, Eyduran E, Rafeeq M, Waheed A, Awan MA, Shafee M, Rasheed N, Mehmood K. Influence of slaughtering age on chemical composition of Mengali sheep meat at Quetta, Pakistan. *Pakistan J. Zool.* 2013; 45 (1): 235–239. Available at: http://zsp.com.pk/pdf45/235-239%20_31_%20PJZ-1042-12%205-1-13%20final%20revised%20tariq%20m%20r.pdf
47. Velychko VO, Luz MV, Midyk VD. The content of amino acids in the body tissues of bulls in different ecological zones at the end of fattening period. *Foothill Mount. Agricult. Livestock Breed*. 2000; 42: 153–158. (in Ukrainian)
48. Wood JD, Enser M, Fisher AV, Nute GR, Sheard PR, Richardson RI, Hughes SI, Whittington FM. Fat deposition, fatty acid composition and meat quality: A review. *Meat Sci*. 2008; 78 (4): 343–358. DOI: 10.1016/j.meatsci.2007.07.019.
49. Yanovych VG, Sologub LI. *Biological Basis of Feed Nutrients Transformation in Ruminants*. Lviv, Triada plyus, 2000: 376 p. (in Ukrainian)
50. Zharuk LV, Shelest PS. *Recommendations on the economic assessment of the energy intensity of livestock production*. Askania-Nova. 2002: 25 p. (in Ukrainian)
51. Zubay GL, Parson WW, Vance AE. *Principles of Biochemistry*. Oxford, Wm. C. Brown publishers, 1995: 839 p.

Біологічні особливості формування м'ясної продуктивності овець*

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Узагальнено дані літератури і власних досліджень про хімічний і біохімічний склад м'язової тканини, її біологічні функції та харчову цінність. Представлено узагальнені дані щодо хімічного складу і поживної цінності м'яса різних видів тварин, зокрема яловичини, телятини, свинини та баранини. Показано, що м'ясо овець характекризується поживними, смаковими і дієтичними властивостями; за біологічною цінністю не поступається яловичині і свинині, а за іншими показниками навіть переважає їх. У баранині міститься така ж кількість протеїну й амінокислот, як і в яловичині та свинині, а жиру у ній більше, ніж у яловичині, тому баранина є калорійнішою. Вона є добрим джерелом вітамінів, мінеральних елементів (Кальцію, Фосфору, Феруму), а за вмістом Купруму та Цинку вона значно переважає інші види м'яса. На світовому ринку ягнятина ціниться вище, ніж інші види м'яса. Особливо високий попит на туші молодняку 13–16 кг. Дієтичність молодої ягнятини зумовлена її протеїновим складом, високим вмістом вітамінів А і Е та групи В, ліпідів, зокрема фосфоліпідів. Щоправда, хоча м'ясо овець і відзначається високими харчовими та біологічними властивостями, недоліком його є значний вміст насичених жирних кислот, що пов'язано з процесами рубцевої біогідрогенізації. Отже, проблема збільшення у баранині частки поліненасичених жирних кислот є надзвичайно актуальною для здоров'я людей. З цією метою у годівлі тварин широко застосовують різні біологічно активні добавки, здатні прямо чи опосередковано впливати на збільшення вмісту полі ненасичених жирних кислот у їхній продукції. Зокрема, широко застосовуються антиоксиданти, які запобігають пероксидному окисненню подвійних зв'язків і тим самим збільшують вміст поліненасичених жирних кислот у продукції. Вирощування і відгодівлю ягнят біологічно доцільно й економічно вигідно проводити до досягнення ними маси тіла 40–50 кг, позаяк у цей період приріст м'язової тканини найбільший порівняно з відкладанням жиру, а витрати кормів — найменші.

Ключові слова: вівці, м'ясна продуктивність, біохімічний склад, біологічна цінність, годівля, порода, схрещування

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Шарану Миколі Михайловичу — 60!

3 березня 2023 року
доктору сільськогосподарських наук, професору,
вченому у галузі тваринництва зі спеціальності «біотехнологія»,
заступнику директора з інноваційно-наукової діяльності
Інституту біології тварин НААН
***Шарану Миколі Михайловичу** виповнилося 60 років*

Народився в с. Загірочко Жидачівського р-ну Львівської обл.

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У вересні-жовтні 1985 р. працював на посаді ветеринарного лікаря колгоспу імені Петровського Любарського р-ну Житомирської обл.

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З 1990 по 1993 рр. навчався в аспірантурі в Українському науково-дослідному Інституті фізіології і біохімії сільськогосподарських тварин (з відривом від виробництва).

З 1993 по 1999 рр. обіймав посаду завідувача сектора реабілітації корів-донорів лабораторії трансплантації ембріонів Львівського біотехнологічного центру — філіалу Інституту розведення та генетики тварин УААН.

З 1999 по 2019 рр. — завідувач лабораторії біотехнології Інституту біології тварин Національної академії наук України. З 2019 р. понині — заступник директора Інституту біології тварин НААН з інноваційно-наукової діяльності.

Крім того, з 2012 по 2013 рр. працював на посаді професора кафедри акушерства, гінекології та репродуктивної біотехнології тварин Львівського національного університету ветеринарної медицини та біотехнології імені С.З. Ґжицького (за сумісництвом).

У 1994 р. захистив кандидатську дисертацію у Львівській академії ветеринарної медицини на тему: «Приживлення трансплантованих ембріонів залежно від функціонального стану статевих органів телиць-реципієнтів». У 2009 р. М. М. Шарану присвоєно вчене звання старшого наукового співробітника. У 2010 р. він захистив докторську дисертацію в Інституті біології тварин НААН на тему: «Експериментальне обґрунтування та вдосконалення методів трансплантації і кріоконсервації ембріонів великої рогатої худоби». У 2015 р. йому присвоєно вчене звання професора за спеціальністю «біотехнологія».

Основні напрями наукових досліджень М. М. Шарана пов'язані з комплексними дослідженнями фізіологічних і біохімічних процесів в організмі та статевих органах тварин та розробленням біотехнологічних методів підвищення відтворної функції великої рогатої худоби, свиней, овець, а також з'ясуванням впливу біологічно активних речовин на фізіолого-біохімічні процеси, запліднення і ранній ембріональний розвиток за удосконалення кріоконсервування та штучного осіменіння тварин, що дає можливість розробити способи підвищення заплідненості та зменшення ембріональної смертності. Він розробив і теоретично обґрунтував технології трансплантації ембріонів, штучного осіменіння корів-донорів, кріоконсервування ембріонів, зокрема надшвидкого заморожування або вітрифікації, а також методи стимуляції статевої охоти овець та підвищення запліднювальної здатності спермієв кнурів і баранів.

М. М. Шаран дослідив ефективність застосування гонадотропінів у складі ліпосомальної емульсії для індукції суперовуляції у корів-донорів. З'ясовано вплив біологічно активних речовин (естрофану, інозину, унітіолу, глутатіону, L-цистеїну), введених зі спермою бугаїв, на заплідненість та якість ембріонів корів-донорів, а також кріопротекторні властивості мембраностабілізувальних речовин (інсолвіту, лінолевої кислоти та холестеролу) за надшвидкого заморожування ембріонів корів. Встановлено залежність приживлюваності ембріонів від мінерального живлення корів-донорів в умовах Західної геохімічної провінції. Досліджено вплив біологічно активних речовин (БАР), фармацевтичних засобів та біотехнологічних прийомів на підвищення приживлення трансплантованих ембріонів у телиць-реципієнтів. Розроблено методи підвищення приживлюваності ембріонів, отриманих *in vitro*.

Результати наукової роботи М. М. Шарана відображені в 231 наукових працях, з яких 1 підручник, 2 довідники, 14 патентів України та майже 200 статей у фахових виданнях України, з яких 6 у виданнях, що входять у міжнародні наукометричні бази даних.

Під керівництвом М. М. Шарана захищено чотири кандидатські дисертації.

М. М. Шаран є членом Українського фізіологічного товариства ім. П.Г. Костюка і Польського товариства біології розмноження (*Towarzystwo Biologii Rozrodu* — TBR), з науковців Інституту біології тварин НААН і Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Ґжицького заснував Львівський осередок TBR.

З ініціативи М. М. Шарана у 1995 р. започатковано співпрацю Інституту біології тварин НААН з Краківським аграрним університетом. У 2015 р. отримав Нагороду Східних Студій Варшавського університету ім. Івана Виговського, яка передбачала чотиримісячне стажування у Краківському аграрному університеті та Варшавському університеті природничих наук, де проводив експерименти з трансплантації ембріонів овець, запліднення *in vitro* котячих, а також лекції та практичні заняття з репродуктивної біотехнології.

За багаторічну сумлінну працю нагороджений Почесною грамотою УААН та Почесною відзнакою НААН, Подяками і Грамотами Львівської облдержадміністрації та обласного управління сільського господарства, Почесною грамотою Краківського аграрного університету ім. Гуґо Коллонтая.

Член спеціалізованої вченої ради Д 35.368.01 із сільськогосподарських наук при Інституті біології тварин НААН (2011–2014 рр.), спеціалізованої вченої ради Д 35.826.01 з ветеринарних наук при Львівському національному університеті ветеринарної медицини та біотехнологій ім. С. З. Ґжицького з 2011 р. та спеціалізованої вченої ради Д 27.821.01 з сільськогосподарських наук при Білоцерківському національному аграрному університеті. Професор М. М. Шаран є експертом-дорадником з надання соціально спрямованих дорадчих послуг з питань тваринництва та агробізнесу. Член редакційної ради журналу «Біологія тварин» і в минулому був членом редакційної колегії Науково-технічного бюлетеня Інституту біології тварин і ДНДКІ ветпрепаратів та кормових добавок.

Колектив працівників Інституту біології тварин НААН щиро вітає ювіляра, зичить міцного здоров'я і творчого довголіття!

Віщуру Олегові Івановичу — 60!

22 березня 2023 року
доктору ветеринарних наук, професору,
вченому у галузі ветеринарної медицини
зі спеціальності «біохімія», «імунологія»
Віщуру Олегові Івановичу
виповнилося 60 років

Народився в м. Нововолинськ Володимирського р-ну Волинської обл.

У 1985 р. закінчив Львівський ордена Трудового Червоного Прапора зооветеринарний інститут за спеціальністю «ветеринарія». Після закінчення інституту працював на виробництві головним ветлікарем.

З 1989 до 1992 рр. — аспірант лабораторії білків і амінокислот НДІ фізіології і біохімії сільськогосподарських тварин, після її закінчення і до 1996 рр. — науковий співробітник лабораторії живлення Інституту фізіології і біохімії тварин УААН.

У 1993 р захистив кандидатську дисертацію на здобуття наукового ступеня кандидата ветеринарних наук за темою: «Вплив лізину, треоніну і метіоніну на показники імунобіологічної реактивності у свиноматок і поросят», виконану під керівництвом видатного українського вченого в галузі живлення сільськогосподарських тварин професора Слабіцького Ярослава Івановича.

У 1999 р. О. І. Віщур очолив і донині є завідувачем лабораторії імунології Інституту біології тварин НААН.

У 2008 р. захистив докторську дисертацію на тему: «Біохімічні особливості формування та регуляції імунної відповіді у телят і поросят у ранньому віці».

З 2009 до 2014 р. — в.о. професора і професор кафедри тваринництва та біотехнологій Львівського національного аграрного університету (за сумісництвом). З 2021 р. і донині — на посаді професора кафедри епізоотології Львівського національного університету ветеринарної медицини імені С. З. Ґжицького (за сумісництвом).

У 2015 р. Олегу Івановичу Віщуру присвоєно вчене звання професора за спеціальністю «біохімія».

Олег Іванович особисто і очолювана ним наукова група працює над вивченням особливостей метаболічного гомеостазу, формування імунної відповіді у тварин в останній період гестації і в критичні періоди постнатальної адаптації. На цій базі розроблено ефективні способи профілактики й лікування інфекційних і незаразних захворювань, імунодефіцитних станів, підвищення резистентності молодняку телят і поросят у ранній постнатальний період. Олег Іванович Віщур є співавтором нових препаратів для лікування та профілактики хвороб тварин — таких, як «Антоксан», «Ліпоген», «Ліпофлок», «Міметон», «Ліповіт», «Інтерфлок», «Амівіт», «Вітан», «Антоксан», «Прегнавітан», «Селцивіт», «Ковісцин», «Цивітар».

Важливою складовою досліджень, проведених О. І. Віщуром, є вивчення механізмі дії нових імунотропних препаратів на імунний потенціал, NO-залежні механізми, систему антиоксидантного захисту, білковий і ліпідний обмін в організмі тварин. Під керівництвом професора Віщура тривають дослідження із застосуванням імуномодулювальних препаратів у системі профілактики хвороб молодняку і для стимуляції імунобіологічної реактивності організму, підвищення продуктивності та збереженості тварин. Олег Іванович і його лабораторія розробили способи виділення та очищення імуноглобулінів класів G, A і M із крові великої рогатої худоби і свиней для отримання моноспецифічних антисироваток з метою створення тест-системи для оцінки гуморального імунітету у тварин. Запатентовано імунонефелометричний метод для визначення концентрації окремих класів імуноглобулінів у біологічних рідинах організму тварин та метод визначення імунного потенціалу за показниками макрофагальної трансформації мононуклеарів. О. І. Віщур здійснює керівництво та приймає участь у виконанні наукової тематики в Інституті біології тварин НААН.

О. І. Віщур є членом вченої ради і методичної комісії інституту. З 2000 р. і до 2020 р. — вчений секретар, а з 2021 р. — заступник голови спеціалізованої вченої ради Д 35.368.01 при Інституті біології тварин НААН. О. І. Віщур є автором понад 350 наукових праць, тринадцяти авторських свідоцтв та патентів, п'яти ТУ України, двох СОУ, трьох монографій, трьох посібників, п'яти довідників і двох підручників. У навчальному процесі в сільськогосподарських вузах України, зокрема у Львівському національному аграрному університеті та Львівському національному університеті ветеринарної медицини та біотехнологій ім. С. З. Ґжицького, використовуються монографії за авторством Олега Івановича Віщура: «Імунний статус, способи оцінки і методи корекції у телят раннього віку» (2015) та «Антиоксидантний захист організму молодняку великої рогатої худоби за хронічного кадмієвого токсикозу та його корекція» (2015).

Суттєве місце у науковому житті О. І. Віщура займає і педагогічна діяльність. Так, у 2009–2014 рр. він працював на посаді професора кафедри тваринництва і біотехнологій Львівського національного аграрного університету. З 2021 р. — професор кафедри епізоотології Львівського національного університету ветеринарної медицини імені С. З. Ґжицького.

Крім того, Олег Іванович здійснює наукове керівництво аспірантами та докторантами, під його керівництвом захищено 9 кандидатських й 1 докторську дисертацію, ведеться підготовка 4 аспірантів.

О. І. Віщур є членом спеціалізованої вченої ради із захисту дисертацій Д 26.004.08 при Національному університеті біоресурсів і природокористування України (з 2014 р.). Неодноразово був опонентом кандидатських і докторських дисертацій. Олег Іванович є членом редакційної колегії наукового журналу «Біологія тварин» і в минулому був членом редакційної колегії Науково-технічного бюлетеня Інституту біології тварин і ДНДКІ ветеринарних препаратів та кормових добавок. О. І. Віщур є членом науково-методичної координаційної ради при Інституті біології тварин НААН. Нагороджений Почесною відзнакою Національної академії аграрних наук України (рішення Президії НААН №5 від 20 березня 2013 р.) та премією імені С. З. Ґжицького за цикл праць «Метаболічні процеси, резистентність та продуктивність у корів і телят та способи їх регуляції».

Колектив працівників Інституту біології тварин НААН щиро вітає ювіляра, зичить міцного здоров'я і творчого довголіття!

Ключем до всякої науки є знак питання.

ІНСТИТУТ БІОЛОГІЇ ТВАРИН НААН ОГОЛОШУЄ НАБІР

у ДОКТОРАНТУРУ

очна (денна) форма навчання

та АСПІРАНТУРУ

очна (денна/вечірня) і заочна форма навчання

за спеціальностями:

09 «БІОЛОГІЯ»
спеціальність 091 «БІОЛОГІЯ ТА БІОХІМІЯ»

21 «ВЕТЕРИНАРІЯ»
спеціальність 211 «ВЕТЕРИНАРНА МЕДИЦИНА»

При вступі до аспірантури складають іспити з іноземної мови і спеціальності.
Підготовка у докторантурі та аспірантурі здійснюється за рахунок:
— коштів держбюджету України — за державним замовленням;
— коштів юридичних та фізичних осіб — на умовах контракту.

Термін подання документів — з 01.06 до 31.08.2023 р.

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Довідки за тел.: (+38 032) 270-23-89, (+38 067) 453-36-39.
e-mail: inenbiol@mail.lviv.ua www.inenbiol.com

КОНКУРС НА ЗДОБУТТЯ ПРЕМІЇ ІМЕНІ С. З. ҐЖИЦЬКОГО

Інститут біології тварин НААН оголошує конкурс на здобуття Премії імені С. З. Ґжицького. Премію імені С. З. Ґжицького присуджують за наукові праці (цикл наукових праць) з фізіології і біохімії, живлення тварин, розроблення та впровадження нових біотехнологічних методів, препаратів, біологічно активних добавок, діагностикумів, створення нових порід, типів і ліній сільськогосподарських тварин та птиці, а також за наукові роботи, які є значущими у розв'язанні актуальних проблем біології, агроекології, ветеринарної медицини.

Премію присуджують раз на два роки за результатами конкурсу, до участі в якому приймають роботи, виконані окремими науковцями або колективами авторів. Висунення робіт на здобуття Премії імені С. З. Ґжицького проводять через вчену (науково-технічну) раду наукової установи чи закладу вищої освіти. Претендентом на отримання Премії може бути колектив до п'яти осіб. Кожен учасник може бути автором чи співавтором лише однієї з представлених на конкурс роботи або циклу робіт. Участь у конкурсі беруть наукові праці, від дня публікації яких минуло не менше шести місяців, але не більше п'яти років, а також винаходи після їх впровадження. Роботи, які вже отримали Державні або інші премії України, до конкурсу не приймають.

На розгляд конкурсного комітету Інституту біології тварин НААН претендентам необхідно подати такі документи:

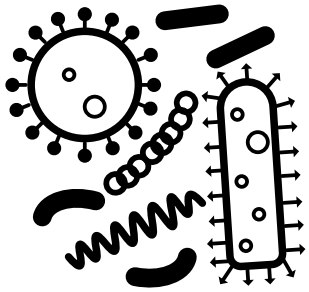
- заява про участь у конкурсі з переліком членів авторського колективу;
- анкета з вказаними особистими даними претендента(тів): ім'я, ПРІЗВИЩЕ, дата народження, місце роботи (адреса), посада, вчене звання, науковий ступінь, контактний телефон, e-mail, фото 3×4;
- робота, яку рекомендують (цикл робіт, публікацій тощо);
- анотація роботи з коротким викладом її змісту і значення для розвитку науки;
- довідка про творчий внесок кожного з претендентів, підписана кожним з авторів роботи;
- протокол вченої (науково-технічної) ради щодо рекомендації роботи на здобуття Премії;
- за наявності — додаткові матеріали (рекомендаційні листи від відомих учених, акти апробацій, акти впровадження, копії патентів, відгуки громадськості тощо);
- претенденти несуть відповідальність за академічну доброчесність.

За результатами конкурсу буде видано диплом лауреата і пам'ятну відзнаку.

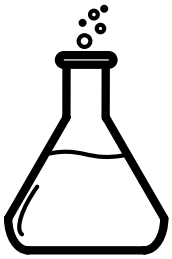
Термін подання конкурсних матеріалів — з 1 квітня до 1 жовтня 2023 року.
Адреса: Інститут біології тварин НААН, вул. Стуса, 38, м. Львів, 79034, Україна.
Контактний тел.: (032) 260-07-95, факс (032) 270-23-89.

ІНСТИТУТ БІОЛОГІЇ ТВАРИН НААН ПРОВОДИТЬ:

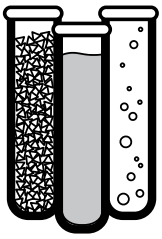
- Дослідження біохімічних показників (аналізатор *Humalyzer 2000*, Німеччина)
- Гематологічний аналіз (аналізатор *Mythic-18Vet*, Швейцарія)



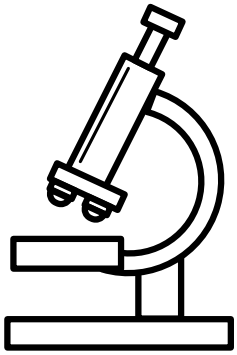
- Мікробіологічні дослідження (посів на стерильність, антибіотикограма, склад мікрофлори кишечнику тварин, мікробіологічний аналіз кормів, води, повітря)
- Імуноферментні дослідження (аналізатор *Stat Fax 3000*, Німеччина)



- Оцінка репродуктивної здатності тварин, штучне осіменіння, трансплантація ембріонів
- Селекційно-генетичні дослідження



- Дослідження кормів
- Дослідження молока
- Дослідження яєць
- Визначення показників якості меду
- Дослідження вовни і волосся
- Атомно-абсорбційний і атомно-емісійний аналіз концентрації хімічних елементів



- Аналіз органічних добрив

Організовує проведення досліджень на лабораторних тваринах і надає кваліфіковану інтерпретацію отриманих результатів.

** можливе проведення інших досліджень*
*** всі лабораторії інституту акредитовані для проведення досліджень*

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ІММУНІТІ СТІМ

ЗАХИСТИТИ І ПЕРЕМОГТИ

Зміцнює організм тварин та птахів, захищаючи кишковий бар'єр

Склад: 1 л містить: Вітамін Е (олл-рац-альфатокоферилацетат), 25000 мг; Вітамін С, 2100 мг; Гліцин 10000 мг; Селен - Se (селеніт натрію), 0,5 мг; Марганець – Mn (Сульфат марганцю моногідрат), 500 мг; Ефірна олія розмарину 10000 мг; Ефірна олія чебрецю 10000 мг; Ефірна олія евкаліпта 10000 мг; Натрію хлорид 1250 мг; Калію хлорид 500 мг; Дріжджовий екстракт 50000 мг; Полісахариди 20000 мг; Гліцерил поліетиленгліколь рицинолеат і Демінералізована вода до 1 л. **Застосування:** до і після вакцинації. ІММУНІТІ СТІМ розроблено для: контролю спалахів вірусних захворювань, контролю всіх видів стресу, покращення титрів вакцинації, прискорюють ріст, покращують конверсію корму, підвищують загальну опірність організму та покращують виводимість у несучок і покращує відтворну функцію. **Показання та цільові види тварин**: сільськогосподарські тварини, птиця, собаки та коти - посилення імунного статусу організму. **Протипоказання, побічні реакції та взаємодії:** Не описано. **Дозування та спосіб застосування:** перорально з питною водою. Ретельно розмішати 1 мл в 1-2 л питної води. **Зберігання.** Зберігати в недоступному для дітей місці. Зберігати в прохолодному, сухому місці, подалі від джерел тепла і прямих сонячних променів. **Для застосування у ветеринарній медицині.**

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