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THE CONTENT OF BENZO(A)PYRENE IN SMOKED FISH AND MEAT PRODUCTS

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ABSTRACT

The contents of benzo(a)pyrene (BaP) from 9 samples of industrially smoked different meat products and 24 samples of traditionally and industrially smoked fish products were analysed. The results were summarized and compared with the maximum acceptable levels set by the European Commission Regulation (EC) No 1881/2006. The BaP content of industrially smoked meat products were below the EU maximum limit of 5 µg kg^{-1} in smoked meat products, however also relatively high BaP content at the level of 4.05 µg kg^{-1} was found in breakfast ham.

The analysis of smoked fish products showed that the level of BaP in traditionally smoked fish products is higher in comparison with industrially smoked fish products. However, the data show that BaP content in 75 % of smoked herring and in all analyzed samples of smoked sprats in oil exceed the EU maximum limit of 5 µg kg^{-1}. The influence of pine cone addition to fuel was analysed and the contents of BaP were determined. The results showed that traditional fish smoking with added cones increased BaP content on average about 17 %.

Key words: *polycyclic aromatic hydrocarbons (PAH), benzo(a)pyrene, smoked fish, smoked meat, Latvia*

INTRODUCTION

The primary objective of food processing operations is to improve the quality of foodstuffs to make them palatable. Thermal processing of foods is probably the most common operation in the food industry.

Benzo(a)pyrene (BaP) is a five-ring polycyclic aromatic hydrocarbon (PAH), belonging to the alternant class of PAHs. BaP has evoked much interest due to its carcinogenic properties [1, 13]. It has produced stomach tumor, mammary gland tumor, lung and respiratory tumors, hepatic tumors in laboratory animals. Human exposure to BaP occurs through several routes namely the skin, the gastrointestinal and the pulmonary tract [7, 10, 14, 18].

Polycyclic aromatic hydrocarbons (PAHs) are generally classified as relatively persistent organic environmental contaminants. There are two major sources of BaP in the human food chain. The principal natural sources of BaP are forest fires, volcanic eruptions, peat fires and burning of crude oil and shale oil, while anthropogenic sources include the incomplete combustion of fossil fuels, coke oven emissions, aluminum smelters, coal combustion and conversion industries, incinerators, vehicle exhausts and cigarette smoke. The other significant source is derived from the formation and deposition of PAHs on foods during heat processing using methods such as roasting, smoking and grilling [7, 12, 14, 15]. Food is a significant source of BaP in Europe due to PAHs in oils, fats and cereals which represent a high percent of the European diets [11].

Smoking is one of the oldest technologies for the conservation of meat and fish products. Today it is supposed that the technology is applied in many forms to treat 40–60 % of the total amount of meat products [15] and 15 % of fish [17]. Smoking is defined as the process of penetration of volatiles resulting from thermal destruction of wood into the surface of meat or fish products. Smoke not only gives special taste, colour and aroma to food, but also enhances preservation due to the dehydrating, bactericidal and antioxidant properties of smoke [14, 15].

In the European Union, a maximum level of benzo[a]pyrene (BaP) in muscle meat of smoked fish, smoked fishery products, smoked meat and smoked meat products is 5 $\mu g\ kg^{-1}$. The objective of this study was to determine the level of the BaP in representative samples of traditional and industrial smoked fish and meat products to be sold in the Latvia Republic.

MATERIALS AND METHODS

Samples and sampling. All commercial samples were purchased from local outlets. To collect representative samples of animal origin products in Latvia, a total of 9 samples of smoked meat products and 24 samples of smoked fish products were analysed. Approximately a sample of 150 g of smoked product was taken according to the sampling procedure (from different places). Packaging of samples followed the Commission Regulation (EC) No 333/2007 [4]. Afterwards, the samples were homogenated in the "Sigra" laboratory using sample mills.

Industrial smoking is characterized by using smoke from external smoke generator, but in traditional methods smoke is generated from the bottom of an oven and the food is placed directly over the smoking wood.

Chemical analysis. For the sample treatment, cyclohexane, N,N-dimethyl-formamide (DMF), methanol, potassium hydroxide, acetonitrile, anhydrous Na_2SO_4 and silica solid phase extraction (SPE) cartrige (500 mg) were purchased from Sigma-Aldrich.

Analysis of BaP. In this study meat and fish samples were analyzed using the method for HPLC [16]. Homogenized samples were hydrolyzed with the solution of potassium hydroxide in ethanol for 2 hours in 40 °C, and then filtered and extracted with cyclohexane. The cyclohexane solution was washed with water and then with a mix solution of methanol/water (4:1). For re-extraction cyclohexane liquid extraction with N,N-dimethylformamide/water (9:1) solution was used. Afterwards – repeatedly combined DMF layer extraction with cyclohexane and extract evaporating by rotation evaporator and diluting in cyclohexane were used. The end stages of analysis were extract purification on Silica SPE column and evaporating and diluting in moving phase (acetonitrile).

Statistical analysis. All data are presented as mean with standard deviation, significance was set at $p<0.05$.

RESULTS AND DISCUSSION

BaP in smoked meat products. In this study, nine samples of smoked different meat products were analysed and the contents of the BaP were determined (Figure 1.).

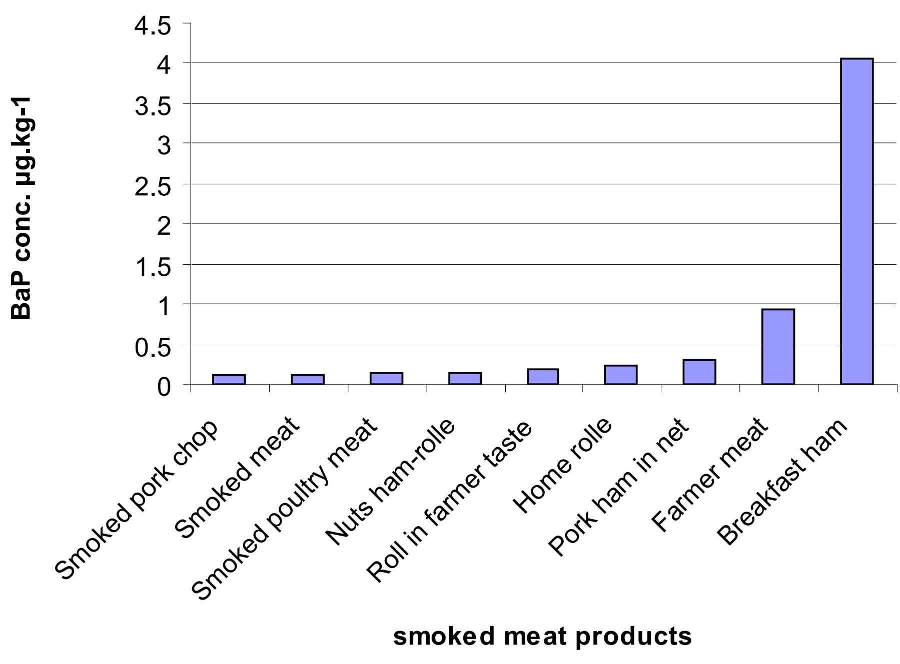

Fig.1. **Benzo(a)pyrene content in industrial Smoked meat products**

Fig.1. clearly shows that all the studied samples contain BaP in concentrations below the EU permitted maximum limit [5]. The highest content of BaP was detected in breakfast ham (4.05 μg kg^{-1}), and the lowest BaP content was detected in smoked pork chop (0.11 μg kg^{-1}). This study clearly demonstrates that the production of smoked meat products with BaP levels lower than 1 μg kg^{-1} is possible in non-intensively smoked products. Considering the genotoxic and carcinogenic properties of several PAH compounds (i.e., BaP), the Scientific Committee on Food (SCF) recommended that the PAH contents in smoked meat products should be as low as reasonably achievable (ALARA) [14].

BaP in smoked fish products. Twenty-four samples of traditional (n=8, i.e., herring (n=4) and scomber 1 (n=4)) and industrial (n=16) smoked fish products were analysed on BaP content. Fig.2. provides a summary of their average concentrations in the samples.

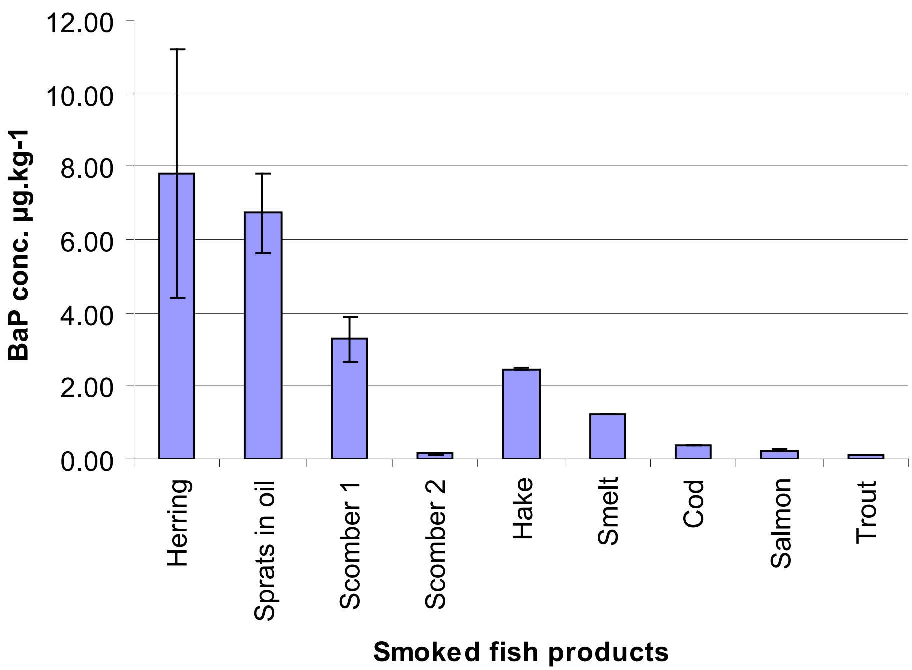

Fig.2. **Benzo(a)pyrene content in industrial and traditional smoked fish products**

The Figure 2. shows that all the studied samples of industrial smoked sprats in oil contain BaP in concentrations higher than the EU permitted maximum limit [5]. On the basis of the obtained results it was found that 75 % traditional smoked Baltic herring samples exceeded the EU maximum acceptable level. Regarding scomber samples, the studied samples of traditional smoking (scomber 1) contained BaP in concentrations substantially higher in comparison with industrial smoking (scomber 2), but not exceeeded the permitted level. The results confirm the data of other researchers that the major part of the samples of smoked sprats in oil, smoked sprats, canned sea fish in oil, smoked herrings and smoked mackerels from Latvia, Estonia, Poland and Lithuania exceed the limit currently in force [8].

The others samples of fish smoked by indirect technique, using smoke from an external smoke generator, had BaP levels below the maximum limit, i.e., from 2.46 μg kg^{-1} (hake) to 0.12 μg kg^{-1} (trout).

The amount of PAH formed during the processing of fish depends mostly on the conditions of smoking. In traditional smoking, smoke is generated at the bottom of an oven and the food is placed directly over the smoking wood. In modern industrial smoking ovens, smoke is generated in a separate chamber and led into the smoking chamber where the products are placed. This facilitates the control of the smoking process [9, 15].

By far more dangerous is the smoking process in uncontrolled conditions, typical for home “wild” smoking [3, 6]. Often in time of traditional smoking pine cones are added to fuel due to aroma and color of fish. The samples of smoked fish products were analysed and the contents of BaP were determined (Fig.3).

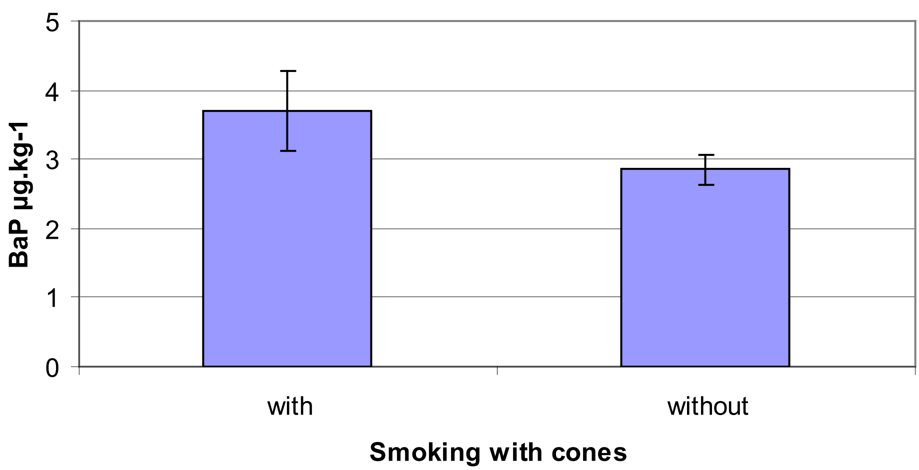

Fig.3. **Benzo(a)pyrene content in traditional smoked scomber**

Figure 3. shows that in the samples of scomber the analysed current limit levels of BaP [5] was not exceeded. Nonetheless the average BaP content in fish smoked with cones is present in the highest concentrations. It was 3.7 μg/kg and that was about 17 % greater than average BaP content in fish smoked without cones. Between both groups p-value = > 0.05 (0.21) indicate low impact of smoking with cones on increasing of BaP level, what is in conflict with the studies of other scientists, who have found that grilling over pine or spruce cones results in serious PAH contamination of tne smoking products [2, 19].

CONCLUSIONS

1. The level of BaP in industrially smoked meat products does not exceed the EU maximum limit.

2. Level of BaP in traditionally smoked fish products is higher than that in industrially smoked fish products.

3. Traditional fish smoking using cones increases BaP content on average about 17 %.

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УДК 664.9

СОДЕРЖАНИЕ БЕНЗО(А)ПИРЕНА В КОПЧЕНЫХ РЫБНЫХ И МЯСНЫХ ПРОДУКТАХ

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Р е з ю м е

В нашем изследовании анализированна концентрация бензо(а)пирена (BaP) в 9 оброзцах промышленно копченых мясных продуктах и 24 оброзцах традиционно и промышленно копченых рыбных продуктах. Концентрация BaP во свех оброзцах промишленно копченых мясных продуктах была ниже максимальнной нормы EC 5 μg kg^{-1}. Однако, сравнительно высокую концентрацию BaP 4.05 μg kg^{-1} мы обнаружили в копченной ветчине.

Аннализ копченых рыбных продуктов показал, что концентрация BaP в традиционно копченых продуктах выше чем в промышленно копченых продуктах. Однако, наше иследование показало, что 75 % копченной салаки и все оброзцы копченных шпротов в масле превысили максимальнную норму ЕС 5 μg kg^{-1}. В нашем иследовании анализировано влияние добавления сосновых шишек к пиломатериалам, используемых для традиционного копчения. Иследование показало, что добавления сосновых шишек повышает концентрацию BaP в продукте на 17 %.

Ключевые слова: бензо(а)пирен, копченые продукты.

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NEW HERMETIC MATERIAL FOR SILAGE QUALITY IMPROVING

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ABSTRACT

There is a lot of current interest in the factors affecting the development of moulds and mycotoxins in stored animal feeds because of the risks posed by mycotoxins to animal and human health. The factors include the epiphytic microflora on the crop at harvest, crop dry matter concentration, oxygen levels in the silo during the initial aerobic phase, density of silage and oxygen ingress during the storage and feed-out periods. Silostop is a new oxygen barrier film for covering bunkers, trenches, and clamps of silage.

Experimentally ensiled silage upper layer (30 cm depth) had less losses (silage losses on average 1.7 :100 t on 1700 t) in hermetization variant when the silage is covered with a single layer of Silostop 45 micron thickness clear oxygen barrier film and with a single layer of Silostop anti - UV net., in comparison with the control variant - the silage is covered with a single layer of conventional 150 micron thickness white of black polyethylene film. The essentially better average data of quality (biochemical and microbiological) of silage upper layer (30 cm) samples were obtained for experimental variant where ensiling mass was covered with single layer of Silostop 45 micron thickness clear oxygen barrier film and with a single layer of Silostop anti - UV net., in comparison with control variant - silage is covered with single layer of convencional 150 micron thickness white on black polyethylene film.

Key words: *silage quality, new technology, silostop*

INTRODUCTION

Silostop is a new oxygen barrier film for covering bunkers, trenches, and clamps of silage. Although the material has been evaluated extensively in the USA, there is no information about its efficacy in Baltic environments where the climate and crop type are different than those in North America. In addition, there is a need for locally-derived information for Latvian farmers on the performance of Silostop compared with the conventional polyethylene film, which is permeable to oxygen [1, 5].

There is a lot of current interest in the factors affecting the development of moulds and mycotoxins in stored animal feeds because of the risks posed by mycotoxins to animal and human health. The factors include the epiphytic microflora on the crop at harvest, crop dry matter concentration, oxygen levels in the silo during the initial aerobic phase, density of silage and oxygen ingress during the storage and feed-out periods [3, 4, 6, 7]. There is no information on the potential impact of the oxygen barrier properties of Silostop on the development of moulds and mycotoxins in the silage in the 30 cm layer below the top surface of bunker and stack silos. Our hypothesis is that Silostop will reduce or prevent the development of undesirable bacteria, moulds and mycotoxins in the uppermost layer of the silage. This layer can often deteriorate substantially during the storage period in silos covered with conventional polyethylene film due to oxygen ingress. Inedible waste silage, which can account for more than 25 % of the total dry matter in the top 50 cm of the silo, should be discarded but is often included together with edible silage in the diet of livestock with potential adverse effects on productivity and animal health. Losses of organic matter from the top layer of farm-scale silos filled with forage sorghum tended to be lower when the silos were covered with "Silostop" oxygen barrier film compared to a single layer of standard polyethylene film [8].

The aim of the study was to investigate the influence of Silostop 45 micron thickness clear oxygen barrier film and Silostop anti-UV net. on the silage quality under Latvia conditions.

MATERIALS AND METHODS

Ensiling procedure and treatments. Silage was made from first cut mixed grass sward, composed of 50 % Timothy (*Phleum pratense L.)* and 50 % Red clover (*Trifolium pratense L.)* for the investigation in field condition. Grass was cut and ensiled from 02.06.09.-.09.06.09 by adding conservant KOFASIL ^{R} LIFE. The biological silage additive was used to improve the fermentation quality of silages from moderately difficult and easy to ensile material, esp. from wilted grass or grass-legume mixtures. It also suppresses enterobacteria and clostridia, prevents butyric acid fermentation, and reduces nutrient losses.

Ingredients: *Lactobacillus plantarum* (DSM 3676, DSM 3677), *Propionibacterium* (DSM 9576, 9577), approx. 4x 10^{8} CFU /g.

1700 t of silage was made in bunker silo by compacting and covering the trench lengthwise half with different material of hermetization on two equal parts:

Part 1 - Silage is covered with a single layer of Silostop 45 micron thickness clear oxygen barrier film and with a single layer of Silostop anti-UV net. – experimental variant (1).

Part 2 - Silage is covered with a single layer of conventional 150 micron thickness white or black polyethylene film – control variant (2).

Sampling and analytical methods Samples taken at random from the crop during the harvesting process and from samples of silage from the top 30 cm of silo, after at least 120 days storage, and assessed for:

Name of characteristic	Methods
Dry matter, %	ISO 6496-1999
Crude protein, %	LVS EN ISO 5983-1-2005
Ash, %	ISO 5984 – 2002
WSC, water – soluble carbohydrates ,%	ГОСТ 26176-91
NDF, % ADF,%	Using FiberCap 2021/2023 system
NEL, MJ/kg	Calculated
Yeast CFU g^{-1}	LVS ISO 21527-2:2008
Mould CFU g^{-1}	LVS ISO 21527-2:2008
Cl. tyrobutyricum CFU g^{-1} spore count	Anaerobic cultivation on selective Bryant and Burkey Medium
	Mycotoxins
Deoxynivalenol DON µg/kg	R-Biopharm Rhône Ltd, 2005 EÜ 401/2006 II Lisa
Aflatoxin B_1i µg/kg	EVS–EN 1412:2008, EÜ 401/2006 II Lisa SANCO 1208/2005
Toxin T – 2 µg/kg	Method of CRL2006, EÜ 401/2006 II Lisa
Ochratoxin A - OTA µg/kg	EVS – EN 14132: 2003/AC:2006, EÜ 401/2006 II Lisa
pH	ГОСТ 26180-84
Lactic acid	ГОСТ 23638-90
Acetic acid	ГОСТ 23638-90
Butyric acid	ГОСТ 23637-90
Water-soluble nitrogen	Moisio, T., Heikonen M., 1989 A Titration method for Silage Assesment, Elsevier Science Publishers B. V., Amsterdam
Ammonia nitrogen	Moisio, T., Heikonen M., 1989 A Titration method for Silage Assesment, Elsevier Science Publishers B. V., Amsterdam

Loses of organic matter were calculated by weighing the material in and out of the silo.

Statistical analyses of data were analysed in Microsoft Office Excel 2003 with Mann-Whitney U-criteria method.

RESULTS AND DISCUSSION

The spring of the year 2009 was late and dry in Latvia. Grasses started to form spires early. Dense herbage did not form in the fields and, therefore, green mass yield per ha was low. It was not possible to fill and cover the silage trench in time according to the technology. The period of rains started and the silage lost a part of its feeding value. In spite of climate difficulties, a set of Silostop (experimental variant) has ensured a good upper layer quality of the silage in the trench in comparison with the control variant where the mass was covered with a conventional polyethylene film.

Table 1. **Biochemical composition of fresh grass in DM average data (n=4)**

Item	Results
Dry matter, %	21.95
Crude protein, %	15.10
Ash, %	7.14
WSC, water – soluble carbohydrates ,%	7.46
NDF, %	50.85
ADF,%	32.67
NEL, MJ/kg	6.00

Green mass was cut in optimal time with regard to chemical composition. The average chemical and microbiological composition of the crop at harvest is shown in Tables 1 and 2. green mass had relatively low concentrations of DM, WSC and energy value.

Table 2. **Microbiological composition of fresh grass average data (n=4)**

Analysis	Unit of measurement	Result
	Microflora	
Yeast	CFU g^{-1}	4×10^4
Mould	CFU g^{-1}	8.85×10^8
Cl. tyrobutyricum spore count	CFU g^{-1}	0
	Mycotoxins	
Deoxynivalenol DON	µg/kg	Not detected
Aflatoxin B_1i	µg/kg	Not detected
Toxin T – 2	µg/kg	Not detected
Ochratoxin A - OTA	µg/kg	Not detected

Saceharolytic *Clostridium tyrobutiricum* was not detected in green mass. The ensiled mass was contaminated with yeasts and moulds but *Cl. tyrobutyricum* spore was not detected. Mould count was relatively high, probably reflecting wet weather. The average chemical composition of samples of the silages taken to 30 cm is shown in Table 3.

Table 3. **Biochemical composition of silage upper layer (30 cm depth) average data (n=6)**

Chemical analysis	Unit of measure	Silostop oxygen barrier film (1) - experimental	Conventional polyethylene film (2) - control
DM	%	21.90	20.70
CP	%	14.20	11.02
Total Ash	%	8.00	9.10
WSC water soluble sugars	%	1.45	0.99
NDF	%	57.01	60.29
ADF	%	43.40	45.98
NEL	MJ/kg	5.14	4.94

The biochemical composition of the silage upper layer (30 cm depth) was essentially ($p < 0.05$ and $p<0.01$) different in the control and Silostop variants. The silage quality of the upper layer was better for the Silostop variant by evaluating silage according to odour, colour and structure, it was not spoiled and silage feeding value was higher.

Differences due to type of covering in chemical parameters were generally small, concentrations of DM, CP and WSC tended to be lower, and concentrations of ash and fibre higher, in the top 30 cm of silage covered by conventional polyethylene (variant 2) compared to that covered by Silostop (variant 1).

Table 4. **Microbiological composition of silage upper layer (30 cm depth) average data (n=6)**

Item	Silostop oxygen barrier film (1)	Conventional polyethylene film (2)	Limit of determination
Microflora, CFU g^{-1}			
Total bacterial count	4×10^8	1.2×10^{12}	1×10^1
Yeast	2×10^5	2.2×10^7	1×10^1
Mould	4×10^2	8×10^4	1×10^1
Cl. tyrobutyricum spore count	0	1×10^2	1×10^1
Mycotoxins, n= 2, µg/kg			
Deoxynivalenol - DON	Not detected	Not found	250
Aflatoxin B_1	Not detected	Not found	0.1
Toxin T – 2	Not detected	Not found	7.0
Ochratoxin A - OTA	Not detected	Not found	0.9

The results shown in Table 4 testify that Silostop film ensures better anaerobic conditions. In the experimental silage samples mesophile anaerobic and facultative aerobic bacteria count (total bacteria count) were lower than in the control silage samples, therefore, organic substances proteolitic destruction reactions take place in lower degree and silage quality is higher.

Due to the fact that anaerobic conditions were ensured during the silage fermentation process, then as can be seen from Table 4, yeasts and moulds development was broken by lack of oxygen; the fungi was lower in the silage covered with Silostop than in the silage covered with conventional polyethylene film. The toxins produced by fungi were not ascertained in the samples, this is an indication that the silage did not contain dangerous fungi – *Fusarium graminearum, Fusarium culmorum* etc., *Fusarium* genus toxines producing species, as well as *Aspergillus* genus fungi.

Cl. tyrobutiricum spores were not ascertained in the silage covered with Silostop.

Fermentation characteristics of the silages are shown in Table 5.

Table 5. **Quality of silage in upper layer (30 cm depth) average data (n=6)**

	Unit of measure	Silostop oxygen barrier film (1)	Conventional polyethylene film (2)
pH		3.71	8.4
Lactic acid	% DM	1.71	0.06
Acetic acid	% DM	1.26	0.31
Butyric acid	% DM	0.00	0.61
Ethanol	g/ kg DM	2.40	1.10
Water-soluble nitrogen	g/ kg DM	8.30	8.85
Ammonia nitrogen	g/ kg total N	69.0	145.0

1 - Silage is covered with a single layer of Silostop 45 micron thickness clear oxygen barrier film and with a single layer of Silostop anti- UV net. – experimental variant (1);
2 - Silage is covered with a single layer of conventional 150 micron thickness white or black polythylene film – control variant (2.)

Silage pH values, butyric acid tended to be lower, and those of lactic acid higher for silage under Silostop than for silage under conventional film. The mean pH value and concentration of ammonia N were extremely high, indicating very substantial deterioration of the silage in the top 30 cm layer under conventional film. Similarly, mean concentrations of lactic and acetic acids were very low for silage under conventional film compared to that under Silostop, indicating fermentation of lactic acid to butyric acid by clostridia and metabolism of both lactic and acetic acids, by yeasts, moulds and aerobic bacteria [2] .

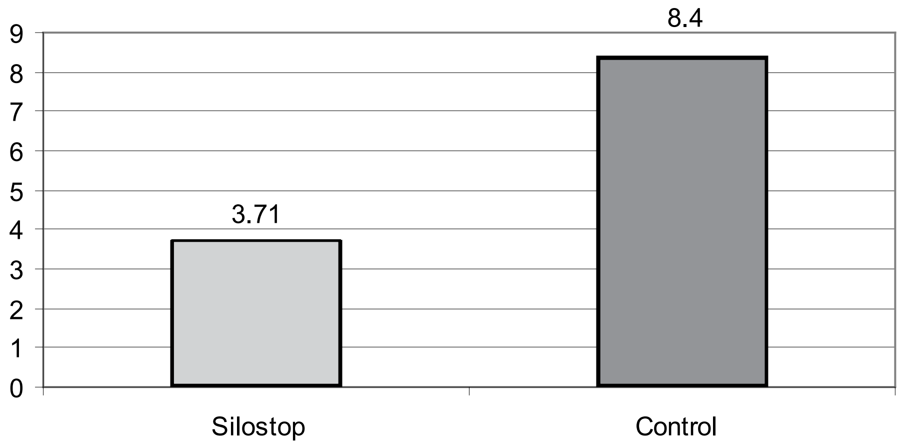

Fig. 1. **pH of silage upper layer (30 cm depth)**

pH essentially ($p<0,01$) was better in the silage upper layer of the experimental variant, when the mass was covered with Silostop material (Figure 1).

CONCLUSION

1. The upper layer of the silage (30 cm depth) had less losses (silage losses on average 1.7 : 100 t on 1700 t) in hermetization variant when the silage was covered with a single layer of Silostop 45 micron thickness clear oxygen barrier film and with a single layer of Silostop anti - UV net., in comparison with the control variant when the silage was covered with a single layer of conventional 150 micron thickness white or black polyethylene film.

2. Significantly higher quality (biochemical and microbiological) of the silage upper layer (30 cm) samples were obtained for the experimental variant when the ensiling mass was covered with a single layer of Silostop 45 micron thickness clear oxygen barrier film and with a single layer of Silostop anti - UV net., in comparison with the control variant when the silage is covered with a single layer of conventional 150 micron thickness white or black polyethylene film.

The data presented in this study were obtained from cooperation project with BRUNO RIMINI LTD and School of Biosciences, University of Nottingham, London, United Kingdom.

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ЗАЩИТА КАЧЕСТВО СИЛОСА ПОКРЫТОВО НОВЫМ ХЕРМЕТИЗИРОВАННЫМ МАТЕРИАЛОМ

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Р е з ю м е

„Silostop" - одна из пленок, которая не пропускает кислород (O_2) в силос во время хранения, останавливает порчу силоса и потери сухого вещества. Чтобы экономить денежные вложения в производство кармов, надо для герметизации силоса использовать „Силостоп", который в два раза эффективнее сохроняет качество силоса, чем стандартная плёнка. Здесь надо рассматривать несколько факторов, которые влияют на плесень и микотоксины в хранящемся корме для животных, потому что есть риск заразить животных и людей. Эти факторы составляют эпифическую микрофлору на растениях во время покоса, концентрацию сухого вещества, уровень кислорода (O_2) в силосе во время начала ферментации и компактность силоса, и проникновение кислорода (O_2) во время хранения и во время взятия корма для кормления.

Цель работы было изучить влияние “Silostop 45 micron thickness clear oxygen barrier film and Silostop anti-UV net.” на качество силоса в условиях Латвии.

Исследование проводилось в производственных условиях, законсервировав 1700 т злаковых и мотыльковых культур (50:50 %) в силос и продольно загерметезировав с 2 разнообразными материалами:

1 - силос обложен полиэтиленовой пленкой “Silostop 45 micron thickness clear oxygen barrier” и одним слоем “Silostop anti-UV net.” – опытный вариант (1).

2 - силос обложен одним слоем конвенциональной 150 микрон густой черно-белой полиэтиленовой пленкой - контрольный вариант (2).

В верхнем слое силоса (30 см глубина) потери корма были меньше в эксперементальном варианте (силосные потери 1.7 t : 100 t на 1700 t), когда силос был покрыт одним слоем Silostop 45-микроновой прозрачной O_2 непропускаемой плёнкой и одним слоем „Silostop anti-UV net” по сравнению контрольным вариантом, в котором силос был покрыт одним слоем конвенциальной 150-микроновой черно–белой полиэтиленовой плёнкой.

„Silostop” может сэкономить деньги, время, сухое вещество и ценность кормов.

Ключевые слова: качество силоса, новая технология, Silostop

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EFFECT OF CONCENTRATED FEED EXTRUSION ON CHEMICAL, MICROBIOLOGICAL CHANGES AND ZOOTECHNICAL-ECONOMIC CHARACTERISTICS

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ABSTRACT

The aim of the study was to investigate the extrusion of the concentrated feed on the chemical and microbiological changes, zootechnical and economic effects on dairy cow feeding. Latvian Brown cows were used in the study and allotted into two groups according to the analogue principle (n=2×50). Lactation dairy cows were included in the trial in the initial lactation phase with the average milk yield of 30.73 kg per day, fat content 3.92 % and 3.16 % protein content in milk. The differences between the trial and control group were that for the trial group of cows the feed was composed of extruded barley and wheat grains while for the control group of cows unprocessed grain was used.

During the extrusion process, the protein content decreased, including all the amino acids, but the amount of glucose in the grain increased at the expense of starch hydrolysis.

The extrusion process was powerful enough to almost completely, i.e., on 99.9 %, reduce the total quantity of bacteria in grain, to halve the number of mould and to completely destroy yeast bacteria populations in grain samples.

Within 150 days of study, milk yield in the experimental group of cows was approximately 0.91 to 1.27 kg higher than that in the control group of cows. In addition, the difference in yield in favor of the experimental cows showed a tendency to increase.

The economic effectiveness of feeding out the extruded grain was positive. Each experimental group of cows, which was fed on the extruded grain, despite *the relatively high cost of extrusion, gave on 8.58 LVL higher milk output than their counterparts in the control group.*

Key words: *dairy cows, extruded grain, productivity, costs*

INTRODUCTION

Research and practical experience shows that the feed processing technology and feeding technology, have a great impact on feed consumption, digestion and animal productivity. The quality of a full value feed is strongly influenced by the manufacturing technology- the physical factors of processing (pressure and temperature of granulation, extrusion, etc.) [1, 2, 6, 7].

The extrusion process under the influence of high temperature of 140-150^0 C and pressure of 4-4.5 atm. affects important physical and chemical changes in the structure of grain starch-to the decomposition of starch to sugars. Consequently, starch becomes more easily digestible and more fully used in the animal body. In the extrusion process, food sanitation occurs to some extent - high temperatures kill mold colonies and weed germination is reduced [3, 4, 6, 5]. Unfortunately, in Latvia feed extrusion, this advanced method of feed preparation is practically not applied. Grain extrusion and feeding extruded feed to animals on farms would enable to organize manufacturing of a full value feed on industrial principles, appropriately using all existing feed resources on the farm.

The aim of the study was to investigate the extrusion of the concentrated feed on the chemical and microbiological changes, zootechnical and economic effects on dairy cow feeding.

MATERIALS AND METHODS

Trials were carried out to determine the zootechnical and biological effects of feeding a complete feed to dairy cows on the farm “Udri”, Pale Parish, Limbazi Municipality. For the trial, two analogue (according to yield, lactation phase, live weight, fat content and protein content) groups of 50 animals of Latvian Brown cows were used in the study. The trial was carried out from 01 December 2009 to 08 April 2010, i.e., 150 days.

The average live weight of cows was 550 kg, the mean age was 2.0 lactations. The cows of high productivity in the initial phase of lactation were included in the experiment with the average yield of 30.73 kg per day, fat content 3.92 % and protein content 3.16 %. The dairy cows were kept in the same rearing and feeding conditions. The differences between the trial and control group in feeding were that for the trial group of cows the feed was composed of extruded barley and wheat grains while for the control group of cows unprocessed grain was used.

During the trial, the dairy cows received the total feed mix (TMR) which consisted, calculating per cow per day of: 35 kg grass + legume silage (80.46

% by mass), 2 kg of beer brewers grain (4.59 % by mass), 2 kg of sugar-beet pulp (dried) (4.59 % by mass) 0.5 kg of treacle (1.17 % by mass) and 4 kg (9.19 % by mass) of farm made concentrated feed, which was composed of wheat+ barley+ oats+ triticale (70 % of the concentrated feed mix), maize (4 % of the concentrated feed mix), soybean meal (16 % of the concentrated mix), soybean meal (4 % of the concentrated feed mix), salt (1 % of the concentrated feed mix), soda (0.5 % of the concentrated feed mix), mono-calcium phosphate (1 % of the concentrated feed mix), lime flour (1 % of the concentrated feed mix), mineral premix (2.5 % of the concentrated feed mix).

The chemical composition of the total feed mix and the feeding value according to the data of agronomical analyses available at the Latvia University of Agriculture (LLU) were as follows**:** dry matter 46.06 %, in turn, dry matter contained 14.15 % of crude protein, 5.89 % of total ash, 21.71 % of crude fibre, 39.71 % NDF, 24.10 % ADF, 0.71 % Ca, 0.48 % P, but quantity of the net energy for lactation (NEL) in 1 kg of the feed dry matter was 6.69 MJ. In addition to the total feed mix, depending on the productivity, the cows received industrially-made complete feed of 250 g concentrated feed per kg of milk yield.

A full value nutrition analyses were conducted by the accredited Scientific Laboratory of the Agronomical Analyses under the Latvia University of Agriculture and the Chemical Analyses Laboratory of Animal Biochemistry and Physiology of Institute of Biology under the Agency of Latvia University. Chemical analyses of the feed samples was carried out in accordance with the ISO 6498: 1998 standards, but the amount of amino acids in the feed samples were determined using the ion exchange method in accordance with the pattern of protein hydrolysis with 6N HCl in an inert atmosphere of the automatic amino acid analyzer T 339 (Microtechna Praha) - AOAC Official Method 985 28, but the amount of glucose – was analysed in accordance with the Nelsen modified method. The microbiological testing of feed samples was carried out by the Scientific Laboratory of Biochemistry and Microbiology under the Scientific Institute of Biotechnology and Veterinary Medicine "Sigra". The biometric data was processed using by the computer program MC Excel. The differences between the group averages were determined by the t-test.

RESULTS AND DISCUSSION

The increased temperature for starch hydrolysis increased the glucose content in extruded grain. Individual grain chemical composition ratios are somewhat contradictory. Thus, for instance, crude fiber in the grain had to be partially hydrolyzed and sugar (glucose) content – had to be increased under the effect of the increased temperature and pressure.

However, the analysis data do not show a reduced amount of crude fiber in the extruded grain, although, the amount of glucose in the grain, on dry weight basis has increased almost eightfold. This was mainly due to starch hydrolysis.

The amount and composition changes of amino acids in the grain mixture resulting from the extrusion process are presented in Table 2.

From the data presented in the chart, it is evident that due to the extrusion process, the amount of all the amino acids in the feed grain decreased. For some amino acids (aspartic acid, alanine, leucine, tyrosine, phenylalanine), it has been somewhat lower, for others (glutamic acid, proline, isoleucine, arginine), the reduction has been already significant.

Table1. **The chemical modifications of grain mixture resulting from extrusion, on dry matter basis**

Item	Before extrusion	After extrusion
Dry matter, %	90.32	95.82
Crude protein, %	13.66	13.52
Total ash, %	2.08	2.33
Crude fat, %	1.87	1.40
Crude fiber, %	3.55	4.79
NDF, %	15.85	14.52
ADF, %	4.24	5.90
NEL, MJ kg^{-1}	8.27	8.14
Starch, %	63.71	60.70
Glucose, %	0.29	2.25
Ca, %	0.04	0.09
P, %	0.43	0.43

Table 2. **Changes in the amino acid content in the extruded grain mixture resulting from extrusion, g 100 g^{-1}**

Amino acids	Grain mixture (before extrusion)	Grain mixture (after extrusion)
Aspargic acid	0.55	0.53
Threonine	0.13	0.10
Serine	0.26	0.23
Glutamic acid	2.47	2.06
Proline	0.99	0.69
Glycine	0.37	0.32
Alanine	0.31	0.27
Valine	0.23	0.17
Methionine	0.23	0.17
Isoleucine	0.24	0.16
Leucine	0.53	0.52
Tyrosine	0.14	0.12
Phenylalanine	0.21	0.20
Histadine	0.35	0.29
Lysine	0.25	0.21
Arginine	0.75	0.50
Total amount of amino acids	8.01	6.54

The decrease of the amino acid content in this case is due to high temperature and pressure during the grain extrusion resulting in amino acid denaturization. The feed, including grain contamination with harmful microorganism cultures for animals, can lead to serious animal illnesses. Therefore, grain processing with high temperature during extrusion, can serve as food sanitation and health preservation [5, 6, 7]. Modifications of microbiological contamination resulting from grain extrusion process are presented in Table 3.

Table 3. **The microorganism counts in grain sample, *CFU g^{-1}**

Type of microorganisms	Before extrusion	After extrusion
Bacteria, in total	2000 x10^7	3 x10^4
Mold	200 x10^4	100 x10^4
Yeast fungi	700 x10^4	Have not been identified

**CFU-colony forming units per gram.*

From the data presented in the chart it can be concluded that the extrusion process has been powerful enough to almost completely (99.9 %) reduce the total quantity of bacteria in the grain, to reduce by 50 % the number of mold and to completely destroy the yeast fungi populations in grain samples.

The cow productivity changes characterize both milk yield and milk composition (milk fat and protein) changes. The changes in milk yield between the two groups of cows are presented in Table 4.

Table 4. **Cow productivity during the trials, on average kg **ECM (n=2×50)**

Group	Before the trials	During the trials	After the trials	±, compared the beginning
Trial	31.15±1.36	30.96±0.68	28.99±0.52	-2.16
Control	30.24±0.81	30.00±0.61	27.72±0.55	-2.52
±, compared the control	+0.91	+0.96	+1.27	-0.36

(***ECM - energy corrected milk)*

As the trials of 150 days showed that, the milk yield in the experimental group of cows was approximately 0.91 to 1.27 kg higher than that in the control group of cows ($p<0.05$). In addition, the difference in yield in favor of the trial cows showed a tendency to increase. Although the daily milk yield for both groups of cows is lower under a normal course of lactation, this decrease for the trial group of cows was 0.36 kg milk per day slower ($p<0,05$). There were no changes in the milk composition (milk fat and milk protein) observed.

The economic efficiency is a key criterion for determining the benefit of one or another feed product fed out.

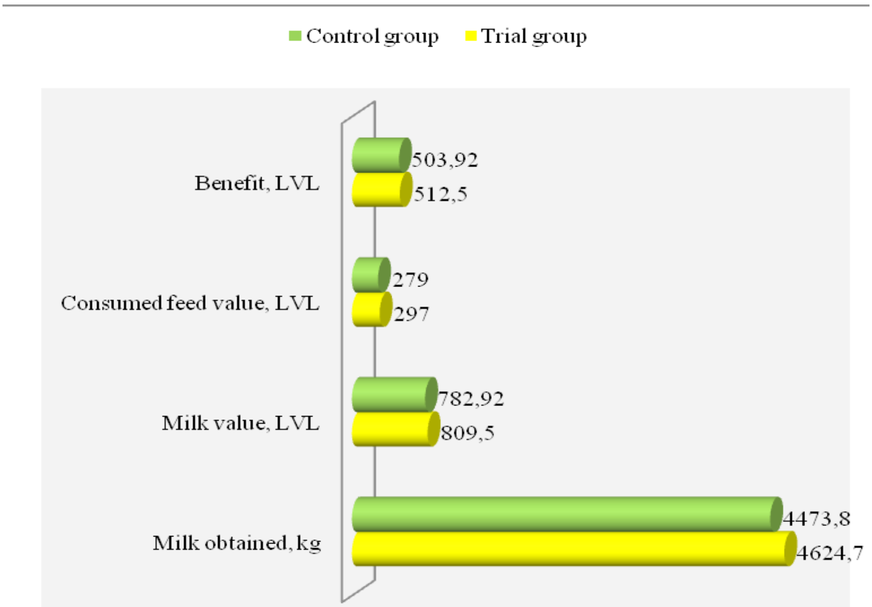

Fig.2. **Milk and feed costs for a cow during the trial of 150 days**

The milk sale and feed cost summary records for the trial that lasted 150 days show that the economic efficiency of extruded grain feeding has been positive. Each group of cows, which was fed with extruded grain, despite the relatively high extrusion cost, gave on average 8.58 LVL higher milk output than the cows in the control group.

CONCLUSIONS

1. During the extrusion period the protein amount decreased, including the content of all the amino acids, and the amount of glucose in the grain increased at the expense of starch breakdown.

2. During the trial, the experimental cows yielded from 0.91 to 1.27 kg more milk than the control group of cows. Feeding extruded grain to cows helped to better maintain the level of milk yield during lactation than in the control group of cows.

3. During the extrusion process, the total amount of bacteria and mold decreased in the grain, and the yeast fungi were completely destroyed.

4. The economic effectiveness extruded grain was positive. Each cow in the experimental group gave on average 8.58 LVL higher milk production than the cows in the control group.

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ЭФФЕКТ ЭКСТРУЗИИ КОНЦЕНТРИ РОВАННЫХ КОРМОВ НА ХИМИЧЕСКИЕ И МИКРОБИОЛОГИЧЕСКИЕ ИЗМЕНЕНИЯ И ЗООТЕХНИЧЕСКИЕ-ЭКОНОМИЧЕСКИЕ СВОЙСТВА

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Резюме

Целью исследования было установить, как экструзия концентрированных кормов влияет на их химический состав и микробиологические свойства, и оценить зоотехнический и экономический эффект при кормлении лактирующих коров. Исследование проводилось с двумя группами лактирующих коров латвийской бурой породы в начале их лактационного периода (средний удой за день составил 30,73 кг молока 3,92 % жирности и 3,61 % белковости), отобранных по принципу аналогов. Коровы экспериментальной группы получали корм из экструдированного зерна, а коровы контрольной группы – неэкструдированный корм. После экструзии количество всех аминокислот и белков в целом уменьшилось, но количество глюкозы – повысилось из-за гидролиза крахмала. Экструзия почти полностью (на 99,9 %) уменьшила общее число бактерий в зерне, полностью уничтожила популяцию дрожжей и на половину уменьшила количество плесени. На протяжении всего исследования (150 дней) молока в экспериментальной группе было надоено на 0,91-1,27 кг больше, чем в контрольной группе. Экономическая эффективность при кормлении экструдированным кормом была положительной. За молоко коров эксперительной группы, несмотря на сравнительно высокую стоимость экструдированного зена, получено на 8,58 латов больше, чем за молоко коров контрольной группы.

Ключевые слова: коровы, экструдированное зерно, продуктивность, цены

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THE ECONOMIC EFFICIENCY OF RAPESEED OIL CAKE IN THE RATIONS OF FARMED RED DEER *(CERVUS ELAPHUS)* IN WINTER

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ABSTRACT

The study was carried out to determine the effects of feeding rapeseed oil cake to farmed red deer (Cervus elaphus) over the winter period thus replacing the traditional ration of rolled grain of the equivalent feed value. It was found that rapeseed oil cake ration of 0.2 kg per day per animal over the winter period increased the dressing percentage by 4.43 % in comparison with the control group and increased the level of fatty acids n-3 by 11.28 %, n-6 fatty acids by 15.13 % of the total lipids in meat. The amount of the total feed consumed in the experimental group decreased by 3.2 % per animal and the feed costs were lower by 8.13 % in comparison with the control group. From the data obtained it can be concluded that the use of rapeseed cake in feeding of farmed red deer is economically cost-effective. Feeding 0.2 kg of rapeseed cake per deer per day, the delivered meat yield from an animal increased on the average by 4.85 % or 15.50 LVL in comparison with the control group.

***Key words**: deer, rapeseed oil cake, meat quality, economy*

INTRODUCTION

Over the last couple of years, amounts of rapeseed cultivation and, consequently, also those from extrusion by-product - oilseed cake – have been increasing. Rapeseed oil cake is characterized by high nutritive value and is composed of approximately 35.0–45.0 % crude protein, 14.0-15.0 % crude fat, 7.27 MJ/kg metabolizable energy, 8.0-9.0 % omega-3 (n-3), 20.0-24.0 % omega-6 (n-6) fatty acids of total lipids.

For providing of the required protein and energy levels, optimum rape-seed cake feeding schemes have been elaborated for cattle, pigs and poultry. Farmed deer-breeding is one of the most prospective, rapidly growing and non-conventional livestock sub-sectors in Latvia, potentially capable of export. In 2009, 70 farms were engaged in farmed deer breeding. Latvian Wild Animal Breeders' Association (SDAA) unites 37 members, and in 2009, it consisted of 26 fully developed deer gardens with 7500 wild animals of different breeds. Basically red deer (*Cervus elaphus*) are farmed (66 %) and followed by a small number (12 %) of fallow deer (*Dama dama*).

One of the goals of deer breeding is acquisition of high quality venison in the highest possible quantities, because foreign experts are of opinion that the main source of income in deer-breeding is meat production [3, 4]. Deer live outside throughout the year and they are kept in enclosed territories or pasture-grounds in Latvia. In winter period red deer are subject to weather impacts, that slow down their metabolism. Consequently, adult animals in winter lose up to 20 % of their bodyweight [3, 6, 8]. To retain their body-weight over the winter period, a well-balanced feeding program should be provided, with 2.6–2.7 kg of dry matter, 320.0-330.0 g of protein and 25.0-39.0 MJ of metabolizable energy (metabolizable energy ME in megajoules MJ [1].

The above feed value in Latvia is ensured by feeding daily on the average 7 kg haylage and 1 kg rolled grain (oats etc.) per animal [6]. The data from the scientific sources indicate that overseas red deer farmers enrich winter rations with high protein fish meal [1, 8]. A similar option may be used in Latvia by applying rapeseed oil cake in winter period.

Locally produced rapeseed oil cake contains a little less protein in comparison with fish-meal, however, the amount of n-3 and n-6 fatty acids is the same. As a component of a traditional by farmed red-deer ration, rapeseed oil cake can successfully replace a relevant amount of grain. In scientific sources there are no detailed references available on rapeseed oil cake feeding to farmed red deer and its impact on the meat quality. The results of the research studies carried out at *Sigra* Research Institute (Scientific projects: Extrusion impact on the protein structure of rapeseed oil cake, its applicability and impact on milk quality and quantity; Use of the rapeseed oil cake as bio-fuel production by-product in nutrition of agricultural animals; Study of the impact of physical factors on the feed conversion of processed products from the mustard family plants in the system of productive poultry) indicate that 5 % rapeseed oil cake supplement has no influence on the sensoric quality of either meat or milk at the same time providing a favourable impact on the productivity of cattle as well as expedite the level of n-3 and n-6 fatty acids in milk and meat.

The objective of our study was to assess the economic efficiency of the rapeseed cake in winter diets of red deer and to determine its influence on meat quality.

MATERIAL AND METHODS

The feeding trial was carried out over the period of three winter months in 2010 with farmed red deer (*Cervus elaphus*). The snow cover in the confined area (pasture ground) was on the average 53 cm and the average air temperature was -5.6 ºC, actually by 0.7 degrees lower than the norm (Meteorology Centre, 2010). The given natural conditions allowed only artificial feeding of red-deer. The design of the feeding trial is shown in the Table 1. Two groups of animals (control 1 and trial 2) of the same age were used in the study.

Both groups of deer received feed of the same value. The composition of the ration ensured the intake of 2.6 kg dry matter containing 320.7 g crude protein relevant to the requirements of the animal body and feeding standards for the particular season [1, 3].

Table 1. **Experimental design**

Group	Number of animals in the group	Composition of the feed ration per deer per day			
		Ingredients	kg	Dry matter (DM), kg	Crude protein (CP), g
1. – control group	10	Haylage	7.0	1.697	188.50
		Rolled grain	1.0	0.903	132.20
		Total	8.0	2.6	320.70
2. – trial group	8	Haylage	7.0	1.697	188.50
		Rolled grain	0.550	0.497	72.71
		Rape-seed cake	0.2	0.406	59.49
		Total	7.750	2.6	320.70

The feed ration of the trial group contained rapeseed oil cake in the amount of 0.2 kg per deer per day. In protein and dry matter such amount of rapeseed oil cake was used to replace an equal amount of rolled grain. Thus, the trial group received 0.2 kg of rapeseed oil cake in place of 0.450 kg rolled grain in comparison with the control group.

The effectiveness of rapeseed oil cake in feeding farmed red-deer was assessed at the end of the trial on the basis of feed consumption, feed costs, meat yield and its quality.

Previously homogenized meat samples were prepared for GLC (gas-liquid chromatography) analysis using direct saponification with KOH/methanol followed by a derivatization with (trimethylsilyl) diazomethane by the method of Aldai et al [2]. An ACME , model 6100, GLC (Young Lin Instrument Co.) equipped with a flame ionization detector, an automatic sample injector, and an Alltech AT-FAME analytical column (fused silica 30m×0.25mm i.d.) was used. As the carrier gas He was used with a flow rate approximately 2 mL/min. Temperature conditions of the oven, injector and detector was the same as in the method of Aldai et al. [2]. Results were evaluated with an conventional integrator program (Autochro-2000, Young Lin Instrument Co.) The individual FAMEs (fatty acid methyl esters) were identified according to similar peak retention times using standard mixture Supelco 37 Component FAME Mix.

Research data were analyzed by a non-parametric method (Mann-Whitney U test) for data comparison. Two independent variables – deer of control group (n_1=10) and deer of trial group (n_2=8) were compared at the essentiality level α=0.05.

RESULTS AND DISCUSSION

When using rapeseed oil cake as a feed ingredient for farmed red-deer, daily feed consumption per animal was 7.750 kg, or by 0.250 kg or 3.2 % less than per one animal in the control group per day (Table 2).

Table 2. **Feed consumption (kg) and costs (LVL) per animal per day**

Parameter	Group 1 - control		Group 2 - trial	
	kg	LVL	kg	LVL
Haylage	7.00	0.126	7.00	0.126
Rolled grain (oats)	1.00	0.120	0.550	0.066
Rapeseed oil cake	-		0.200	0.034
Total:	**8.00**	**0.246**	**7.750**	**0.226**
% versus control	100	100	96.80	91.87

The prices are calculated according to 2009 Prices Roundup provided by LR Central Statistics Bureau.

The costs of the feed consumed by one animal receiving rapeseed oil cake was by 8.13 % lower than the same costs for the control group. The difference in costs was related to the protein content in rolled grain and rapeseed oil cake. Rolled grain (oats) contained on the average 14.64 % protein (DM) and rapeseed oil cake - 29.82 % protein (DM). 1 kg protein in the form of rolled grain costs 0.820 LVL, while in the form of rapeseed oil cake - 0.570 LVL. The difference of protein costs per kg is 0.250 LVL. Thus the protein costs of rapeseed oil cake origin are lower than those of the rolled grain origin, consequently, the use of rapeseed oil cake as a feed ingredient in the ration of farmed red-deer is more cost-effective. In the feed ration for the trial group, the amount of 0.200 kg rapeseed oil cake (0.034 LVL) was used to replace 0.450 kg rolled grain (0.054 LVL) and resulted in savings of 0.020 LVL ration per deer.

Though the rations contained similar amounts of protein and dry matter, but the meat proportion in meat cuts for trial and control groups was different (Tab. 3).

Table 3. **Composition of carcasses (average, at the end of winter)**

Group	Meat, %	Fat, %	Bones, %	Meat/Bones
1 - control	62.80	3.34	33.86	1.85
2 - trial	67.23	5.66	27.11	2.48
± versus control	+4.43	+2.32	-6.75	+0.63

By feeding rapeseed oil cake, it was possible to acquire 4.43 % higher meat proportion from deer carcass in comparison with the control group. A significant increase of meat proportion in meat cuts for the trial group of animals was established by the mathematical processing of the data ($p<0.01$). The proportion of bones in carcass was respectively lower (by 6.75 %). Thus the correlation between meat and bones in the carcass for the trial group was higher (2.48).

It should be pointed out that rapeseed oil cake contained a significant amount (10-15 %) of crude fat. It is possible that the amount of crude fat consumed with rapeseed oil cake increased deposition of fat in carcass, thus, increasing the fat proportion by 2.32 % in comparison with the control group. However, the difference of fat content in both groups of carcasses was not significant ($p>0.01$).

At the end of the trial period, the content of fatty acids was evaluated along the same lines in red-deer meat. The meat of deer fed with rapeseed oil cake contained about 27.76 % of saturated, 19.98 % of monounsaturated and 49.80 % polyunsaturated fatty acids of total lipids (Table 4).

Table 4. **Composition of fatty acids in the meat of deer (% of total lipids)**

Parameters	Group 1 - control	Group 2 - trial	± to control
Saturated fatty acids (SFA)			
Myristic acid $C_{14:0}$	5.32	1.24	-4.08
Palmitic acid $C_{16:0}$	19.43	11.91	-7.52
Margaric acid $C_{17:0}$	0.60	0.41	-0.19
Stearic acid $C_{18:0}$	18.67	14.20	-4.47
Total	44.02	27.76	-16.26
Monounsaturated fatty acids (MUFA)			
Palmitoleic acid $C_{16:1}$	3.80	1.73	-2.07
Oleic acid $C_{18:1}$ cis n-9	6.75	15.38	+8.63
Elaidinic acid $C_{18:1}$ trans n-9	3.34	2.87	-0.47
Total	10.09	19.98	+9.89
Polyunsaturated fatty acids (PUFA)			
Linoleic acid $C_{18:2}$ cis n-6	13.10	27.22	+14.12
Alpha - linolenic acid (ALA) $C_{18:3}$ n-3	2.56	4.83	+2.27
Eicosadienoic acid $C_{20:2}$	0.31	0.51	+0.20
Eicosatrienoic acid $C_{20:3}$ n-6	0.19	1.00	+0.81
Eicosatrienoic acid $C_{20:3}$ n-3	5.65	11.41	+5.76
Eicosapentaenoic acid $C_{20:5}$ n-3(EPA)	1.58	4.83	+3.25
Total	23.39	49.80	+26.41
Quality indices of fatty acids			
Ratio amount saturated and polyunsaturated fatty acids	1.88 : 1	0.56 : 1	-
Total n-3 fatty acids	9.79	21.07	+11.28
Total n-6 fatty acids	13.60	28.73	+15.13
Σn-6: Σn-3	1.38 : 1	1.36 : 1	-

In comparison with the control group, the use of rapeseed oil cake in the ration of farmed red-deer improved the contents of fatty acids in meat by decreasing the amount of saturated fatty acids by 26 % and increasing that of monounsaturated fatty acids by 9.89 % and polyunsaturated fatty acids by 26.41 %.

Under the influence of rapeseed oil cake, the amount of especially favourable n-3 fatty acids was increased by 11.28 % and n-6 fatty acids – by 15.13 % of the total lipid content. These fatty acids are not synthesized by the human system, therefore, their consumption with food is necessary.

n-6 fatty acid (linoleic acid) in a human body is able to bind itself to cholesterol and reduce its` amount [2, 7]. The positive role of n-3 (linolenic acid) and eicosapentaenoic acid in food is connected with their ability to inhibit a variety of risk factors causing cardiovascular and other diseases in humans [5].

Thus, it can be concluded that feeding rapeseed oil cake to red-deer increased the level of fatty acids favourable to human body and unavailable or scarsely available through food products.

The economic cost-effectiveness of adding rapeseed oil cake to red-deer rations was assessed comparatively from the receipts for the delivered meat and costs of the utilised feed over 3 months of the winter period (Table 5).

Table 5. **Economic cost-effectiveness from rapeseed oil cake in red-deer ration (according to trial data)**

Item	Group 1 - control	Group 2 - trial	± to control	% to control
Amount of acquired meat, average, from 1 red-red deer, kg	63.90	67.00	+3.10	+ 4.85
Sales price of venison, wholesales, LVL/kg*	5.00	5.00	-	-
Receipts from delivered meat, LVL	319.50	335.00	**+15.50**	**+ 4.85**
Costs of feed utilised over the trial period on the average, per animal LVL**	22.14	20.34	**-1.80**	**- 8.13**

**average sales price in Latvia over Quarter 1 of 2010.*
***the last cost items in both groups are identical.*

According to the trial data, over the 3 winter months, supplementation of traditional red-deer feed with rapeseed oil cake increased the yield of meat on the average by 4.85 % (67.0 kg) per deer in comparison with the control group - (63.9 kg) per animal. Consequently, the receipts from the meat sales were on the average by 15.50 LVL or 4.85 % per animal higher than for the control group.

The costs of the feed used per one animal in the trial group were on the average 20.34 LVL what is by 8.13 % lower than for the control group. The savings of the feed utilised on the average per animal over the trial period were 1.80 LVL higher in comparison with the control group. It can be concluded that the use of rapeseed oil cake in red-deer feed is economically cost-effective.

CONCLUSIONS

The effectiveness of rapeseed oil cake as a feed ingredient for farmed red-deer (*Cervus elaphus)* winter ration was evaluated in this study by replacing traditional rolled grain with rapeseed oil cake of equal feeding value.

1. In comparison with the control group the amount of 0.2 kg of rapeseed oil cake per deer per day:

- Increased the proportion of meat in carcass by 4.43 %;
- Improved the meat quality by increasing the contents of n-3 fatty acids by 11.28 %, n-6 fatty acids by 15.13 % of total lipids in meat;
- Reduced the amount of the feed consumed on the average by 3.2 % per deer and feed costs by 8.13 %.

2. On the basis of the data obtained in the study it can be concluded that the use of rapeseed oil cake was economically cost effective as the amount of 0.2 kg of rapeseed oil cake per animal per day increased income from the delivered meat by 15.50 LVL or 4.85 % on the average per animal in comparison with the control group.

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ИСПОЛЬЗОВАНИЕ РАПСОВОГО ЖМЫХА В РАЦИОНЕ ОЛЕНЕЙ В ЗИМНЕМ ПЕРИОДЕ И ЭКОНОМИЧЕСКАЯ ЭФФЕКТИВНОСТЬ

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Р е з ю м е

В опытных условиях исследовалось влияние рапсового жмыха на качество мяса оленей и была определена экономическая эффективность использования рапсового жмыха в рационе оленей в зимнем периоде.

В результате опытов было установлено, что используя в рационе оленей рапсовый жмых в количестве 0,2 кг на одного животного в день, увеличился удельный вес мяса в туше на 4,43 %, количество омега – 3 (n-3) жирных кислот - на 11,28 %, омега – 6 (n-6) жирных кислот - на 15,13 % от общих липидов в мясе, снизился расход корма на 3,2 %, а так же затраты на корм – на 8,13 % по сравнению с контрольной группой.

Доход за реализацию мяса в подпытнной группе был на 4,85 % выше чем в контрольной группе. В рационе оленей экономически выгодно использовать рапсовый жмых для замены относительного количества плющенного зерна.

Ключевые слова: олень, рапсовый жмых, качество мяса, экономическая эффективность

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EVALUATION OF FATTY ACID COMPOSITION OF DEER *(Cervus elaphus)* MEAT PRODUCED ON LATVIA FARMS AND WILDLIFE

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ABSTRACT

The diversity of species grown under organic farming system has recently expanded. Beside beef and ostriches, deer are becoming more popular, however investigations in this area are insufficient. Wild and farm deer meat could be of different meat composition. Therefore, the aim of the investigation was to compare the biochemical composition of farm deer meat with wild deer meat and beef produced under organic production system in Latvia.

The investigations were carried out in different regions of Latvia. Welfare requirements were ensured in these farms – free keeping of suckling cows, non restricted feeding and watering of animals, sufficient pastures and walk ensurance and providing feed organic origin. In the studied samples protein, intramuscular fat, fatty acids and cholesterol were determined. The chemical analyses of 30 samples were done. The results of analysis showed that the meat samples from wild deer had higher protein 23.59 %, significantly lower fat content 1.23 % ($p<0.05$), lower sum of saturated fatty acids 33.1 % and higher sum of polyunsaturated fatty acids 38.8 % in comparison with the farm deer meat samples and beef. The contents of saturated fatty acids in the meat samples of farm deer and beef were 40.9 % and 40.1 %, the content of polyunsaturated fatty acids 26.4 % and 15.4 %, respectively. The content of cholesterol was similar in the meat samples from different species – wild deer meat samples had 70.57; farm deer 74.23, but beef samples had 76.31 mg 100 g^{-1}.

***Key words**: game meat, fat composition, farm deer, beef, dietetic product*

INTRODUCTION

Many factors have an impact on ruminant meat quality; they can generally be divided into two categories: somatic factors (e. g. breed, age, sex) and environmental factors (e. g. diet, climate, slaughtering procedures) [4]. Meat characteristics may be changed due to the dietary components particularly fat content and composition [13, 15]. Any improvement of meat production by nutritional means should take into consideration the composition and palatability of the meat and human health. Polyunsaturated fatty acids are not produced in human organism therefore these must be committed with products of animal origin mostly fish, but wild animal meat also is one of good source.

Composition of fatty acids, especially the ratio of polyunsaturated fatty acids to saturated fatty acids (P/S), is more significant for human health than total fat content. MacRae et. al. noted that lower content of saturated fat, especially myristic acid and palmitic acid improved the level of cholesterol in blood and lowered the risk of heart diseases [11]. Wood reported that recommended ratio P/S must be higher than 0.4 and for domestic animals it is too low 0.1 [16]. On the other hand too high polyunsaturated n-6 fatty acids level gives undesirable impact on human health because of produced eikasanoids of inflammation and inflammation are involved in the development of heart diseases and cancer. Diets enriched diet with polyunsaturated n-3 lowered the risk of atherosclerosis, hipertension and artrite in human organism. Therefore the ratio n-6 / n-3 is so significant. The British Department of Health suggest that the mentioned ratio should be lower than 4 [3]. This ratio is lower if animals are grazed because green forage has higher content of linoleic acid [16].

Saturated fatty acids (SFA) are typical for meat. Such ruminants as cattle and sheep have higher content of SFA 44-46 %, wild animals have lower content of saturated fatty acids 41 % [14]. The meat of wild animals is more favourable for human health because it has lower SFA content but higher content of polyunsaturated fatty acids [2, 7]. Meat and fat of wild animals have significantly higher content of long chain fatty acids n-3 than the meat of domestic animals. Cattle breeds under organic farming system also have higher amount of polyunsaturated fatty acids that is comparable with wild animal meat [1, 6]. The meat composition of farm deer has not been completely investigated. The aim of our investigation was to analyse the composition of deer meat and beef and compare the composition of fatty acids.

MATERIAL AND METHODS

Experimental design. The research was conducted at the laboratory of Biochemistry and Microbiology of the Research Institute of Biotechnology and Veterinary Medicine „Sigra".

Meat samples (*m. logissimus lumborum*) were collected in the autumn-winter season. The chemical analyses of 30 samples were done, i.e. wild deer samples (7) after hunting in Vidzeme and Latgale regions in Latvia, farm deer samples (8) from farms „Zemitani" and „Saulstari" and beef samples (15) from organic farming cooperative „Zaube" were collected from 2007 till 2009. In the studied samples protein, intramuscular fat, fatty acids and cholesterol were determined. Sample preparation was made in 48 hours after slaughtering or hunting. Meat samples of 200 g–400 g were homogenized with BŰCHI B-400 [5].

Methods. P r o t e i n was determined as total nitrogen content by Kieldahl method and using coefficient 6.25 for calculation [9].

I n t r a m u s c u l a r f a t content was determined by Sochlet method with hidrolysis procedure (boiling in the hidrocloric acid) using SoxCap 2047 and SOX TEH 2055 equipment (FOSS) [8].

C h o l e s t e r o l content was detected by Blur colorimetric method using a spectrometer.

F a t t y a c i d a n a l y s i s o f m e a t. Homogenized meat samples were prepared for GLC (gas-liquid chromatography) analysis using direct saponification with KOH/methanol followed by a derivatization with (trimethylsilyl) diazomethane by the method of Aldai et al. [1]. An ACME , model 6100, GLC (Young Lin Instrument Co.) equipped with a flame ionisation detector, an automatic sample injector, and an Alltech AT-FAME analytical column (fused silica 30m×0.25mm i.d.) was used. As the carrier gas He was used with a flow rate approximately 2 mL/min. Temperature conditions of the oven, injector and detector was the same as in the method of Aldai et al. [1]. Results were evaluated with an conventional integrator program (Autochro-2000, Young Lin Instrument Co.) The individual FAMEs (fatty acid methyl esters) were identified according to similar peak retention times using standard mixture Supelco 37 Component FAME Mix.

The statistical analysis was performed using SPSS 17. Statistical significance was declared at $P<0.05$.

RESULTS

Protein content of deer and beef meat samples is compared in Table 1.

Table 1. **Protein content of meat samples**

Group	n	Average, %	Standard dev.	Minimum	Maximum
Deer wild	7	23.59	1.37	22.01	23.94
Deer farm	8	21.84	1.14	19.76	23.41
Beef	15	19.61	2.77	15.87	24.81

The results of the investigation show that the average protein content in both wild and farm deer meat samples was higher than the protein content in beef samples. The protein content in farm deer meat samples varied on a wider range 19.76–23.41 %, than the protein content in wild deer meat samples. The results of the statistical analysis showed that the protein content in the ruminants meat did not differ significantly ($F = 1.286$; $p = 0.297 > 0.05$).

Feeding is one of the most significant environmental factors that influences the fat content. The comparison of fat content in deers and beef meat samples is shown in Table 2.

Table 2. **Content of intramuscular fat, %**					
Group	n	Average, %	Standard dev.	Minimum	Maximum
Deer wild*	7	1.23	0.23	0.48	1.0
Deer farm	8	1.44	0.75	0.43	2.7
Beef*	15	1.48	1.89	0.19	7.03

*Fat content of wild deer meat was significantly lower ($p<0.05$).

It can be concluded from the results of the investigation presented in Table 2 that the fat content in beef samples varied from 0.19 till 7.03 %. Fat content in wild deer meat samples was significantly lower than in beef samples produced on organic farms ($F = 3.04$; $p = 0.021 < 0.05$). The composition of dietary fat is more significant for consumers than the total fat content, therefore, composition of fatty acids, sum of saturated, monounsaturated, polyunsaturated fatty acids and cholesterol content of deer and beef meat samples were compared. The comparison data is shown in Table 3.

Table 3. **Comparison of fatty acids composition and cholesterol content of deer meat and beef**				
Fatty acids, % of total		Wild deer	Farms deer	Beef
Lauric acid	C 12:0	0.51	0.29	0.24
Myristic acid	C 14:0	3.85	3.41	3.62
Pentadecanoic acid	C 15:0	0.63	0.76	0.41
Palmitic acid	C 16:0	14.50	16.72	21.43
Margaric acid	C 17:0	0.37	0.58	0.84
Stearic acid	C 18:0	12.87	18.52	13.71
Arahidic acid	C 20:0	-	-	0.10
Lignoceric acid	C 24:0	0.91	0.91	-
Myristoleic acid	C 14 :1	0.75	1.07	1.64
Palmitoleic acid	C 16 :1	2.88	4.08	3.17
Oleic acid	C 18 :1	15.10	16.95	29.28
Eicamonoenoic acid	C 20 :1	-	-	0.04
Nervonic acid	C 24 :1	0.84	0.53	
Linoleic acid	C 18 :2 n-6	21.51	14.56	12.05
α-Linolenic acid	C 18 :3 n-3	5.68	3.40	2.65
γ-Linolenic	C 18 :3 n-6	0.33	-	0.16
Eicosatrienoic acid	C 20 :3 n-6	0.80	0.64	0.50
Arachidonic acid	C 20 :4 n-6	6.74	6.60	-
Eicosapentaneoic acid	C 20 :5 n-3	2.83	1.21	-
Docosahexaenoic acid	C 22 :6 n-3	0.94	-	-
Sum of n-3		9.45	4.61	2.65
Sum of n-6		29.38	21.8	12.71
n-6/n-3*		3.1	4.7	4.8
P/S ratio*		1.17	0.64	0.38
Cholesterol, mg 10g[1]		70.57	74.23	76.31

*$p<0.005$

Table 3 shows that the average content of myristic and lauric acids that most influence the cholesterol level in human blood did not differ significantly. Wild deer meat samples had lower content of palmitic acid - 14.5 %, farm deer meat samples had 16.72 %, but beef samples had 21.43 % palmitic acid. The results of statistical analysis confirmed that the content of saturated fatty acids did not differ significantly ($F=1.35$; $p=0.283>0.05$). Wild deer meat samples had lower contents of monounsaturated fatty acids than farm deer and beef meat samples.

The content of cholesterol was similar in the meat samples of different species – wild deer meat samples had 70.57; farm deer 74.23, but beef samples had 76.31mg 100 g^{-1}.

British Department of Health suggest the ratio of n-6 / n-3 lower than 4. The results of the study showed that the meat samples of wild deer had the ratio 3.1, but the meat samples of farm deer and beef showed the ratio of 4.7 and 4.8, respectively. Medeiros et.al. reported that the ratio n-6 / n-3 of deer meat is 3.45 [12]. As mentioned above, the recommended ratio of polyunsaturated fatty acids to saturated ones must be higher than 0.4. The results of the investigation showed that the closest to these requirements was the meat of wild deer P/S=1.17. Unfortunately meat of farm deer did not have so good a ratio, it was 0.64. Regarding beef samples, the results of our study are in agreement with the literature. Medeiros et. al. reported that the ratio P/S of beef samples is 0.38 [12].

The sum of saturated fatty acids, the same as the sum of monounsaturated and polyunsaturated fatty acids in deer and beef meat samples were compared. This comparison is shown in Figure 1.

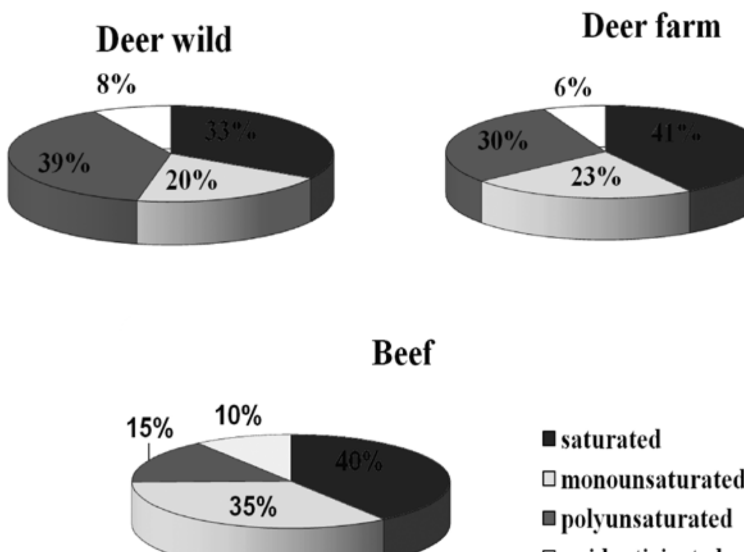

Fig1. **Composition of groups of fatty acid in wild deer, farm deer and beef meat samples (%)**

From the dietetic point of view the «ideal» composition of fatty acids is if the amount of saturated, monounsaturated, polyunsaturated fatty acids is equal to 33.3 %-33.3 %-33.3 % [12]. Meat samples of wild deer, where saturated fatty acids accounted for 33.1 %, monounsaturated to 19.9 % and polyunsaturated for 38.8 % were the closest to this proportion. Investigation results in Figure 1 showed that the content of saturated fatty acids in meat samples of farm deer and beef were 40.9 % and 40.1 %, respectively. Unfortunately, it must be concluded that the biochemical composition of farm deer meat was not so special as the meat of wild deer, what it might be a result of feeding. Farms deer are supplied with complementary feed in winter season, but wild deer are not.

CONCLUSIONS

1. Fat content in wild deer meat samples was significantly lower than in beef meat samples produced on organic farms ($p<0.05$).

2. The content of saturated fatty acids was lower in the meat samples of wild deer 33.1 %, while in the meat samples of farm deer and beef it was higher 40.9 % and 40.1 % respectively.

3. The meat samples of wild deer had ratio n-6 / n-3 =3.1, but in the meat samples of farm deer and beef the mentioned ratio was 4.7 and 4.8 respectively.

4. The content of cholesterol was similar in the meat samples from different species – wild deer meat samples had 70.57; farm deer 74.23, but beef samples had 76.31mg 100 g-1.

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ОЦЕНКА ЖИРНОКИСЛОГО СОСТАВА МЯСА ДИКОГО ОЛЕНЯ И КРУПНОГО РОГАТОГО СКОТА ЛАТВИИ

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Р е з ю м е

Разнообразие животных, выращиваемых в экологических хозяйствах в последние годы увеличиваеться. Наряду с крупным рогатым скотом и страусами все больше популярным старовится выращивание оленей в неволе, но научных исследований в этом направлении мало. Можно полагать, что биохимический состав мяся в неволе выращиваемых оленей отличается от состава мяса диких оленей и крупного рогатого скота. Поэтому цель нашего исследования было сравнить биохимический состав мяса диких оленей, в неволе выращиваемых оленей и крупного рогатого скота, выращенного экологическом хозяйстве Латвии.

Исследования проводились в Научном институте биотехнологии и ветеринарной медицины „Sigra”. Образцы комплектованны на охоте в двух районах Латвии, на оленеводческих фермах и экологическом хозяйстве Латвии. Было проанализировано 30 образцов, определено количество белка, жира, состав жирных кислот и содержание холестерина. Результаты показали, что образцы мяса дикого оленя содержат больше белка 23,59 %, значительно меньше жира 1,23 % (p<0,05), меньше насыщенных жирных кислот 33,1 % и больше полиненасыщенных жирных кислот 38.8 % по сравнению с в неволе выращенными оленями и крупным рогатым скотом, где содержание насыщенных жирных кислот составило 40,9 % и 40,1 %, а содержание полиненасыщенных жирных кислот - 26,4 % and 15,4% соответственно. Содержание холестерира отличалось незначительно.

Ключевые слова: жирные кислоты мяса, олень, крупный рогатый скот

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THE INFLUENCE OF PHYTOGENIC ADDITIVES ON PIG PRODUCTIVITY, CARCASES AND MEAT QUALITY

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ABSTRACT

The study was conducted to determine the efficiency of a new phytogenic additive on the growth process, carcases and meat quality. The phytogenic additive contained ground thyme (Thymus vulgaris L.) leafs, nettle (Urtica dioica L.) leafs, oak (Quercus robur L.) cortex, balm (Melissa officinalis L.) leafs. The feeding trial was carried out with Landrase pigs (n=30). The pigs of the control group were fed without the phytogenic additive. The feed of the trial group contained 1 % phytogenic additive per tonne feed used for pigs from 42 to 78 days of age, 0.5 % per tonne feed from 78 to 170 days of age. The study indicated that the average daily gain for the trial group was 0.777±0.009 kg, or by 12.0 % higher than that in the control group of pigs (p<0.05). Feed conversion in the trial group was 8.1 % lower than in the control group. Phytogenic additives improved the carcases and meat quality. Lean meat content in the trial group was 53.41 % or by 2.7 % higher than in the control group. The biochemical analysis of meat samples (m. longissimus lumborum) showed that the intramuscular fat content in the control group was 2.38 %, and in the trial group it was by 0.31 % lower. The cholesterol content was 9.2 % lower in the trial group. The indices of tryptophan and methionine ratio were by 20 % higher in the trial group (p<0.05). Water holding capacity in the muscle samples from the trial group was 2.6 % higher than in the control group.

***Key words**: pigs, phytogenic additive, meat quality*

INTRODUCTION

The productivity level of pigs is largely determined by the functional activity of digestive system and the microbiological background of the gastro-intestinal tract. The balance and composition of bacteria found in digestive tract have a decisive role in ensuring an adequate functioning of the latter and formation of intestinal immunity system [3, 4, 9].

The scientific data published indicate that pigs receiving the additive of medicative herbs on top of their diet (30 grams per 1 kg of feed) containing nettle *(Urtica dioica)*, rosmary *(Rosmarinus oficinalis)*, thyme *(Thymus vulgaris*, *Thymus serpyllum)*, juniper *(Juniperus communis)* berries achieve higher live weight gains than the control group [5]. Pigs, having received the additive of thyme in combination with sage, coriander and common yarrow achieved 7 % higher weight gain and 3 % higher feed conversion in comparison with the control group which was fed only complete ration [17].

Similar data were also found in the studies of other authors. In the studies concerning feeder pigs, it was demonstrated that organically active substances of plant origin in combination with organic acid additive improved live weight gain of pigs by 10 % and feed conversion by - 8 % [12, 13].

The studies *in vitro* indicate that phytogenic additives containing thyme, consequently its active components, volatile oils and thymol provide also anti-fungal activity. It is effective for prevention of *Cryptococcus neoformans, Aspergillus, Saprolegnia and Zygorhunchus species* [10, 11, 14, 15]. Both volatile oils and thymol possess antibacterial properties against *Salmonella typhimurium*, *Staphylococcus aureus, Escherichia coli*, and many other bacteria. Also the data found in scientific sources indicate that adding of phytogenic additives to pig feed, reduced the back fat layer by 8.4 % and increased the cross cut area of *m. longissimus lumborum* by 15.1 % and the amount of muscle tissue in carcass by 6.7 % [2, 7].

The study was conducted to determine the efficiency of a new phytogenic additive on the growth process, carcases and meat quality.

MATERIALS AND METHODS

New composition phytogenic additive was developed containing ingredients of locally grown medicative herbs. The following ingredients were included: leaves of thyme *(Thymus vulgaris L.)*, leaves of nettle *(Urtica dioica L.)*, oak *(Quercus robur L.)* bark, leaves of balm *(Melissa officinalis L.)*. The parts of dried herbs were milled and mixed in a powder-form phytogenic additive**.**

Table 1. **Experimental design**

Group	Number of animals within a group	Feeding pattern at different age periods	
		42-78 days	78-170 days
Control group	15	Complete ration without additives (CR)	CR
Trial Group	15	CR + 1 % phytoadditiv	CR + 0.5 % phytoadditive

For impact evaluation of the phytogenic additives developed pursuant to the set target, the trial group and control group of feeder pigs were formed at the pig barn of the agricultural holding, Kraslava district.

Every group included 15 Landrase pigs from weaning (42 days) until finishing, i.e., 170 days old. The study was carried out in accordance with the design indicated in Table 1.

The productivity of the feeder pigs was evaluated in relation with the technological process according to the live weight increase and live weight changes by weighing every pig individually at the start of the trial, at weaning age (42 days) as well as at the age of 78, 114 and 170 days.

The amount of the feed consumed was recorded by groups on average over the trial period.

Making use of the weighing results obtained over the trail period, the following indicators were calculated and compared: average live weight increase in 24 hours per pig, feed consumption and conversion on average per pig, live weight and carcass weight at delivery.

For experimental pigs the post-slaughter carcass weight and the percentage of muscle tissue in the carcass was determined according to the SEUROP classification and additional measurements with introscope Optical Probe. After chilling for 24 hours, the cross-cut was made in *m. longissimus lumborum* at the left side of the carcass after the last rib, its area measured and meat samples drawn for biochemical tests.

The quality of the muscle tissue in *m. longissimus lumborum* was evaluated by: chemical composition (dry matter, crude protein, amino acids – oxyproline, tryptophane and proportions thereof, crude fat, phosphorous, calcium and cholesterol), pH level and water holding ratio.

The biochemical and microbiological tests were performed in the biochemistry and microbiology research laboratory of the Research Institute of Biotechnology and Veterinary Medicine *Sigra.* All the tests were performed in accordance with duly accredited ISO standards. The quality of the muscle tissue in *m. longissimus lumborum* was determine (dry matter by ISO 6496-1999, crude protein, crude fat, phosphorous, calcium LVS EN ISO 5983-1-2005, amino acids – oxyproline, tryptophane by photometric method, cholesterol by Blur method, pH level with OAKTON-pH6 equipment and water holding capacity was determine by filter paper method).

Carcass quality was assessed in the slaughter house of the agricultural holding *Pakalni*.

The statistical processing of the obtained data was performed with the Microsoft Excel software package. The data were subjected to the descriptive analyses. The t test was used to ascertain the existence of significant differences between the groups. Significance was determine at $P<0.05$. The data was presented as means and standard errors.

RESULTS AND DISCUSSION

In our study, the use of the phytogenic additive increased the daily weight gain (Table 2) by 12 % (p<0.05) in comparison with the control group.

A distinctive impact of the phytogenic additive on the live weight gain of feeder pigs at different age periods is associated with the direct influence of it on the development of morpho-functional activity of the gastro-intestinal tract and the ability of the gastro-intestinal tract to digest the feed ingredients.

For young animals, the functional activity of the digestive system has not yet been fully developed. Phytogenic additives stimulated its development and functionality, thus, increasing the digestibility of the nutrients in feed and resulting in live weight.

Evaluating live weight increase by age periods showed that the highest impact was observed for pigs from 42 to 78 days of age, it was by 34.1 % (p<0.05) higher than for the control group. With animals turning older, the positive impact of the phytogenic additive on the live weight gain was gradually reduced. That can be explained by the beneficial impact of biologically active substances in different combinations of additives fed to pigs on the development and functions of their digestive system.

Table 2. **Impact of phytogenic additives on daily gain of pigs, kg**

Item	Control group	Trial group
	$\bar{x} \pm s_{\bar{x}}$	$\bar{x} \pm s_{\bar{x}}$
	n=15	n=15
Feed additives	Complete ration (basic feed) (CR)	CR + phytoadditive
from 42 to 78 days of age, kg	0.490±0.018	0.657±0.024*
Coefficient of variation, (S%)	14.60	14.26
from 78 to 114 days of age, kg	0.673±0.021	0.751±0.020*
Coefficient of variation, (S%)	13.17	11.10
from114 to 170 days of age, kg	0.869±0.021	0.904±0.017
Coefficient of variation, (S%)	9.21	7.09
from 42 to 170 days of age, kg	0.694±0.009	0.777±0.009*
Coefficient of variation, (S%)	4.77	4.61

* *p<0.05*

Feed consumption per 1 kg live weight gain or feed conversion ratio for animals having received phytogenic additive was by 8.1% lower than for the control group.

The applied additive facilitated the digestive processes. This was demonstrated by the quantitative changes of microflora in the rectum. The applied phytogenic additives facilitated the increase of lactic bacteria favourable for the digestive process. By comparative testing of the impact on the rectum micro-flora, the phytogenic additive applied increased the number of lactic bacteria by - 47.8 x 10^5 $KVVg^{-1}$ in comparison with the control group of 170 day old pigs.

Due to the growing numbers of lactic bacteria, there was a tendency towards lower amount of pathogenic and relatively pathogenic micro-flora like mesophile forms of *Escherichia coli*, thermophillic forms of*, Escherichia coli*, *Staphyloccocus spp.,* moulds and yeasts.

In the rectum contents of 170 days old pigs the phytogenic additive decreased the number of bacteria of mesophile and thermophillic forms of *Escherichia coli* accordingly by 6.2x10^5 $KVVg^{-1}$ and 0.8 x 10^5 $KVVg^{-1}$, in comparison with the control group.

It can be concluded that the application of the newly developed phytogenic additive in feeding of feeder pigs facilitated the development of favourable microflora (lactic bacteria) as well as the functions of the digestive tract.

Thus the phytogenic additive supported the digestibility and feed conversion in the system of animals, ensuring a relatively higher live weight gain and live weight. These data are conformable to those obtained by other scientists [2, 7].

For description of the carcass quality, material quality criteria were analysed: carcass weight, composition of the muscle tissue or the lean meat ratio (SEUROP class), the cross cut area of *m longissimus lumborum* as well as the biochemical composition of meat.

The slaughter weight of delivered pigs at the age of 170 days, after feeding them the ration with the phytogenic additive - 73.48 kg additive supplemented) increased the average carcass weight by - 4.4 % in comparison with the control group ($p<0.05$).

The lean meat content in the carcass of pigs having received the phytogenic additive was - 2.7 % higher. Significant differences in the contents of the muscle tissue of the carcass were established between the groups ($p<0.05$).

Comparing the impact of the additive applied on the carcass quality class, it was established that higher class carcasses according to SEUROP classification were obtained from the pigs that received the feed ration containing the phytogenic additive. According to the trial data carcasses conformed to the class E accordingly 33 % and 54 % of carcasses – to class U and 13 % to class R of carcasses , compared with the control group where class E was 20 %, class U - 33 %, class R - 27 %.

The cross-section area of the *m. longissimus lumborum* is also one of the most important indicators of the carcass quality. A high quality carcass is characterized by maximum large cross-section area of *m. longissimus lumborum*.

Feeding pigs with the ration containing the newly developed phytoadditive showed, the best results regarding the cross-section areas of the *m. longissimus lumborum*. Which was 51.95 cm^2 for phytogenic additive group and 48.41 cm^2 for the control group

The biochemical composition and the nutritive value were evaluated from the following indicators: dry matter, crude protein, crude fat – intramuscular fat, cholesterol, pH and the water holding capacity (Table 3).

Table 3. **Impact of phytogenic additives on *m. longissimus lumborum* chemical composition**						
Group	Traits	Dry mater, %	Crude protein, %	Crude fat, %	Phosphorus, %	Cholesterol, mg kg $^{-1}$
Control group	$\overline{x} \pm s_{\overline{x}}$	24.52±0.31	20.90±0.42	2.38±0.18	0.19±0.01	558.47±20.96
	min	23.15	18.26	1.60	0.16	423.90
	max	26.28	22.84	3.37	0.22	673.9
Trial group	$\overline{x} \pm s_{\overline{x}}$	25.30±0.47	22.27±0.27*	2.07±0.16	0.19±0.01	512.16±27.49
	min	23.44	20.64	1.41	0.16	358.70
	max	27.14	23.56	3.01	0.22	630.40
* P<0.05						

Judging by the contents of dry matter, crude fat and phosphorous, applied additive did not largely influence the biochemical composition of the pig muscle tissue. However there were significant differences between the crude protein content of the trial group compared with the control group ($p<0.05$).

The protein composition and nutritive value of the muscle tissue is characterized by quantitative ratio of two amino acids – tryptophan and oxyproline. In this correlation tryptophan characterizes the protein composition of complete amino acids while oxyproline describes the contents of the incomplete proteins, mainly connective tissue. The higher the content of tryptophan in the muscle tissue, the higher value is attributed to the protein content. In muscle protein on the average, the trypthophane content was 3.02 in the control group and 3.05 % - in the trial group, or by 0.99 % higher (Table 4.).

Table 4. **Impact of phytogenic additives on tryptophane and oxyproline content**				
Groups	Traits	Tryptophane, g/kg $^{-1}$	Oxyproline, g/kg $^{-1}$	Tryptophane oxyproline ratio
Control group	$\overline{x} \pm s_{\overline{x}}$	3.02±0.09	0.88±0.04	3.53±0.23
	min	2.62	0.70	2.57
	max	3.50	1.08	4.65
Trial group	$\overline{x} \pm s_{\overline{x}}$	3.05±0.05	0.73±0.04*	4.31±0.21
	min	2.80	0.56	3.02
	max	3.25	1.06	5.13
* P<0.05				

The highest tryptophane - oxyproline ratio was obtained by feeding the phytogenic additive. It was 4.31, or by 22.09 % higher than for the control group, ($p>0.05$). Consequently the phytogenic additive as a pig feed supplement ensures a higher protein quality in muscle tissue, i.e., a higher nutritive value.

The intramuscular (crude) fat content in the muscle tissue was within the limits of 2.38 in the control group and it was 2.07 % in the trial group, the differences were not significant (p>0.05).

It should be pointed out that the intramuscular fat content influences meat flavours quality. The minimum intramuscular fat content indicated by different authors is 2.5 - 3.0 %. Danish scientists point out that 2 % intramuscular fat content is optimum for achieving well-tasting meat [1, 6].

Supplementing of the feeder pig feed ration with the phytogenic additive reduced the cholesterol level in muscular tissue of 170 day old pigs by 46.31 mg kg^{-1}. According to King (2003), organically active substances, volatile oils and anti-oxidants contained in the phytoadditive had reduced the cholesterol synthesis in the system of animals thus decreased the deposition of cholesterol in the muscle tissue.

For assessment of the impact of the additives applied on the quality of muscle tissue pH level in *m. longissimus lumborum* was measured. It was established that supplementation of the diet with the phytogenic additive resulted in pH - 5.84 and in the control group pH was 5.69.

Scientists emphasize that for acceptable quality meat pH stays with in the limits of pH 5.6-6.29 [16]. In our study the pH in *m. longissimus lumborum* was within the indicated limits and the meat was of high quality.

Meat quality is characterized by the water holding capacity in the muscle tissue. When feeding the diet with the phytogenic additive, water holding capacity of *m. longissimus lumborum* was 21.39. The feed additive applied increase water holding capacity in the muscle tissue. In case of the phytogenic additive it was by 2.6 % higher in comparison with the control group (p<0.05).

It can be concluded that application of the newly developed phytoadditive promoted acquisition of high quality pig meat.

CONCLUSIONS

1. A new phytogenic additive from local herbs has been developed containing thyme *(Thymus vulgaris L.)* leaves, nettle *(Urtica dioica L.)* leaves, oak *(Quercus robur L.)* bark and balm *(Melissa officinalis L.)* leaves. Using the phytogenic additive in the diets of pigs increased their productivity and improved:

- daily gain - by 12.0% (p<0.05),
- feed conversion ratio - by 8.1% (p<0.05).

2. The additive increased the level of beneficial lactic bacteria by 47.8x105 KVVg-1 and decreased the numbers of unfavourable moulds and yeasts in the contents of rectum: mesophile and termophile forms of Escherichia coli, Staphylococcus sp. KVVg-1, consequently reducing the environment pollution as well.

3. The applied feed phytogenic additive improved the quality of the final product:

- slaughter weight increased by 4.4 % ($p<0.05$),
- the muscle tissue content in carcass was increased by 2.7 % and the carcass quality class was improved according to SEUROP scale,
- cholesterol level in the muscle tissue decreased by 9.2 % ($p<0.05$).

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ВЛИЯНИЕ ФИТОГЕННОЙ ДОБАВКИ НА ПРОДУКТВНОСТЬ И КАЧЕСТВО МЯСА СВИНЕЙ

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Р е з ю м е

Разработан и проверен новый состав фитогенной добавки на прирост живой массы и качество мяса свиней.

Фитогенная добавка содержала *Thymus vulgaris L.*, *Urtica dioica L.*, *Melissa officinalis L.* листья и *Quercus robur L.* кору.

Иследование проводилось на свиней породы Ландраса (n=30). Контрольную группу свиней кормили с стандартным полноценным кормом, а в корме свиней опытной группы от 42-78-дневного возраста добавляли 1,0 % фитогенной добавки, а от 78–170 дневного возраста 0,5 % добавки.

Прирост живой массы свиней от 42–114 дневного возраста достигл в среднем 0,777 кг в день и превысил прирост живой массы свиней контрольной группы на 12,0 %.

Конверсия кормов свиней в опытной группы была на 8,1 % ниже чем в контрольной группе. Применение фитогенной добавки в кормлении свиней увеличило качество туш и мяса. Содержание постного мяса туш свиней в опытной группе было на 2,7 % больше по сравнению с контрольной группой.

Биохимические анализы мускульной ткани (*m. longissimus lumborum*) показали, что применение в кормлении свиней разработанного состава фитогенной добавки снизило количество внутримышечного жира на 0,3 % и холестерина на 9,2 % по сравнению с контрольной группой.

Ключевые слова: свиньи, продуктивность, качество мяса

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EVALUATION OF DIFFERENT FEED MIXTURES FOR FATTENING PIGS

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ABSTRACT

Five granulated full value feed mixtures were used for pig feeding: grower, finisher, feed for fattening pigs with the liveweight 25-55 kg, feed for fattening pigs with the liveweight 55-100 kg and feed for fattening pigs with the liveweight 30-105 kg. The study was conducted in two experiments. In the first experiment - more efficient and cost-effective was the feed mixture for fattening pigs with the liveweight 25-55 kg in the first fattening period. Daily live weight gains of pigs were 783 g, 18 % higher than in the control group. In the second fattening period, more efficient and cost-effective was the finisher feed. Daily live weight gains of pigs were 797 g or 13 % higher. In the second experiment - more efficient and cost-effective was the feed mixture for fattening pigs with the liveweight 30-105 kg in both fattening periods. Daily live weight gains of pigs were, respectively, 799 g, 859 g or 14 % and 9 % higher than those in the control group. The comparison of the feed costs and expenses on the live weight gains of pigs in both experiments showed, that in the first fattening period feed mixture for fattening pigs with the liveweight 25-55 kg was economically advantageous. In the second fattening period finisher feed was economically profitable.

***Key words:** fattening pigs, feed, mixtures, liveweight, feed costs*

INTRODUCTION

The largest cost factor in producing fattening pigs is the cost of feed. Fattening section is the area of the highest feed input in the unit. The actual management of feed presentation is important in both optimising the intake and minimising the feed costs. In the original process feed is composed of different components. The most important ones are: barley, wheat, peas, wheat middlings, sunflower meal, maize, maize gluten feed, premix (vitamins and minerals) [1].

In order to run a beneficial business many farmers want to use their own grain [2]. Therefore, they need a high quality mineral feed which enables them to have the best results and cost efficiency.

The goals of this study were to evaluate the effect of different feed mixtures for fattening pigs.

MATERIALS AND METHODS

The study was carried out on a pig farm which was put into operation in 1973, as the Soviet farm "Rudbārži" intensive pig fattening house. Nowadays it is Company Ltd. "Korkalns". There are 5,000 pigs under 30 kg live weight and 4000 pigs weighing over 30 kg and 1,300 sows. The company generally operates 269.2 hectares of agricultural land, of which 219.1 ha are owned, while 50.1 ha are leased. The production on the pig farm is divided into two major directions:

- breeding sows and piglet production,
- pig meat production.

The farm is equipped with automatic climate control which provide the necessary air exchange according to pig weight and physiological needs. Room ventilation fans with low noise levels are installed. Each hull is fitted in the space of three fans with a capacity of 12.4 m^3 h. The fan is regulated by a temperature sensor signals. Mainly works the average fan, the other two are used when the room temperature exceeds 17 ^{0}C.

Each fattening pig house accommodates up to 990 pigs. The hull is divided into three rooms, which contain 32 pens of 2.5 x 4.5 meters in size. One pen holds from 10 to 11 pigs. The pens are assembled from plastic boards and stainless steel pipes. One third of pen area is a monolithic concrete floor and two thirds are concrete floor grids. Under every of the four pens there is liquid manure collection bath, which is emptied about once a week.

Full value granulated food, prepared by the Company "Tukums Straume" is used for pig feeding. The feed is supplied by a special tanker and pumped from the feed storage towers. Each farm has two feed storage towers. The capacity of one tower is 17 m^3, and at the same time it can store about 13 tons of forage. The farm is equipped with an automatic power line. From the feed storage towers the feed through galvanized metal pipe is supplied to the closed automatic feeders. Pig fattening farm needs of water from the water hole "Kalnluikas". Water from the borehole is fed to the water tower. Each hull has a separate water supply line for watering individual nipples which are installed in boxes. The highest water consumption is for animal watering. Pigs with drinking water are provided continuously. Washing is carried out after each feeding cycle when the pens are empty.

Choice of animals and housing conditions. The experiments were carried out in "Korkalnam" owned farm "Aigšluikas". Four groups of pigs were used in the study. Every group had 24 animals which were similar in the live weight, age, gender and origin. Every animal was marked with ear tags. The housing conditions for pigs were the same. In the barn there was automatic microclimate control. The air temperature was maintained at 17 °C, humidity 65 %. The pigs received the feed from automatic feeders that were disconnected from the overall food supply system. The pigs received the feed *ad libitum.* Feed intake was recorded for the whole group from the beginning to the end of the experiment. Feed intake was recorded every day.

Data, records and biometric processing. The effect of five feed mixtures for fattening pigs has been evaluated.

The experimental pigs were fed of full value feed pellets:

Growers (2-4 month old piglets) - wheat 34.6 %, barley 30 %, wheat bran 9 %, soybean meal 10 %, yeast 6.5 %, corn-processing product 5 %, fish meal 1.5 %, Premix premivit 0.5 % monocalcium phosphate 0.5 %, lime flour 2 %, salt 0.2 %, zinc oxide 0.15 %, acid Gustor XXI B-29 0.05 %.

Finisher (pigs) - wheat 33.5 %, barley 32 %, triticale 10 %, wheat bran 7 %, soybean meal 5 %, sunflower meal 9 %, fish meal 1 %, Premix premivit 0.5 %, monocalcium phosphate 0.2 %, lime flour 1.3 %, salt 0.35 %, lysine 0.15 %.

Pigs with the liveweight of 25-55 kg - wheat 35 %, barley 29.97 %, triticale 10 %, soybean meal 14.9 %, sunflower meal 2.3 %, yeast 3 %, vegetable oil 1.5 %, Premix premivit 0.55 %, monocalcium phosphate 0.9 %, lime flour 1.3 %, salt 0.3 %,lysine 0.13 %, methionine 0.06 %, threonine 0.09 %.

Pigs with the liveweight of 55-100 kg - wheat 35 %, barley 26.21 %, triticale 15 %, wheat bran 8 %, soybean meal 2.8 %, sunflower meal 6 %, yeast 3 %, Premix premivit 0.5 % monocalcium phosphate 0.7 %, lime flour 1.2 %, salt 0.3 %, lysine 0.14 %, threonine 0.05 %.

Pigs with the liveweight of 30-105 kg - wheat 50 %, barley 32.33 %, soybean meal 14:17 %, vegetable oil 0.5 %, Premix Hjemmix 3 %.

Every feed mixture was tested for moisture, crude protein, fiber and fat at the laboratory "Tukums Straume". The test results showed that the feed mixtures were produced according to the given recipe.

Before, during and at the end of the experiments, all the animals were individually weighed.

The study was conducted in two experiments. At the start of the first experiment the pigs were 88 days old with liveweight 38.2-28.6 kg. The pigs were weighed after 21 feeding day, when they reached approximately 55 kg live weight (day 109). This stage is called the first fattening period. Before the sale, the pigs were weighed again. The period from 109 days till the sale was the second fattening period (Table 1).

At the start of the second experiment the pigs were 77 days old with live weight 28.3-28.5 kg. The pigs were weighed after 33 days, when they reached 55 kg (day 110). The first fattening period was from 77-110 days and from 110 day till the sale was the second fattening period (Table 1). Pigs received feeds according experimental design.

During the test, the results were subjected to biometric processing and analysis. Statistical analysis was performed with MS EXCEL mathematical program, calculating the arithmetic mean, standard error, standard device, variance. The results were compared using t-test.

Table 1. **Experimental design**

	Feed mixture type	
Group	Experiment 1	Experiment 2
Control	Grower in first fattening period Finisher in second fattening period	Grower in first fattening period Finisher in second fattening period
Experimental	Feed for fattening pigs with liveweight 25-55 kg in first fattening period Feed for fattening pigs with liveweight 55-100 kg in second fattening period	Feed for fattening pigs with liveweight 30-105 kg in both fattening periods

RESULTS AND DISCUSSION

The pigs were given different types of feed mixtures which differed in composition but the main quality indicators were similar (Table 2).

Table 2. **Nutritive value of feeds for experimental pigs in fattening period 1**

Nutrients	Requirements	Control group	Group 1	Group 2
Metabolisable energy, $MJkg^{-1}$	13.6	13.7	13.5	13.5
Crude protein, $g\ kg^{-1}$	163	165	164	163
Lysine, $g\ kg^{-1}$	7.2	8.0	8.1	8.1
Methionine +cysteine, $g\ kg^{-1}$	4.3	5.1	5.2	5.3
Crude fibre, $g\ kg^{-1}$	60	61	59	58
Ca, $g\ kg^{-1}$	8.4	8.3	8.1	8.2
P, $g\ kg^{-1}$	7.0	7.0	6.9	6.8

The protein for pigs during this period was from 163 till 165 $g\ kg^{-1}$. After comparison of the protein content in feeds, it can be concluded that it was similar in all groups and met the requirements for pigs.

For pig feed high-grade protein sources are used, which have well balanced amino acids with high biological value. If amino acids are not balanced, the surplus is excreted in faeces. Lysine is the main limiting amino acid [3, 4]. Lysine and methionine + cystine for all groups of pigs were sufficient and even exceeded the needs. Lysine, methionine + cystine and tryptophan ratio in the pig feed can be expressed 5: 3: 1 [5, 6, 8].

Lysine and methionine + cystine ratio in the control group was 5 : 3.1, in the first experimental groups it was 5 : 3.0, but in the second experimental group it was 5 : 2.7 [4, 7, 8, 10].

Mineral supply can not implement themselves a basic feedstuffs. The minerals found in plant feed products are insignificant. Mineralpremixes which are tested in practice are used for pigs.

In fattening period 2 the pig feed was also composed of different types of feed mixtures which differed in composition. The main indicators were also similar and satisfied the demands of pigs needs (Table 3).

Table 3. **Feed nutrients for experimental pigs fattening period 2**

Nutrients	Requirements	Control group	Group 1	Group 2
Metabolisable energy, MJkg $^{-1}$	14.2	14.3	14.5	14.4
Crude protein, g kg $^{-1}$	151	153	154	153
Lysine, g kg $^{-1}$	6.3	8.9	8.7	8.8
Methionine + cysteine, g kg $^{-1}$	3.8	6.2	6.3	6.0
Crude fibre, g kg $^{-1}$	70	60	59	62
Ca, g kg $^{-1}$	8.1	7.3	7.2	7.4
P, g kg $^{-1}$	6.7	6.4	6.0	6.1

The pigs were completely supplied with amino acid, lysine and methionine + cystine contents and their amount even exceeded the needs. Lysine and methionine + cystine ratio in the control group was 5 : 3.5, in the experimental group 1.5 : 3.0, and in both experimental group 2.5 : 2.8. [9, 10, 11].

The analysis of the feed showed that in the fattening periods, pigs were satisfied with nutrients.

During the experiments, it was important to determine which feed gives the greatest weight gain. We compared weight gains in the first and second periods separately. Afterwards we compared weight gains throughout the whole experimental period (Table 4).

At the start of the experiment, the average live weight of pigs was not significantly different. After 21 days (end of the first period) live weight growth rates showed a significant difference. The daily weight gain was about 18 % higher than in the control group. At the end of the second fattening period (after 77 days), live weight indicators differed significantly. In the control group, the daily weight gain was 13.3 % higher than that in the experimental group. There was a significant difference in comparison with the live weight increase during the whole fattening period. The largest weight gain was in the control group. The daily weight gain of the control group was 6.2 % higher than that in the experimental group.

Table 4. **Live weight changes during experiment 1**		
Item	Groups	
	Control	Experimental
The average live weight at the beginning of the trial, kg	38.2 ± 0.15	38.6 ±0.16
The average live weight in first feeding period, kg	52.1±0.15	55.0±0.29*
Weight gain in the first feeding period, kg	13.9±0.08	16.4±0.30*
Daily weight gain in the first fattening period, g	664±3.9	783±14.3*
%	100	118
The average live weight at the end of the experiment, kg	99.6±0.14*	96.1±0.28
Weight gain in the second fattening period, kg	47.5±0.04*	41.1±0.06
Daily weight gain in the second fattening period, g	847±0.8*	734±1.1
%	100	86.7
Weight gain during the whole experimental period, kg	61.4±0.09*	57.6±0.29
Daily weight gain during the whole experimental period, g	797±1.2*	748±3.7
%	100	93.8
** P <0.01.*		

From the results of the study it can be concluded that in the first fattening period the feed for fattening pigs with the liveweight 25-55 kg was more effective. In the second period finisher feed in the control group was more effective.

In the second experiment the first period was lasted 33 days. Then the pigs reached 55 kg liveweight, and the feed was changed for the control group, but the experimental group of pigs ate the same feed (feed for fattening pigs with the liveweight 30-105 kg) in both fattening periods. The second fattening period lasted 56 days. The total experiment lasted 89 days (Table 5).

Table 5. **Live weight changes during experiment 2**		
Item	Groups	
	Control	Experimental
The average live weight at the beginning of the trial, kg	28.3 ± 0.13	28.6 ±0.14
The average live weight in first feeding period, kg	51.4±0.15	55.0±0.13*
Weight gain in the first feeding period, kg	23.2±0.07	26.4±0.06*
Daily weight gain in the first fattening period, g	702±2.4	799±1.7*
%	100	114
The average live weight at the end of the experiment, kg	97.4±0.18	105.1±0.15*
Weight gain in the second fattening period, kg	46.0±0.07	50.1±0.07*
Daily weight gain per day second fattening period, g	822±1.3	895±1.2*
%	100	109
Weight gain during the whole experimental period, kg	69.2±0.09	76.5±0.10*
Daily weight gain during the whole experimental period, g	777±1.0	859±1.1*
%	100	110
** P <0.01.*		

At the start of the experiment the average live weight of pigs was not significantly different. In 33 days after the completion of the first fattening period, the liveweight growth rates were significantly different. The daily weight gain during this period in the experimental group pigs was 14 % higher than in the control group. Also in the second fattening period, the liveweight indicators differed significantly. The daily weight gain in the second fattening period in the experimental group of pigs was 9 % higher than in the control group. In both feeding periods the total live weight growth rates were significantly different. The experimental group pigs had on average 4.1 kg higher live weight of than the control group. The daily weight gain in the experimental group was 10 % higher than in the control group.

According to Latvian swine breeding program the daily weight gain of pigs in the fattening period will be higher than 800 g and 100 kg live weight will be reached in 160 day. The experimental pigs met those requirements. The daily weight increase was 859 g and 105.1 kg live weight of pigs was reached in 165 days.

The results showed that in both periods the feed for fattening pigs with the liveweight 30-105 kg was more efficient.

Feed costs in pig production account for most of the costs. Therefore, the cheapest and most efficient feed should be carefully chosen [7, 8, 9].

Table 6. **Feed costs**

Groups	Experiment 1			Experiment 2		
	Feed cost per1 kg, Euro	Feed consumption per 1 kg liveweight gain, kg	Feed expenses per 1 kg liveweight gain, Euro	Feed cost per 1 kg, Euro	Feed consumption per 1 kg liveweight gain, kg	Feed expenses per 1 kg liveweight gain, Euro
Control group in fattening period 1	0.18	2.4	0.44	0.18	2.3	0.42
Control group in fattening period 2	0.16	2.8	0.45	0.16	2.3	0.46
Experimental group in fattening period 1	0.18	2.2	0.41	0.19	2.8	0.42
Experimental group in fattening period 2	0.18	2.9	0.52	0.19	3.0	0.55

The comparison of the feed costs and expenses in both experiments, showed, that in the first fattening period the feed for fattening pigs with the liveweight 25-55 kg was economically advantageous. In the second fattening period finisher feed was economically profitable (Table 6).

CONCLUSIONS

1. In the first experiment - more efficient and cost-effective was the feed mixture for fattening pigs with the liveweight 25-55 kg in first fattening period. Daily live weight gains of pigs were 783 g or 18 % higher than in the control group. In the second fattening period, more efficient and cost-effective was the finisher feed. Daily live weight gains of pigs were 797 g or 13 % higher.

2. In the second experiment - more efficient and cost-effective was the feed mixture for fattening pigs with the liveweight 30-105 kg in both fattening periods. Daily live weight gains of pigs were, respectively, 799 g, 14 % and 859 g, 9 % higher than in the control group.

3. The comparison of the feed costs and expenses on the live weight gains of pigs in both experiments showed that in the first fattening period feed mixture for fattening pigs with the liveweight 25-55 kg was economically advantageous. In the second fattening period finisher feed was economically profitable.

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ОЦЕНКА РАЗЛИЧНЫХ КОРМОВЫХ СМЕСЕЙ ДЛЯ ОТКОРМА СВИНЕЙ

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Резюме

В ходе экспериментов была проведена оценка пяти кормовых смесей, которые скармливались свиньям, предназначенным на откорм: корм (grower), корм для кормления на последней стадии откорма (finisher), корма для свиней на откорме с живым весом 25-55 кг, 55 - 100 кг и от 30 – 105 кг.

В ходе исследований проводились два эксперимента. В результате первого эксперимента более эффективной и экономичной оказалась кормовая смесь для свиней на первичном откорме с живым весом 25-55 кг. Прирост живого веса составил 783 г в сутки, что на 18 % выше, чем в контрольной группе. Во втором откормочном периоде более эффективен и с наименьшими кормовыми затратами оказался корм на последней стадии откорма (finisher). Прирост живого веса свиней составил 797 г в сутки, что на 13 % выше, чем в контрольной группе.

В результате второго эксперимента более эффективной и экономичной в обоих откормочных периодах оказалась кормовая смесь, предназначенная для свиней на откорме с живым весом от 30 – 105 кг. Прирост живого веса составил 799 г и 859 г в сутки соответственно, что на 14 % и 9 % выше, чем в контрольной группе.

В результате экспериментов более экономически выгодной на первой стадии откорма оказалась кормовая смесь для свиней с живым весом 25-55 кг, а на второй – кормовая смесь на последней стадии откорма (finisher).

Ключевые слова: свиньи, корм, откорм, привес, эффективность

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INTERACTION BETWEEN GOAT NUTRITION AND MEAT COMPOSITION

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ABSTRACT

Meat is the primary reason to raise goats, which is why meat goats constitute the majority of the world's goat production systems. Goat meat is lower in calories, total fat, saturated fat and cholesterol, than traditional meats. The effect of breed-type and diet on goat carcass characteristics has been investigated in only a limited number of studies. We have assessed the influence of special concentrated feed for calves (CFC) and concentrated feed for goats and sheep (CFGS) on goat meat productivity and quality indices, and made recommendation for feeding of goat kids and production of meat. The trial period lasted for 167 days, meat samples were analyzed at the laboratory of the Research Institute of Biotechnology and Veterinary Medicine "Sigra". The dietary treatment resulted in that the live weight of goat kids that received CFC was about 7.5 % higher at the end of the trial than that of goat kids that received CFGS. However, CFGS group kid meat showed lower dry matter content by 3.4 %, and crude protein, crude fat and crude ash content in meat was higher respectively by 3.0 %, 20.8 % and 16.4 %. The meat from CFGS group was richer in copper, zinc and magnesium respectively by 6.4 %, 21.4 % and 11.2 % compared to the meat of kids from CFC group. Meat pH in both groups was 5.3, which is a very good index and showed that animal was not affected by the stress. In the analyzed kid meat samples, the cholesterol level ranged from 77.09 to 77.68 mg % but the cholesterol content of the kid liver samples ranged from 223.21 to 241.04 mg %. Higher live weight gains and carcass weight were reached with CFC feeding, but higher livestock output and higher meat quality were when feeding the kids with a special concentrated feed CFGS.

Key words: *goat meat, nutrition, chemical composition*

INTRODUCTION

Goat is thought to have been the earliest animal domesticated besides sheep and dogs. At the present time, goats provide the principle source of animal protein in many North African and Middle Eastern nations. Goat is also important in the Caribbean, in Southeast Asia, and developing tropical countries. Three-fourths of all the goats in the world are located in the developing regions of the world [18].

Meat is the primary reason to raise goats, which is why meat goats constitute the majority of the world's goat production systems. Goat meat comprises 63 percent of all red meat that is consumed worldwide. Currently, goats are the main source of animal protein in many North African and Middle Eastern nations. Goats are also important in Southeast Asia, the Caribbean, and other tropical regions [19].

In the Baltic States goat farming focuses mainly on milk production, however, recently there also have been raising interest and demand for goat meat. For milk production most common breeds in Latvia are Latvian local and Saanen, also German White noble and the Alps breed, but the majority of the meat-type goats in Latvia are of the Boer breed and crossbreeds. The Boer breed was developed in South Africa for the purpose of meat production. This breed is known for its large frame size, muscularity, and characteristic white body and brown or red–colored head [17]. Boer goats were imported into Latvia in 2005, and used in cross breeding for improving of goat meat quality and quantity [10].

Kids are often slaughtered at the age of 3 to 5 months and weight from 10 to 20 kg. Kids do not store much body fat until they are about a year of age. Many goats are older and heavier when marketed, but most, except aged cull goats, are slaughtered at less than a year of age. The meat of older goats is darker and less tender, but more juicy and have more flavor than that of kid. The meat from males is lighter in color and lower in fat. The meat from females is more desirable for steaks and chops, and is more tender [18].

Goat meat is lower in calories, total fat, saturated fat, and cholesterol than traditional meats. Goat meat is 50 %-65 % lower in fat than similarly prepared beef and have between 42 %-59 % less fat than lamb's meat and about the same fat content to 25 % lower than veal, but protein content is similar [4, 20]. In addition, the percentage of saturated fat in goat meat is 40 % lower than that in chicken (without skin) and is far below than that in beef, pork and lamb by 850, 1100, and 900 %, respectively [2,3,15]. Less saturated fat and less cholesterol mean healthier red meat for the health-conscious consumer. Additionally, goat meat has higher levels of iron (3.2 mg) when compared to a similar serving size of beef (2.9 mg), pork (2.7 mg), lamb (1.4 mg), and chicken (1.5 mg). Comparatively, goat meat also contains higher potassium content with lower sodium levels. Regarding essential amino acid composition, goat meat closely resembles that of beef and lamb. The nutritive value of goat meat is becoming increasingly important in the health management of people. Not only is goat meat lower in total fat and cholesterol, but it is also lower in saturated fats than traditional meats. Saturated fatty acids, which form solid or semisolid fat at room temperature, cause cholesterol levels to rise. The amount of cholesterol in the food has only a moderate effect on the amount of cholesterol in the bloodstream. Furthermore, the amount of saturated fat in goat meat is less than the total amount of unsaturated fats, which may be important in human nutrition [19].

Feed can account for up to 50–60 % of total production costs, and the goal of providing livestock with high quality feeds must be met in a manner that allows the animals' needs to be met without jeopardizing sustainability while also being economically feasible for the farmer [16]. Usually, nutrient requirements are defined for a certain level of production, using factorial approaches (i.e. calculating requirements as a function of body weight, physiological status and level of performance, using established factors for use of nutrients and energy [6]. The probability of nutrition-related problems increases with increasing level of production, decreasing forage quality and lack of home-grown feedstuffs with a high nutrient concentration. Problems may occur also in connection with an unbalanced supply of different nutrients. The magnitude of imbalance between protein and energy intake will depend, among other things, on the soil type, the proportion of legumes in the diet, and the availability of feedstuffs with relatively high energy content [1]. Typically, goat farmers will focus on forage and pasture systems and use less concentrates and mineral supplements than intensive foreign farmers. Under these circumstances, nutrition will probably limit milk and meat production and eventually affect the milk's and meat's nutrient content [5]. Because extensive farms rely on home-grown feedstuffs much more than intensive farms, low feedstuff quality, which may temporarily occur because of unfavorable conditions, will be important for the nutrition of ruminants [7]. Temporary nutrient deficits can be covered by using supplementary feedstuffs such as concentrates or different mineral sources.

The effect of breed-type and diet on goat carcass characteristics has been investigated in only a limited number of studies [8], and we will try to find the answer to the question how to produce qualitative meat and why consumer should prefer goat meat.

The objective of our study was to assess the influence of different concentrated feeds on goat meat productivity and quality indices, and make recommendations for feeding of goat kids and production of meat.

MATERIALS AND METHODS

The study was carried out in goat farm „ Kannenieki" (Ventspils reg.) in Latvia during spring – summer period and the trial period was 167 days. During the experimental period, goat kids of the 1st group (control) were fed basal feed (BF) produced on the farm, and as concentrated feed received a special concentrated feed for calves (CFC), produced in "Dobeles dzirnavnieks". Goat kids of the 2nd trial group received BF and a special concentrated feed for adult goats and sheep (CFGS), also produced in "Dobeles dzirnavnieks" (Table 1), was feed.

Nutrient requirements in goat kids were determined according to animal age and live weight following the normative regulations adopted in Latvia, and also according the National Research Council (NRC) recommendations.

Table 1. **Experimental design**		
Groups	Number of animals per group	Feed pattern
1st control - CFC	5	Mother milk. Pasture grass – 2 kg, hay – 0.5 kg (BF), concentrated feed for calves 0.2-0.3 kg (CFC).
2nd trial - CFGS	5	Mother milk. Pasture grass – 2 kg, hay – 0.5 kg (BF), concentrated feed for goats and sheep 0.2-0.3 kg (CFGS)

In both groups were crossbreeds kids (Latvian local X Boer; Saanen X Latvian local). Kids under 2 months of age were nursed by their mothers receiving on average of 80 kg of milk for 60 days. Goat kids of the first control group consumed 122 kg of "Compounded feed for Calves (CFC)" at 1-6 months age or 24.4 kg per kid. The second trial group of kids consumed 122 kg of "Complementary feed for goats and sheep" (CFGS), i.e. 24.4 kg per kid.

Ingredients of CFC: wheat 50 %; barley 19 %; soya cake 14 %; fodder yeast 5 %; sunflower cake 4.2 %; corn 4 %; premix 2 %; lime flour 1.5 %; salt 0.3 %.

Ingredients of CFGS: wheat 45.5 %; wheat bran 19 %; barley 5 %; rape cake 8 %; sunflower cake 18 %; $CaCO_3$ 2 %; $CaHPO_4$ 1.3 %; salt 1.2 %.

During the trial, i.e. in 167 days, the feed quantity consumed by every kid in the 1st control group and 2nd trial group was practically equal (Table 2).

Table 2. **Consumed feed per goat kid**						
Feedstuffs; groups	Amount, kg	Feed units	Digestible protein, g	Ca, g	P, g	Caro-tene, mg
Milk	80.0	24.8	2800	96	80	160
Compounded feed						
1st group - CFC	24.4	25.86	3392	290	195	73
2nd group - CFGS	24.4	24.40	3733	264	239	73
Hay	18.0	9.18	847	119	43	540
Pasture grass	320	70.00	5760	960	160	13440
Total per period:						
1st control - CFC	X	129.84	12799	1465	478	14213
2nd trial - CFGS	X	128.38	13140	1439	522	14213
Total per day:						
1st group - CFC	X	0.78	76.6	8.8	2.86	85
2nd group - CFGS	X	0.77	78.7	8.6	3.13	85

By the amount of feed units (FU), digestible protein (DP), calcium, phosphorus and main biologically active substances feed rations for the goats of the 1st and 2nd groups were practically of equal value (Table 2).

The samples (300-400 g from each carcass) for analysis of the chemical composition (dry matter, water, protein, fat, ash, etc.) of meat were taken from the hip part muscle. Prepared samples were analyzed at the laboratory of the Research Institute of Biotechnology and Veterinary Medicine “Sigra”.

The methods used for the analysis of meat samples were: quantity of water – ISO 6496–1999; dry matter – drying method; crude protein – LVS EN ISO 5983-1-2005; crude fat – ГОСТ 13496.15-85; ash – ISO 5984–2002; Ca – ISO 6490/1-1985; P – ISO 6491-1998; trace elements – LVS EN ISO 6869-2002; pH – ГОСТ 26180-84; cholesterol – colorimetric method. The results were statistical analyzed. The difference statistically reliable when $p<0.05$.

RESULTS AND DISCUSSION

Both groups of kids consumed practically the same food quantity. Weight gain during the trial is shown in the Table 3.

Table 3. **Weight of kids during the trial, kg**

Groups	At the start	At the end	Daily weight gain
1st group - CFC	3.14 ± 0.27	20.54 ± 1.26	0.104 ± 0.74
2nd group - CFGS	2.78 ± 0.26	19.00 ± 0.65	0.097 ± 0.49

The live weight of goat kids fed compound feed for calves (CFC) at the end of the trial was about 7.5 % higher than that of kids fed concentrated feed for goats and sheep (CFGS). Besides live weight gain per trial period was higher for kids in the first control group.

As it can be seen from Table 4, there are some differences in the content of trace elements, crude protein, fat and energy of concentrated feeds that were included in the ration of kids.

Higher amount of energy (NEL), crude protein, calcium (Ca), zinc (Zn), iodine (J), cobalt (Co) was found in kid’s diet of 1st control group, fed special concentrated feed for calves (CFC). Higher amount of protein and energy in the diet can lead to better effect on the growth of kids. Cobalt is a component of vitamin B-12, and it is essential for its synthesis. Deficiency signs include loss of appetite, emaciation, weakness, anemia, and decreased production. Iodine is necessary for the formation of thyroxine, a hormone of the thyroid gland. A deficiency of iodine results in an enlargement of the thyroid gland, a condition called goiter. Zinc is essential for goats. Deficiency symptoms include reduced feed intake, weight loss, parakeratosis, stiffness of joints, excessive salivation, swelling of the feet and horny overgrowth, small testicles, and low libido. Zinc must be supplied continuously because little is stored in the body in readily available form [6, 21].

Table 4. **Chemical content of complementary feed, on a dry matter basis**

Nutrients	CFC (1st control group)	CFGS (2nd trial group)	± to control
NEL, MJ kg-1	7.64	6.69	- 0.95
ADF, %	7.5	10.05	+ 2.55
NDF, %	23.8	22.44	- 1.36
Crude protein, %	21.0	19.36	- 1.64
Crude fat, %	1.8	3.49	+ 1.69
Ash, %	6.5	7.89	+ 1.39
Ca, %	1.19	1.08	- 0.11
P, %	0.80	0.98	+ 0.18
NaCl, %	0.44	0.49	+ 0.05
Fe, mg kg-1	13.0	87.88	+ 74.88
Cu, mg kg-1	16.0	19.43	+ 3.43
Mn, mg kg-1	41.0	59.97	+18.97
Zn, mg kg-1	148.0	86.33	- 61.67
J, mg kg-1	5.0	2.65	- 2.35
Se, mg kg-1	0.25	0.31	+ 0.06
Co, mg kg-1	1.0	0.69	- 0.31
Vitamin A, IU	10056	7947	- 2109
Vitamin D, IU	3000	2275	- 725
Vitamin E, mg kg-1	20.0	27.0	+ 7.0

Higher amount of crude fat, phosphorus (P), iron (Fe), copper (Cu), manganese (Mn) and selenium (Se) was in the diet of 2nd trial group fed special concentrated feed for goats and sheep (CFGS). Copper and molybdenum are interrelated in animal metabolism; hence, herein they are considered together. The most common problem occurs when a normal or low level of copper is accompanied by a high level of molybdenum. In this case, copper is excreted and a deficiency occurs. Few studies on copper and molybdenum have been conducted with goats. It appears that sheep are sensitive to copper toxicity and resistant to molybdenosis, but it is not known whether this is also the case with goats. Iron is a component of blood hemoglobin that is required for oxygen transport. It is also required for some enzyme systems. Although iron deficiency seldom occurs in mature grazing animals, it may occur in young goat kids because of their minimal body stores of iron at birth and the iron content of milk. Manganese is an essential mineral in the ration of goats, required for skeletal development and reproductive efficiency. Selenium is essential, but only in minute amounts. It is a component of glutathione peroxidase, the metabolic role of which is to protect against oxidation of polyunsaturated fatty acids and resultant tissue damage. Also, selenium is interrelated with vitamin E - they spare each other, and with the sulfur-containing amino acids [6, 21].

Goat kid's carcass weight did not differ significantly between the trial groups (Table 5).

Table 5. **Carcass weight**			
Groups	Live weight, kg	Carcass weight, kg	Livestock output, %
1st group - CFC	20.54 ± 1.26	7.5 ± 0.98	39.9
2nd group - CFGS	19.00 ± 0.65	7.3 ± 0.84	41.6

The kids reached higher live weight in the first control group where the animals received concentrated feed for calves, but better livestock output was in 2nd trial group and accounted for 41.6 %, i.e. it was about 1.7 % higher than in the control group.

Meat quality is determined by its composition, mainly by content of dry matter, nutrients and physiologically active substances (Table 6).

Table 6. **Chemical composition of goat kid's meat**			
Indices	Groups		
	1st group - CFC	2nd group - CFGS	± to control
Dry matter, %	19.99	19.32	-0.67
Protein, %	20.07	20.68	+0.61
Fat, %	1.20*	1.45*	+0.25
Ash, %	1.16*	1.35*	+0.19
Phosphorus, %	0.16	0.16	-
Calcium, %	0.03	0.03	-
Copper, mg kg-1	4.50	4.79	+0.29
Mangan, mg kg-1	2.42	2.38	-0.04
Zinc, mg kg-1	22.24*	26.99*	+4.75
Magnesium, mg kg-1	213.8*	237.8*	+24.00
Iron, mg kg-1	64.96	64.76	-0.20

*$p<0.05$

Kid's meat from group 2 had lower dry matter content by 3.4 %, but crude protein, crude fat and crude ash contents were higher, respectively, by 3.0 % 20.8 % and 16.4 % in this group where kids were fed special concentrated feed for goats and sheep. It means that meat from 2nd trial group could be more succulent and tastier. The often quoted standard composition of normal adult mammalian muscle is 75 % water, 19 % protein, 2.5 % lipid, 0.65 % minerals and <0.1 % vitamins [22]. Goat lean meat is an excellent source of minerals for human diets. The meat from 2nd trial group was richer in copper, zinc and magnesium, respectively, by 6.4 %, 21.4 % and 11.2 % compared to the meat of kids in 1st control group. The trace minerals Cu, Mn and Zn in meat are highly bioavailable since meat does not contain inhibitors present in some vegetables [22].

Meat pH is an essential index to show the conditions of slaughtering period, i.e. if the animals were or not affected by stress. Adrenaline under stress affects muscle blood vessels and they are enlarged, so after slaughtering capillaries and tiny blood vessels contain a lot of blood. This reduces the value of meat and its quality. Meat pH plays an important role during meat storage and in evaluation from veterinary sanitary and technological points of view (Table 7).

Table 7. **pH and cholesterol in goat meat**

Groups	pH	Cholesterol, mg %	% to control
1st group - CFC	5.30	77.68	100.0
2nd group - CFGS	5.30	77.09	99.2

Meat pH should range from 5.01 to 5.51, which is very good and shows that the animal wasn't affected by stress. Exhaustive pre-mortem stress yields dark, firm and dry meat with high ultimate pH (pH>6.0) [22]. In the analyzed kid meat samples cholesterol level ranged from 77.09 to 77.68 mg %. This is small compared with the cholesterol content of the kids liver samples where it ranged from 223.21 to 241.04 mg %. Goat muscle meat is the equivalent in caloric value to chicken and has 94 fewer calories than beef per serving. This is desirable for persons with a need to reduce their caloric intake. Overall, goat meat is similar in most nutrients to other species, but the cholesterol content of goat meat is slightly lower than that of beef or chicken [20]. Cholesterol content is controversially similar to that of beef, lamb, pork, and chicken and much lower than some dairy, poultry products and some seafoods. Further studies of goat meat cholesterol indicates levels of 76 mg % compared to 70 mg % for beef, fish, and lamb and 60 mg % for pork and chicken [11,12]. Cholesterol of beef meat, uncooked, ranges from 36 mg % to 78.2 mg % [13, 14] compared to 57.8 mg % to 69.5 mg % of chevon [9].

Goat meat not only provides nutrients but contains the most important quality parameters. Quality parameters have an indirect effect on consumption where the mere availability of food is not a factor. These parameters become more important when meat is merchandised and the customer has free choice between meat types.

CONCLUSIONS

1. Goat carcasses and meat quality affects the process of slaughtering and carcass processing.
2. Live weight of goat kids that received compound feed for calves (CFC) at the end of the trial was about 7.5 % higher than that of kids that received concentrated feed for goats and sheep (CFGS).
3. Dry matter content of meat was by 3.4 % lower in the second group of kids.
4. Crude protein, crude fat and crude ash content in meat was higher respectively by 3.0 %, 20.8 % ($p<0.05$) and 16.4 % ($p<0.05$) in trial group, where kids were fed on special concentrated feed for goats and sheep.

5. Meat from 2nd trial group was richer in copper, zinc and magnesium respectively by 6.4 %, 21.4 % ($p<0.05$) and 11.2 % ($p<0.05$) compared to the meat of kids in the 1st control group.

6. Meat pH in both groups was 5.3, which is a very good index and showed that animals were not affected by the stress.

7. In the analyzed kid meat samples the cholesterol level ranged from 77.09 to 77.68 mg % but the cholesterol content of the kid liver samples ranged from 223.21 to 241.04 mg %.

8. Higher live weight gain and carcass weight were reached by feeding a special concentrated feed for calves, but higher livestock output and higher meat quality were reached by feeding of kids with special concentrated feed for goats and sheep.

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ВЗАИМОДЕЙСТВИЕ МЕЖДУ КОРМЛЕНИЕМ КОЗЛЯТ И КАЧЕСТВОМ МЯСА

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Р е з ю м е

Мясо является главной причиной разводить коз, поэтому мясные козы составляют большую часть коз в мире. Мясо коз содержит меньше калорий, жиров, насыщенных жиров и холестерина, чем традиционные мяса. Проведено лишь немногочисленные исследования по влиянию породы и типа кормления на характеристики козлятины. Мы оценили влияние специальных комбикормов для телят (CFC) и концентрированных кормов для коз и овец (CFGS) на рост козлят и показатели качества мяса. Подготовили рекомендации для кормления козлят и производства мяса. Исследование длилось 167 дней. Мясные пробы анализировали в лаборатории Научно-исследовательского института биотехнологии и ветеринарной медицины «Сигра». Результаты исследования показали, что при включении в рационы для козлят CFC, можно получать живой вес на 7,5 % выше, чем при включении CFGS, но мясо CFGS группы показало снижение содержания сухого вещества на 3,4 %, а сырого протеина, сырого жира и сырой золы в мясе было больше соответственно на 3,0 % 20,8 % и 16,4 %. Мясо группы

CFGS было богаче медью, цинком и магнием соответственно на 6,4 %, 21,4 % и 11,2 % по сравнению с мясом козлят группы CFC. В обеих группах pH мяса был 5,3, что является очень хорошим показателем, и доказал, что животные не подвергались стрессу. В анализируемых образцов мяса уровень холестерина был от 77,09 до 77,68 мг %, а содержание холестерина в печени колебалось от 223,21 до 241,04 мг %. Наибольшее увеличение живого и убойного веса достигнуто при кормлении с добавлением CFC, но более высокие качественные показатели мяса были получены при кормлении козлят специальным концентрированных кормом с CFGS.

Ключевые слова*:* козлятина, кормление, химический состав

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ECONOMIC PROFITABILITY OF INNOVATIVE COMPOSITION BROILER CHICKEN MEAT PRODUCTION IN LATVIA

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ABSTRACT

Innovative composition of broiler chicken meat, in comparison with the commercial mass production, contains higher levels of omega-6 (n-6) and omega-3 (n-3) fatty acids and carotenoid complex which positively influences human health and prevents risk factors that cause different diseases. The aim of investigations was to evaluate the possibility to obtain broiler chicken meat of the innovative composition, and to evaluate the expenses of production in bioeconomic aspects by using feed that contains an increased amount of n-6 and n-3 fatty acids. The feeding trial was carried out with the cross ROSS 308 broiler chicken at the age from 1 to 42 days (n=300). It was concluded that the best combination in broiler chicken feed for producing innovative composition meat is 1 % flax seed oil, 1 % rapeseed oil and 2 % soyabean oil. By using the mentioned oil composition, broiler chicken meat contained the amount of n-6 fatty acids 27.4 %, n-3 fatty acids 8.3 % of total lipids; it is by 3.9 % and 3.2 % higher in comparison with commercial mass production. Metabolic processes in the poultry organism are essential factors that determine the carry over levels of fatty acids and carotenoids in meat, and it is impossible to evaluate and calculate these physiological processes in organisms exactly economically.

In the trial the expenses of feed consumption per 1000 broiler chicken breeding were by 6.28 % higher than the use of commercial feed. The live weight of broiler chickens was higher by 7.87 % in comparison with the commercial production. The economic calculations of the possible economic profitability of broiler chicken meat production per1000 broilers were by 15 % higher in case of innovative composition of broiler chicken meat production.

Key words: *broiler chicken meat, fatty acids, expenses*

INTRODUCTION

The development of poultry industry in Latvia, the amount of production and technical base provide all the possibilities for producing natural innovative composition-based poultry meat for the future. In Latvia poultry meat plays a significant role in the meat production sector. Consumers' demand for qualitative and healthy poultry meat products increases. Innovative food products with a health benefit are constantly demanded. Qualitative and healthy poultry meat is characterized as having high content of polyunsaturated fatty acids (n-6 and n-3), vitamins, anti-oxidants (carotenoids) and mineral substances, and low level of saturated fatty acids and cholesterol [2, 4]. Hence, the current goal for poultry meat production is not to increase the quantity of poultry output, but to increase the production of qualitative and innovative poultry products. Innovative food-stuff contains biologically active substances which favourably influence vital functions of the human body, reduce risk factors of different diseases and promote health preservation [10]. The necessity to produce innovative food products with the appropriate content increases constantly. It shall be noted that the population of the world and Latvia mostly suffer from cardiovascular diseases [11]. The shortage of omega group fatty acids (linolenic acid and linoleic acid) and antioxidants (carotenoids) in everyday food products is one of the risk factors for cardiovascular diseases. The intake of omega group fatty acids and antioxidants with nutrients enables cholesterol metabolism in human body, and averts the risk factors causing cardiovascular, tumour, rheumatic, and other diseases [1]. Fatty acids in human body are more or less subjected to oxidation processes. Free radicals, which are neutralized by antioxidants, carotenoids, selenium, vitamin E etc. originate due to the oxidation process of fatty acids. Hence, when producing fatty acid-rich products, the content of antioxidants, especially carotenoids will be increased [8]. It should be specified that currently studies are being carried out on the production of innovative composition broiler chicken meat. Researchers in Estonia have studied the possibilities on increasing n-6 and n-3 fatty acids in broiler chicken and quail meat and fat [3, 9]. Latvia has all the possibilities to develop the production of innovative composition broiler chicken meat with an increased content of omega group fatty acids and antioxidants due to: - production of the necessary feeding stuff for production of innovative composition broiler chicken meat with an increased n-6 and n-3 content; - breeding of highly productive avian crosses; - annual growth tendency related to poultry consumption and production rate.

Unfortunately, the production of innovative composition poultry meat containing an increased omega group fatty acids and carotenoid level is not developed in Latvia. With the development of foodstuff production technologies, innovative high-quality food products are supplied to the market, thus consumers may shape balanced and healthy everyday diet. Innovative food production has attracted a pretty big attention [6] and it represents one of the growing food industry sectors in the world [4]. The production of innovative composition meat requires increased expenses, thus sales prices of such meat might be higher. Prices differ significantly in the UK; they are as high as the prices of poultry products obtained in the process of organic farming, which are usually twice higher than the prices of commercial products. The price difference mainly is due to the costs of additional feeding stuff included into the avian feed [7]. In the USA annual sales of innovative food equals to USD 50 billion due to the increase of innovative food production [4].

This fact actually determines the research importance for the national economy of Latvia to enhance the production of innovative composition broiler chicken meat containing an increased amount of n-6 and n-3 fatty acids, and carotenoids. Feed costs amounting to 73-76 % of total costs constitute the majority of production costs related to broiler chicken meat production. The intensive production of such innovative broiler chicken meat products requires economic and scientific assessment. The research aim is to assess the economic aspects for production of innovative broiler chicken meat under trial conditions. The following tasks are defined to achieve the set aim:

1. to clarify the quality of available feeding stuff, doses and costs of avian feeding for the production of innovative composition meat;
2. to verify avian productivity and the quality of innovative composition broiler chicken meat as a result of practical trials;
3. to assess production costs and possible revenues of innovative composition broiler chicken meat.

MATERIALS AND METHODS

The feeding trial was carried out at the Research Institute of Biotechnology and Veterinary Medicine “Sigra”, Latvia University of Agriculture, with cross ROSS 308 broiler chickens, at the age from 1 to 42 days (n=300), (Table 1). Broiler chickens were divided into 2 groups: Group 1 – control and Group 2 – trial. Broiler chickens from the two groups were fed with the basic feed (BF) of the same content.

Table 1. **Trial scheme for production of innovative composition broiler chicken meat (content of fed feed for chicken from 1 to 42 days of age)**

Group	Feeding pattern
Group 1-control	BF content 4 % soya bean oil
Group 2 - trial	BF content 2 % soya bean oil and 1 % rapeseed oil and 1 % flaxseed oil and 0.1 % carotenoids

**the content complies with the standard requirements.*

In order to obtain broiler chicken meat of innovative composition, broiler chicken were fed on a diet enriched with fatty acid-containing feed stuffs: flaxseed and rapeseed oils in combination with conventionally used oils in poultry feeding: soya bean and sunflower oils.

The difference between the trial groups is shown in Table 1, when soya bean oil, flaxseed oil and rapeseed oil in various combinations and an additive containing antioxidant carotenoids were included into the basic feed for broiler chickens. These oil blends contained high levels of n-3 and n-6 fatty acids.

The content of basic feed for broiler chickens of all groups was balanced in compliance with the requirements of cross ROSS 308 standards. The broilers of the control group (Group 1) were fed the basic feed containing 4 % soya bean oil, whereas 2 % soya bean oil, 1 % rapeseed oil and 1 % flaxseed oil, and a complex additives containing antioxidants with the purpose to increase the content of n-3 and n-6 fatty acids, and antioxidants carotenoids in feed doses were added to the feed of Group 2 broilers (Table 3).

The productivity of broiler chickens during the trial period was evaluated by:

live weight of broilers, weighting each bird individually at the age of 7, 14, 21, 28, 35 and 42 days;

feed consumption – weighting feed every day by groups;

survival–dead birds were counted every day.

Eight feed samples and 30 meat samples were used to determine fatty acids. The amount of fatty acids was determined in the average meat sample taken from the **breast muscle** tissue mass by the method of gas chromatography. The amounts of n-3 and n-6 fatty acids in broiler meat at 42 days of age (sales age) were analyzed. The sample of muscle tissue for fatty acid analysis was prepared in correspondence with the demands for the gas chromatography method. Total lipids were extracted from the meat, adipose tissue with hehane. Fatty acid methyl esters (FAME) were prepared using BF3/methanol complex for transesterification. Meat samples were analysed by gas chromatography. The gas chromatograph (ACME, model 6100) was equipped with a flame ionisation detector and analytical column (DB 23; 60 m × 0.25 mm i.d., 0.25 μm film thickness consisting of 50 % cyanopropylmethylpolysiloxan, (J&W Scientific, CA).

The oven temperature programme started at 160°C,then the temperature was increased at a rate of 3.6°C·min^{-1} until reaching 230°C. The detector temperature was set at 250°C. Hydrogen was used as a carrier gas at a flow velocity of 40 cm·s^{-1}. The injection volume was 1 μL and the split ratio was set to 1:100. All fatty acids were identified using appropriate standards (Sigma-Aldrich, Deisenhofen, Germany, Restek).

The statistical analysis was performed using SPSS 17. Statistical significance was declared at $P<0.05$.

RESULTS AND DISCUSSION

The production of innovative composition broiler chicken meat, which compared with the conventional composition broiler chicken meat contains an increased n-6 (linoleic acid) and n-3 (linolenic acid) content requires avian feed that consists of fatty acid containing feed stuffs – seed oils (flaxseed, rapeseed, soya bean). Thus the content of n-6 and n-3, and costs per dose were assessed in locally produced (in Latvia) rapeseed and flaxseed oils. The content of these fatty acids in imported soya bean oil frequently used in poultry farming was analyzed comparatively (Table 2).

Table 2. **Content and ratio of fatty acids in vegetable oils**

Item	n-3 linolenic acid, %	n-6 linoleic acid, %	n-6: n-3 ratio
Flaxseed oil	55.0	13.0	0.2 : 1
Rapeseed oil	9.0	20.0	2.8 : 1
Soya bean oil	8.0	54.0	6.8 : 1

The largest n-3 fatty acid content was observed in flaxseed oil amounting to 55.0 %, what exceeds the respective figures in rapeseed oil and soya bean oil 6-7 times; while the largest n-6 amount is observed in soya bean oil amounting to 54.0 %, if calculated in per cent of the total lipid amount. It is 3-4 times higher than in rapeseed oil and flaxseed oil (Table 2).

Flaxseed oil contained most n-3 and n-6 fatty acids, namely, 666 g/kg, while the lowest amount was detected in rapeseed oil (Table 3).

Table 3**. Amount (g) of linolenic acid and linoleic acid per one kg of feeding stuff**

Item	Flaxseed oil	Rapeseed oil	Soya bean oil
n-3 linolenic acid, g	539	88	78
n-6 linoleic acid, g	127	245	529
Total, g	666	333	607

One kilogram of flaxseed oil contained 539 g of n-3 and 127 g of n-6 fatty acids. According to the total content of n-3 and n-6 fatty acids (Table 3), flaxseed oil was the most valuable feeding stuff, though it was also the most expensive one. Total content of n-6 and n-3 fatty acids in flaxseed oil is 666 g/kg and its price equals to 1.68 LVL/kg.

Out of the two analyzed fatty acids in the composition of innovative products, n-3 fatty acid has a special physiological significance in a human body. The majority of conventional food products contain insufficient amount of n-3 fatty acid, while the shortage of n-6 fatty acid is not so expressed. Hence, the content of n-3 in the used feeding stuff is of great importance, and the larger the content of n-3 in the used feeding stuff, the greater the possibility that the obtained innovative product contains larger content of this fatty acid. Consequently, according to the content of n-3 fatty acid soya bean oil is less valuable than flaxseed oil. Rapeseed and soya bean oils are almost equivalent according to n-3 content, but rapeseed oil has lower content of n-6 fatty acid (Table 3).

Locally produced flaxseed oil and rapeseed oil as well as imported sunflower-seed oil and soya bean oil might be used for the production of innovative poultry products. The most economically profitable feeding stuff used for the production of innovative products is determined following the costs of fatty acid amount (kg) in oils, amount costs of the used doses and impact of this dose on poultry productivity and content of fatty acids in the obtained production. Therefore, it is necessary to add oil blends containing both high n-3 and n-6 levels to feeding stuff to produce innovative broiler chicken meat.

Flaxseed oil contains the most balanced ratio of n-6 and n-3 fatty acids, i.e. 0.2:1. Consequently to produce more economically profitable innovative composition broiler chicken meat with higher content of n-6 and n-3 fatty acids, the following oil blend should be included into the feeding stuff fed to broilers: oil with the highest and cheapest level of n-3 fatty acids and oil with the highest and cheapest level of n-6 fatty acids. Out of the analyzed oils, a blend of rapeseed oil and flaxseed oil correspond to such requirements.

The evaluated feeding stuff may be included into the poultry feed (according to the standards) only in a certain amount. The standards determine and practical poultry farming applies optimum feeding stuff doses admissible for avian organism, including also the studied oils that are allowed to add to the poultry feed in the amount of 2-4 %.

The amount of fatty acids of the feed has no proportional relation to the content of fatty acids in broiler chicken meat, as a certain transition stage of fatty acids from the amount of fatty acids in the feed to the content of fatty acids in the production output exists in an avian organism.

Basic parameters of broiler productivity are as follows: live weight, live weight gain, food consumption and costs. During the trial period broiler productivity was high. The average live weight for broilers of sales age ranged between 2822 -3044 g with the live weight gain per day equaling to 66.21-71.49 g (Table 4).

The live weight and daily gain of broilers in Group 2 was higher by 7.87 % and 7.98 % respectively compared with the broilers of Group 1 (control group).

Table 4. **Productivity of a broiler chicken**

Item	Group 1 - control	Group 2 - trial
Daily live weight, g	41.3	41.3
Live weight at the age of 42 days, g	2822	3044
% to control	×	7.87
Live weight gain per day, g	66.21	71.49
% to control	×	7.98
Survival, %	98	99

Each broiler chicken during the growing period consumed on average the following feed amount: in Group 1 - 5.40 kg and Group 2 – 5.20 kg. Feed consumption for growing one broiler in Group 2 was by 0.20 kg lower than in Group 1. As a result, feed consumption for production of 1 kg live weight was by 10.47 % lower than in Group 1. Feed costs (0.38 LVL/kg) for production of 1 kg live weight gain were lower than for Group 1, mainly due to the fact that the broilers in Group 2 had higher daily live weight gain.

Table 5. **Feed consumption and feed costs for trial broilers**

Item	Group 1 - control	Group 2 - trial
Feed consumption per one broiler during the breeding period, kg	5.40	5.20
Feed consumption for production of 1 kg live weight, kg	1.91	1.71
% to control	×	10.47
Feed price of 1 kg, LVL	0.207	0.220
% to control	×	6.28
Total feed costs for growing one bird, LVL	1.12	1.14
% to control	×	1.79
Feed costs for production of 1 kg live weight gain, LVL	0.40	0.38
% to control	×	5.00

The costs of 100 kg feed fed to broilers ranged between LVL 20.70 and LVL 22.00. The mix of oils included into the feed and the costs of antioxidant doses were the factors determining the amount of feed costs. The difference in feed costs was LVL 1.30 or 6.28 % compared with the first- base group.

The research aim was to produce innovative composition broiler chicken meat with an increased amount of n-3 and n-6 fatty acids, and antioxidant carotenoids.

Feeding broilers with the feed of conventional composition (Group 1) broiler meat contained 23.5 % of n-6 and 5.4 % of n-3 fatty acids in percent of total lipids (according to the chemical analyses) (Table 6).

Table 6. **Quality indices of innovative composition of broiler chicken meat**

Item	Group 1 - control	Group 2 - trial	± to control
∑ n-6 fatty acids, % of total lipids	23.5	27.4	+3.9
∑ n-3 fatty acids, % of total lipids	5.4	8.3	+3.2
∑ (n-6) : ∑(n-3)	4.3 : 1	3.3 : 1	-1.0 : 1
∑ total carotenoids, mg kg^{-1} (antioxidant)	0.62	0.86	+0.24

Adding 2 % of soya oil, 1 % of rapeseed oil, 1 % of flaxseed oil, and 0.1 % of carotenoids to the feed (Group 2), the level of n-6 fatty acids increased to 27.4 % (3.9 % more than for Group 1) and the level of n-3 fatty acids was higher up to 8.3 % (3.2 % more than for Group 1), while the content of carotenoids increased by 0.24 mg kg^{-1}.

In poultry farms the costs for broilers feed consumption constitute approximately 73-76 % of the total costs. The costs for food consumption and other costs related to growing of broilers were mathematically calculated based on the mentioned fact.

When feeding broilers with the feed enriched with fatty acids, the carcass weight of innovative composition broilers was 195.92 kg higher (calculating per 1000 broilers) than the carcass weight of broilers fed with the conventional composition feed (Group 1). Nevertheless, the costs of the new feed for growing 1000 broilers were LVL 20 higher than in a standard variant, revenues from sales of innovative composition meat were LVL 293.47 larger (calculating per 1000 broilers) than from the sales of Group 1 broilers. These higher financial results are obtained thanks to a poultry survival indicator and mainly thanks to the larger total live weight of broilers. It should be noted that the meat of Group 2 broilers had the highest content of n-3 fatty acids and the most optimum ratio of n-6 : n-3 fatty acids. The meat of Group 1 broilers had the highest quality and the highest broiler live weight at the age of 42 days. Thus a more valuable and healthier product is obtained even at an equal sales price of broilers, besides total producer's revenues might be 15 % higher than in the case of feeding standard broiler chickens.

CONCLUSIONS

1. It is recommended to feed broiler chickens with the feed containing 2 % soya bean oil, 1 % of rapeseed oil, 1 % flaxseed oil, and 0.1 % carotenoid additives to produce the innovative composition of broiler chicken meat containing an increased amount of n-3 and n-6 fatty acids and carotenoids.
2. Feed costs for production of broiler chicken meat of innovative composition are 6.28 % higher than in a standard feeding variant, though the feed consumption per one broiler is lower.
3. By using the mentioned oil composition, broiler chicken meat contained the amount of n-6 fatty acids 27.4 %, n-3 fatty acids 8.3 % of total lipids; it is by 3.9 % and 3.2 % higher and the live weight of broiler chickens was higher by 7.87 % in comparison with the commercial mass production.
4. Feeding stuff containing fatty acids are available also in Latvia, like flaxseed oil and rapeseed oil, should be included into poultry feeds for the production of broiler chicken meat of innovative composition.
5. Economic calculations on the possible economic profitability of broiler chicken meat production carried during the experiment were by 15 % higher in case of innovative composition broiler chicken meat production

when calculated per 1000 broilers.

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ЭКОНОМИЧЕСКАЯ ЭФФЕКТИВНОСТЬ ПРОИЗВОДСТВА МЯСА БРОЙЛЕРОВ ИНОВАТИВНОГО СОСТАВА В ЛАТВИИ

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Р е з ю м е

Мясо бройлеров иновативного состава содержит повышенное количество омега-6 (н-6) и омега-3(н-3) жирных кислот и комплекс каротинойдов по сравнению с мясом бройлеров традиционного состава.

В опытных условиях исследовались затраты на производство мяса бройлеров иновативного состава.

В опытах включили цыплята бройлеров кросса ROSS 308. Цыплят бройлеров контрольной группы кормили стандартным кормом, а к корму цыплят опытной группы добавляли 2 % соевый, 1 % рапсовый и 1 % льняного масло для увеличения в мясе бройлеров омега-6 и омега-3 жирных кислот.

Было установлено, что скармливание бройлерам корма с выше упомянутыми маслами, в мясе бройлеров уровень н-3 жирных кислот был 8,3 %, и н-6 жирных кислот – 27,4 % от общих липидов.

Производство мяса бройлеров иновативного состава повысило затраты корма – на 6,28 %, но одновременно повысилось живая масса бройлеров на 7,87 % по сравнению с контрольной группой.

В связи с этим, экономически выгодно производить мясо бройлеров иновативного состава.

Ключевые слова: мясо бройлеров, жирные кислоты, затраты производства

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