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Reproductive and meat characteristics of Polish ducks threatened with extinction

Reprodukční a jatečné charakteristiky polských kachen ohrožených plemen zařazených do genetických zdrojů

J. Książkiewicz

Department of Waterfowl Breeding Dworzyska, National Research Institute of Animal Production, Kórnik near Poznań, Poland

ABSTRACT: Conservative flocks of Miniducks (K2) and Polish Pekin (P33), registered by FAO as domestic genetic resources (World Watch List, 2000), were kept in 1982-2001 in comparable environmental and feeding conditions without selection and the mean values of their reproductive and meatiness traits were determined. The experimental flocks showed significant variations in the number and weight of eggs, body weight at 3 and 7 weeks of age, and the proportion of breast and leg muscles in eviscerated carcasses. K2 ducks are characterized by outstanding musculature of breast and P33 ducks by that of thigh and lower thigh, and both flocks are distinguished by low fatness. During the first year of breeding, the number and weight of laid eggs and percentage hatchability of ducklings from fertilized eggs were higher in both flocks than in the second year of breeding. During the first and second years of breeding, upward time trends for the number and weight of eggs, egg fertilization and hatchability of ducklings from set and fertilized eggs were determined in both flocks in 10 generations based on linear regression equations. The number of eggs showed an upward trend, egg weight was stable in K2 and showed a downward trend in P33, while egg fertilization showed a downward trend in K2 and an upward trend in P33. Both flocks were characterized by downward trends for body weight at 3 and 7 weeks of age and for percentage of breast muscles, and by upward time trends for percentage content of leg muscles and skin with subcutaneous fat in carcass.

Keywords: ducks; biodiversity; conservative flock; reproductive traits; meat traits; linear regression equations

ABSTRAKT: Tradiční hejna minikachen (K2) a polských pekingských kachen (P33), které FAO registrovala jako domácí genetické zdroje (World Watch List, 2000), jsme v letech 1982 až 2001 chovali bez selekce ve srovnatelných podmínkách prostředí a výživy a stanovili jsme u nich reprodukční znaky a znaky zmasilosti. Pokusná hejna vykazovala významné kolísání počtu a hmotnosti vajec, živé hmotnosti ve třech a sedmi týdnech věku a podílu prsní svaloviny a stehenního svalstva z jatečného trupu. Pro kachny K2 je typické vynikající osvalení hrudi a pro kachny P33 stehna a dolní části stehna, obě hejna vynikají nízkou tučností. V prvním roce chovu byl počet a hmotnost snesených vajec a procento líhnivosti z oplodněných vajec vyšší než ve druhém roce chovu. Na základě lineárních regresních rovnic jsme v průběhu prvního a druhého roku chovu zjistili v obou hejnech v 10 generacích v čase stoupající trendy u počtu a hmotnosti vajec, oplodnění vajec a líhnivosti kachen z násadových a oplodněných vajec. Počet vajec se zvyšoval, hmotnost vajec byla u K2 stabilní, zatímco u P33 klesala. Oplozenost vajec se u K2 snižovala, ale u P33 stoupala. Pro obě hejna bylo charakteristické snížení hmotnosti ve věku tří a sedmi týdnů. S věkem se u jatečného trupu snižoval podíl prsní svaloviny, podíl stehenního svalstva a podíl kůže s podkožním tukem se zvyšoval.

Klíčová slova: kachny; biodiverzita; tradiční hejna; reprodukční znaky; jatečné znaky; lineární regresní rovnice

The need for preserving domestic animal diversity (DAD), including bird diversity, is dictated not only by breeding or scientific concerns but also by economic, biological and even cultural and historical reasons (Yang and Wu, 1988; Alderson, 1990; Crawford, 1990; Baumgartner *et al.*, 1992; Wężyk *et al.*, 1998).

In Poland, more than ten conservative and genetic reserve flocks of ducks are under the conservation program, but only two conservative flocks of Polish origin ducks, i.e. Pekin (P33) and Miniducks (K2), have been listed by FAO (World Watch List, 2000) and registered as the protected world genetic resources. Due to the small stock of less than 100 females, these populations, according to FAO classification, are acknowledged as critical. The breeding program for the preservation of duck genetic resources (Książkiewicz, 2000), which specifies, among others, the methods of management, evaluation and mating of parental stock and size of the population, is carried out by the National Research Institute of Animal Production in Cracow. Populations of K2 and P33 ducks have been tested for reproductive and meatiness traits so far. The studies of Książkiewicz (1996, 1997a) conducted on several generations of these ducks indicate that Miniducks are characterized by a low number of laid eggs but good hatching parameters. Compared with Pekin-type ducks, eviscerated carcasses of Miniducks are characterized by a higher content of breast muscles and those of P33 ducks by a higher proportion of thigh and lower thigh muscles and a lower proportion of skin with subcutaneous fat in carcass (Książkiewicz, 1997b). A comparison of conservative and breeding flocks made by Witkiewicz (2002) shows that breast muscles of ducks from conservative flocks are lower in white and higher in red fibers, with lower fiber diameter. In addition, Miniduck breast muscles were found to be highest in polyunsaturated fatty acids and lowest in energy value. This makes them highly valuable for human nutrition.

The aim of the present experiment was to compare reproductive and meatiness traits of ducks from two conservative flocks included in the FAO list. Comparisons were made over ten generations by analyzing changing temporal trends of traits using linear regression equations.

MATERIAL AND METHODS

The experiment involved ducks from two conservative flocks, kept *in situ* at the Department of Waterfowl Breeding, National Research Institute of Animal Production:

- Miniducks (K2), which were produced from wild mallards (*Anas platyrhynchos* L.) and Pekin-type ducks, first described by Książkiewicz (1982)
- Polish Pekin ducks (P33), which were an old breeding strain subjected to selection and taken over as a conservative flock in 1978

These ducks are described in the World Watch List (2000).

The Minikaczka (local name), established in 1982, was found in the Poznań region (central Poland) and developed in the western-central part of Poland from wild ducks (mallard) and Pekin duck. It has self-white colored plumage with no special pattern within the feathers, white skin, yellow shanks and feet and egg shells that may be greenish (50%) or white (50%) in color. It is a medium-size duck with adult male weighing 1.7 kg and female 1.6 kg on average. The birds are characterized by very well developed muscles and low fat content.

The Polski Pekin (local name), established in 1978, found in the Poznań region (central Poland), is an old indigenous breeding strain that originated from central Poland. It has self-white colored plumage with no special pattern within the feathers. It possesses yellow skin, shanks and feet and white eggshells. Adult males weigh 3.1 kg and females 2.9 kg on average. The animals are known for good quality feathers, good musculature, satisfactory reproductive performance and low skin and subcutaneous fat content in carcass.

Parental ducks were kept in 1982–2001 in the unchanged methodological layout, testing selected reproductive traits over 10 generations in the first and over 10 generations in the second year of breeding. The birds were reproduced in subgroups, every second year, using randomly chosen animals for reproduction, without selection for productivity traits. Meatiness traits were tested on the progeny obtained from parents in the second year of breeding. This procedure was in accordance with a breeding program for the conservation of genetic resources of duck populations elaborated by Książkiewicz (2000). In each conservative flock and in each generation, a consistent system of four subgroups was applied. This made the rotation of males possible and thus a decreased rate of genetic relationship. In the first year of breeding until 1988, each K2 flock had 60 males and up to 160 females, and this number gradually decreased to 20–32 males and to 80 females. In each generation and throughout the

experiment, the P33 parental flock had at least 20 males and 64 females (Table 1). In the second year of breeding, the number of birds decreased due to mortality and culling for health reasons.

The formula of Wright (1931) was used to calculate the effective size of the population (N_e), i.e. the rate of gene elimination as a result of random genetic drift and the increase in flock homozygosity (ΔF) which is inversely proportional to the effective size of the population according to the formulas:

$$N_e = \frac{4N_m \times N_f}{N_m + N_f}$$

$$F_x = \frac{1}{2N_e}$$

where: N_m = number of males
N_f = number of females

The number of ducks of the same sex evaluated for body weight in the third and seventh week of age ranged from 50 to 200 individuals in each flock and generation. In the seventh week of age, from each flock 5 males and 5 females having body weights close to the arithmetic mean of body weight of males and females in a particular flock were taken for carcass dissection.

The housing system in particular years of the study was similar and in accordance with the rules of raising and keeping parent stock of ducks (Książkiewicz, 1996). During the testing period, the birds from all conservative flocks were kept in one windowless poultry house with controlled environment and without access to the yard. While ducks were kept in a heated rearing house to the fourth week of age, and afterwards they were kept on yards of restricted area, partially shedded and covered with straw.

In each generation birds were fed *ad libitum* on complete feeds of similar chemical composition. This diet until the third week of age contained up to 20% crude protein and up to 12.13 MJ metabolizable energy, and later up to 16.5% crude protein and 12.34 MJ metabolizable energy per 1 kg of feed. The mashes were of commercial origin and therefore their composition of raw material slightly differed.

The mean number of eggs per one layer was calculated from laying performance records collected

Table 1. Actual and effective size of the population (N_e) and the increase in homozygosity (F) in ducks from conservative flocks

Flock symbol	Year	Actual size of the population		Effective size of the population (N_e)	Increase in homozygosity (ΔF)
		♂	♀		
K2	1986	60	160	174.5	0.29
	1990	36	120	110.8	0.45
	1998	36	144	115.2	0.43
	1999	36	80	99.3	0.50
	2000	36	96	104.7	0.48
	2001	36	96	104.7	0.48
P33	1986	32	80	91.4	0.55
	1990	20	72	62.6	0.80
	1998	28	80	83.0	0.60
	1999	24	80	73.8	0.68
	2000	28	76	81.8	0.61
	2001	24	64	69.8	0.72

from January to June each year. All eggs laid during two weeks of the peak laying period were weighed. The percentage of egg fertilization and hatchability was determined each year by analyzing 4 to 6 hatches conducted in walk-in incubators of type ATLAS S-18 (setter) and ATLAS 180 hatcher. Since 1999, hatches were conducted in Petersime walk-in incubators. The time trends of traits of all generations were presented as linear regression equations.

RESULTS

Mean values of reproductive traits and their variations (SEM) obtained over ten generations were compared in the two periods of breeding (Table 2). In the second year, decreased number and weight of laid eggs and decreased hatchability of ducklings from fertilized eggs were found in both flocks. Egg fertilization percentage was found to increase in the K2 flock and to decrease in the P33 flock compared with the first period of breeding. Both in the first and second year of breeding, a significantly higher mean number of eggs per layer and a significantly higher mean weight of egg was found in the P33 flock compared with K2. No statistically significant differences were found between the flocks in egg fertilization and duckling hatchability.

Linear regression equations and their graphic representation of reproductive traits of K2 and P33 ducks are given in Figures 1 and 3. In both flocks and periods of breeding, upward trends for egg number and for hatchability of ducklings from set and fertilized eggs were found over ten generations. The mean egg weight was stable in the K2 flock and showed a downward trend in P33. Egg fertilization showed a downward trend in K2 and an upward trend in P33.

Table 2. Mean values ($\bar{x}$) and standard errors of mean (SEM) of reproductive traits in ten duck generations from two conservative flocks separately in the first (1) and second period (2) of utilization

Flock		Number of eggs laid		Egg weight (g)		Egg fertility (%)		Ducklings (%)			
								from set egg		from fertile egg	
		1	2	1	2	1	2	1	2	1	2
K2	$\bar{x}$	103.0 b	98.4 b	70.0 b	69.5 b	88.0 a	93.5 a	64.8 a	67.9 a	73.6 a	72.7 a
	SEM	5.103	5.103	0.948	0.948	1.762	1.762	2.913	2.913	2.704	2.704
P33	$\bar{x}$	137.4 a	118.8 a	86.2 a	85.8 a	92.3 a	88.1 a	67.2 a	63.1 a	72.7a	71.5 a
	SEM	4.787	4.787	1.113	1.113	2.424	2.424	2.714	2.714	2.022	2.022

Values in the same columns with different letters differ significantly ($P \leq 0.05$)

Table 3. Mean values ($\bar{x}$) and standard errors of mean (SEM) of meat traits in ten generations of drakes and ducks from two conservative flocks

Flock		Body weight (g)				Content in carcass (%)					
		3 weeks		7 weeks		breast muscles		leg muscles		skin with subcutaneous fat	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
K2	$\bar{x}$	558.0 b	574.9 b	1572.9 b	1450.8 b	13.5 a	14.8 a	13.8 b	13.3 b	25.0 a	25.3 a
	SEM	34.692	34.692	35.688	35.688	0.800	0.848	0.496	0.526	1.127	1.195
P33	$\bar{x}$	737.1 a	747.4 a	2471.9 a	2385.7 a	10.5 b	11.6 b	15.1 a	14.7 a	25.5 a	25.1 a
	SEM	40.053	40.053	51.627	51.627	0.587	0.587	0.431	0.431	1.363	1.363

Values in the same columns with different letters differ significantly ($P \leq 0.05$)

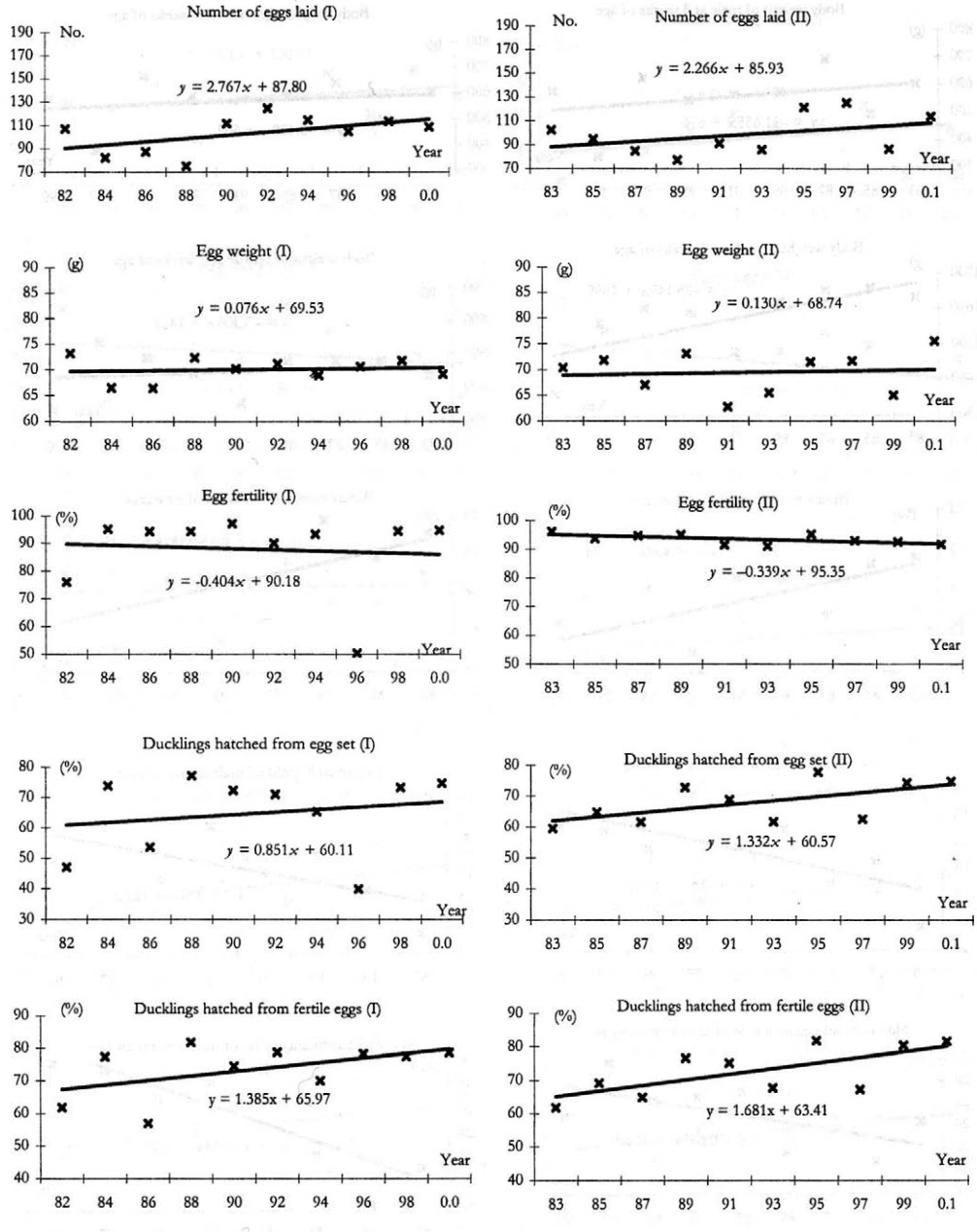

Figure 1. Time trends of reproductive traits in the first (I) and second (II) year of performance in K2 flock of ducks

With regard to meatiness traits (Table 3), statistically significant differences were found between flocks in both sexes for body weight of ducks at 3 and 7 weeks of age and for the content of breast, leg and lower thigh muscles in carcass. There were no statistically significant differences between flocks in the content of skin with subcutaneous fat in carcass. Compared with K2 birds, drakes

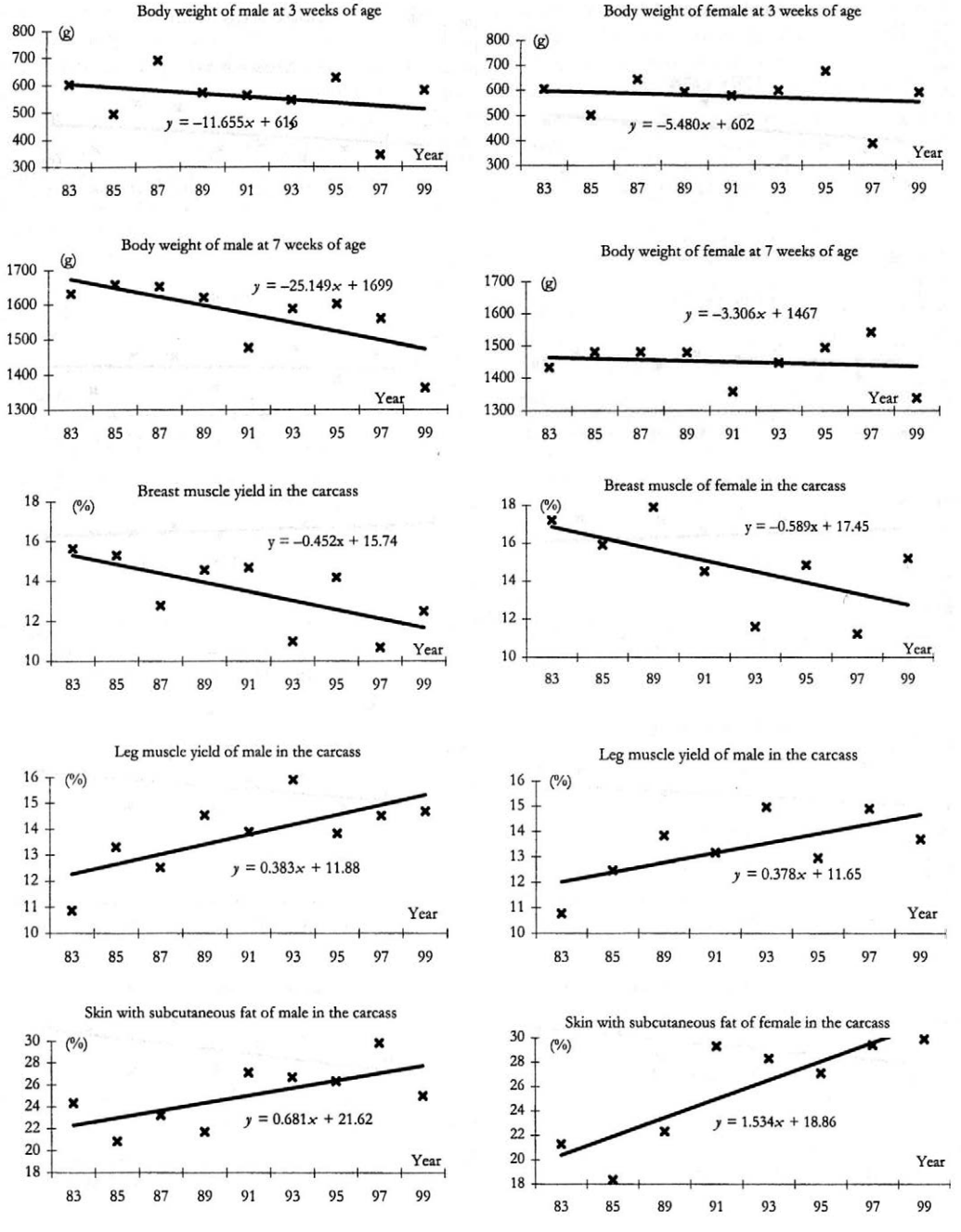

Figure 2. Time trends of meat traits in male and female ducks from K2 flock in 9 generations

and ducks from the P33 flock were characterized by higher body weight at 3 and 7 weeks of age, by lower percentage content of breast muscles in carcass, by higher percentage content of leg muscles, and similar content of skin with subcutaneous fat.

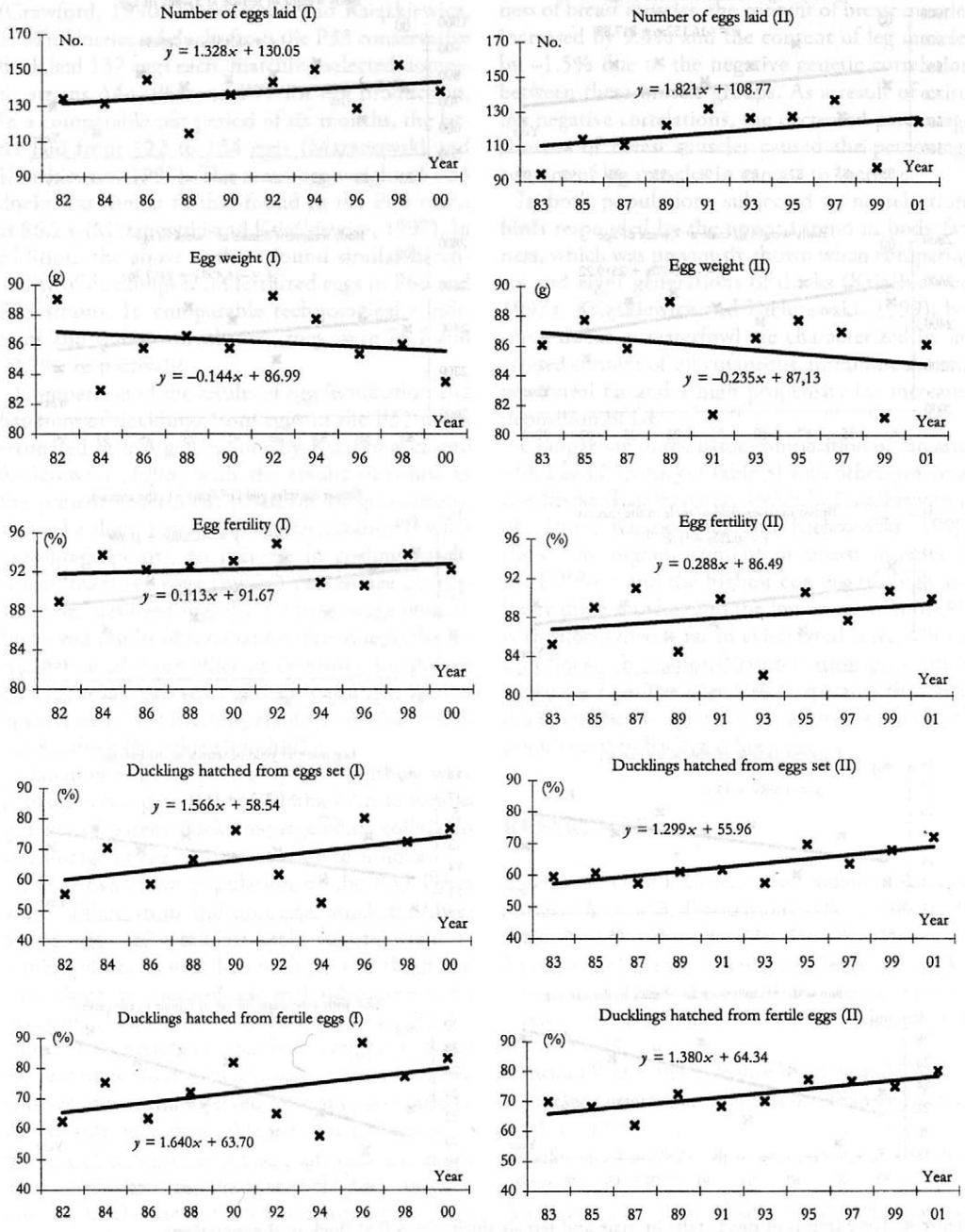

Figure 3. Time trends of reproductive traits in the first (I) and second (II) year of performance in P33 flock of ducks

In both flocks and in both sexes, a comparison of body weights at 3 and 7 weeks of age and percentage content of breast muscles in carcass showed downward trends. Upward trends were noted for percentage content of leg muscles and skin with subcutaneous fat in carcass (Figures 2 and 4).

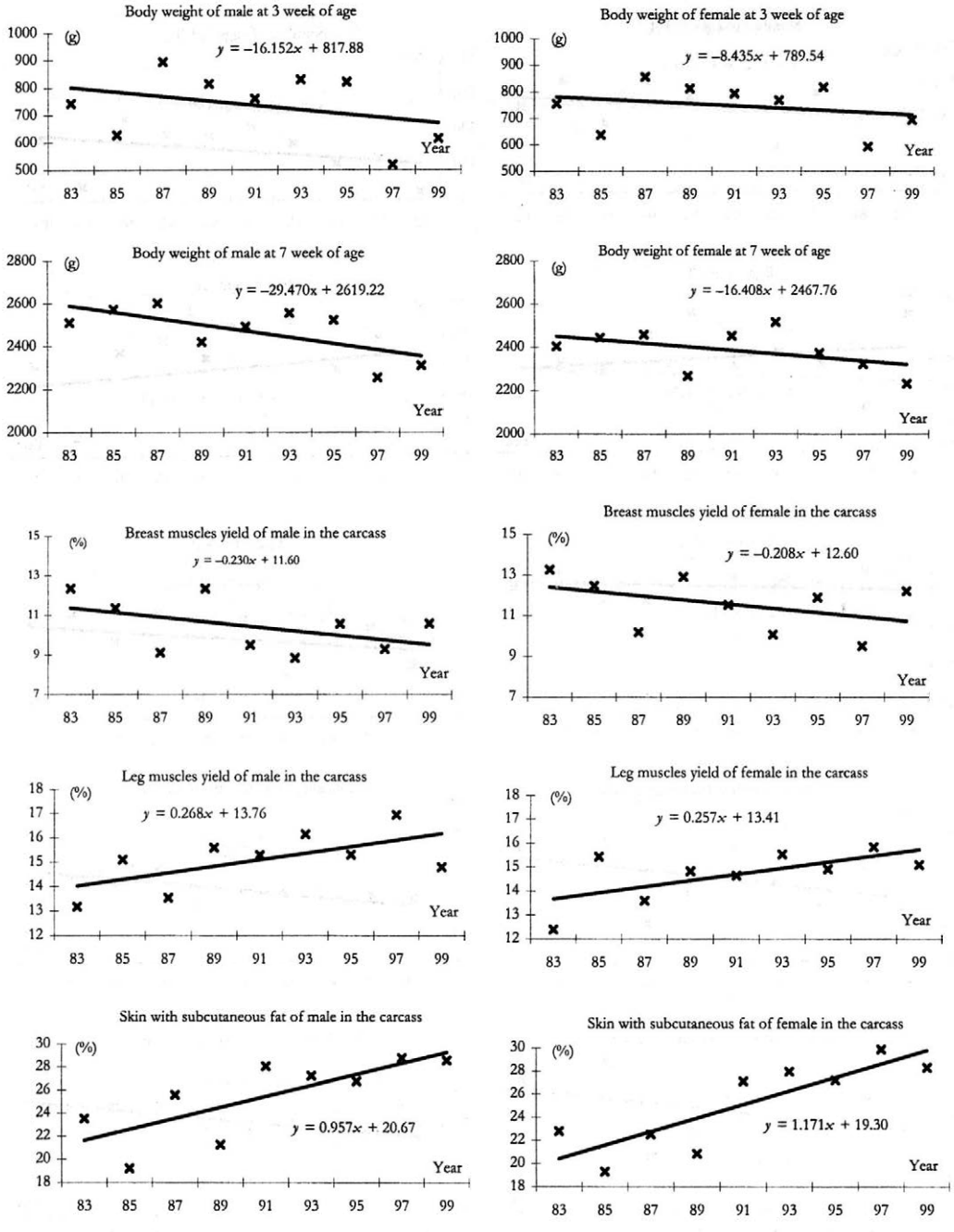

Figure 4. Time trends of meat traits in male and female ducks from P33 flock in 9 generations

DISCUSSION

The studies of Stasko (1980) demonstrated that ducks produced from wild mallards (*Anas platyrhynchos* L.) laid a small number of eggs. This explains the lower egg production of Miniducks compared with other flocks.

The values of reproductive traits of P33 birds confirm the reports of many authors concerning the high reproductive capacity of Pekin-type ducks

(Crawford, 1990; Mazanowski and Książkiewicz, 1997). Unselected ducks from the P33 conservative flock laid 137 eggs each, matching selected domestic strains A44, P66 and P77 for egg production. In a comparable test period of six months, the latter laid from 122 to 134 eggs (Mazanowski and Książkiewicz, 1997). The mean egg weight of P33 ducks was similar to that found in the P66 strain at 86.2 g (Mazanowski and Książkiewicz, 1997). In addition, the above authors found similar hatchability of ducklings from fertilized eggs in P66 and P33 strains. In comparable technological conditions and walk-in incubators, they were 73.1 and 72.7%, respectively.

Comparison of the results of egg fertilization and hatching of ducklings from eggs in the P33 flock, estimated over 8 generations by Książkiewicz and Kiełczewski (1998) with the results obtained in the present experiment based on 10 generations, showed a slight increase in egg fertilization (by 0.3 percentage point), an increase in gosling hatchability from set eggs (by 2.2 percentage points) and from fertilized eggs (by 1.7 percentage points). Improved results of incubation were due to the introduction of more efficient Petersime incubators during the last two years of the experiment. Similar upward trends for hatching results were observed in the K2 flock (Książkiewicz, 2002).

Hatching results reported by other authors were difficult to compare with my findings due to various systems of parent flocks management, collection and storage of eggs and incubation technique.

The conservative population of the P33 Pekin ducks differs from the domestic stock by lower body weight of 7-week-old ducks, lower percentage content of breast muscles and higher of thigh and lower thigh muscles and skin with subcutaneous fat in carcass (Mazanowski and Książkiewicz, 1997).

Decreasing trends in duck body weights at 3 and 7 weeks of age and in percentage content of breast muscles in carcass, observed over nine generations, are considered unfavorable. This is a reaction to the lack of selection for these traits and may result from the inbreeding of the experimental populations (Table 1) due to the attainment of their critical values (World Watch List, 2000) and from the effect of genetic drift.

Pingel (1990) showed negative values of the genetic correlation coefficients between the content of breast and leg muscles in duck carcasses. His studies also demonstrate that as a result of selection over 7 generations for increased body weight and thickness of breast muscles, the content of breast muscles increased by 9.4% and the content of leg muscles by –1.5% due to the negative genetic correlation between these muscle groups. As a result of existing negative correlations, the decreased percentage content of breast muscles caused the percentage content of leg muscles in carcass to increase.

In both populations subjected to no selection, birds responded by the upward trend in body fatness, which was previously shown when comparing six and eight generations of ducks (Książkiewicz, 1997a; Książkiewicz and Kiełczewski, 1999), because ducks as waterfowl are characterized by increased content of subcutaneous, intramuscular and peritoneal fat and a high propensity for increased deposition of fat.

Comparison of the tissue composition of carcasses of K2 and P33 ducks (Table 3) with other conservative flocks (Książkiewicz, 1997a,b; Książkiewicz *et al.*, 1997; Książkiewicz and Kiełczewski, 1999) shows the highest content of breast muscles in the K2 flock and the highest content of thigh and lower thigh muscles and the lowest content of skin with subcutaneous fat in eviscerated carcass in the P33 flock. The national conservation program of indigenous poultry populations specifies that these ducks will be introduced into agritourist farms and popularized in backyard keeping.

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Corresponding Author

Prof. dr. hab. Juliusz Książkiewicz, Department of Waterfowl Breeding Dworzyska, National Research Institute of Animal Production, 62-035 Kórnik, Poland
E-mail: ksiaz@poczta.onet.pl

Polymorphism of genes encoding for ryanodine receptor, growth hormone, leptin and MYC protooncogene protein and meat production in Duroc pigs

Polymorfismus genů kódujících protein ryanodinového receptoru, růstového hormonu, leptinu a MYC protoonkogenu a produkce masa u prasat plemene durok

T. Urban, J. Kuciel, R. Mikolášová

Department of Genetics, Mendel University of Agriculture and Forestry Brno, Czech Republic

ABSTRACT: This study investigated the associations of ryanodine receptor 1 *(RYR1)*, growth hormone (*GH1*), leptin (*LEP*) and MYC protooncogene protein (*MYC*) with parameters of growth rate and fat deposition in 117 pigs of Duroc breed (sex ratio 1 : 1). PCR-RFLP's were genotyped for *RYR1* (*Hha*I), *GH1* (*Msp*I and *Hae*II), *LEP* (*Hin*fI) and *MYC* (*Hpa*II) loci. The following allele frequencies were found: *GH1-Hae*II + = 0.54 and – = 0.46; *GH1-Msp*I + = 0.85 and – = 0.15; *LEP T* = 0.65 and *C* = 0.35 and *MYC A* = 0.82 and *B* = 0.18, respectively. *RYR1* gene was monomorphic (*C* = 1.00). Neither of *GH1* loci (*Hae*II and *Msp*I) showed any effect on variability of meat performance traits under study apart from *GH1-Msp*I, which affected average daily gain (+/+ = 582.44 ± 7.02 g/d vs. +/– = 599.85 ± 8.54 g/d; $P \leq 0.05$). *LEP* influenced average daily gain (*TT* = 578.55 ± 10.73 g/d vs. *TC* = 597.39 ± 11.27 g/d, $P \leq 0.01$) and backfat thickness (*TT* = 9.04 ± 0.52 mm vs. *TC* = 8.03 ± 0.54 mm, $P \leq 0.01$) and percentage of lean meat content (*TT* = 59.88 ± 0.42% vs. *TC* = 60.36 ± 0.54% and *CC* = 60.91 ± 0.52%; $P \leq 0.05$). *MYC* genotypes affected average daily gain (*AB* = 565.22 ± 10.79 g/d vs. *AA* = 594.82 ± 9.78 g/d, $P \leq 0.001$; *AB* vs. *BB* = 608.66 ± 19.28 g/d, $P \leq 0.05$) and average daily gain in the test period (*AA* = 966.93 ± 19.94 g/d vs. *AB* = 929.87 ± 21.96 g/d, $P \leq 0.01$). These results have to be confirmed on another population with larger number of animals of Duroc breed.

Keywords: *RYR1*; *GH1*; *LEP*; *MYC*; meat production traits; pigs; Duroc breed

ABSTRAKT: Byly sledovány asociace polymorfizmů ryanodinového receptoru 1 *(RYR1)*, růstového hormonu (*GH1*), leptinu (*LEP*) a MYC protoonkogenu (*MYC*) s ukazateli růstu, zmasilosti a tučnosti u 117 prasat plemene durok (poměr kanečků a prasniček 1 : 1). Pomocí PCR-RFLP byly testovány polymorfizmy v lokusech *RYR1* (*Hha*I), *GH1* (*Msp*I a *Hae*II), *LEP* (*Hin*fI) a *MYC* (*Hpa*II). Byly zjištěny tyto frekvence alel pro *GH1-Hae*II: + = 0,54 a – = 0,46; *GH1-Msp*I: + = 0,85 a – = 0,15; *LEP*: *T* = 0,65 a *C* = 0,35 a pro *MYC*: *A* = 0,82 a *B* = 0,18. *RYR1* byl monomorfní, *C* = 1,00. Asociace genů s produkčními vlastnostmi byly hodnoceny GLM procedurou (SAS, 2000). Polymorfizmy *GH1* (*Hae*II a *Msp*I) neměly vliv na proměnlivost hodnocených ukazatelů produkce masa, *GH1-Msp*I ovlivňoval průměrný denní přírůstek (+/+ = 582,44 ± 7,02 g/den vs. +/– = 599,85 ± 8,54 g/den; $P \leq 0,05$). *LEP* se značně podílel na průměrném denním přírůstku (*TT* = 578,55 ± 10,73 g/den vs. *TC* = 597,39 ± 11,27 g/den; $P \leq 0,01$),

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na výšce hřbetního tuku (*TT* = 9,04 ± 0,52 mm vs. *TC* = 8,03 ± 0,54 mm; $P \leq 0,01$) a na procentu libového masa (*TT* = 59,88 ± 0,42 % vs. *TC* = 60,36 ± 0,54 % a *CC* = 60,91 ± 0,52 %; $P \leq 0,05$). Genotypy *MYC* měly vliv na průměrný denní přírůstek (*AB* = 565,22 ± 10,79 g/den vs. *AA* = 594,82 ± 9,78 g/den, $P \leq 0,001$; *AB* vs. *BB* = 608,66 ± 19,28 g/den, $P \leq 0,05$) a průměrný denní přírůstek v testu (*AA* = 966,93 ± 19,94 g/den vs. *AB* = 929,87 ± 21,96 g/den; $P \leq 0,01$). Tyto výsledky však musí být prověřeny na další a větší populaci prasat plemene durok.

Klíčová slova: *RYR1*; *GH1*; *LEP*; *MYC*; produkce masa; prase; durok

Recent research effort in the field of molecular genetics has brought about a nearly exponential growth of information about numerous genes determining variability of performance traits of farm animals. In pigs the research has been focused on intensive studies on marker genes affecting meat production and meat quality.

HAL (halothane sensitivity) gene, lately known as *RYR1* (ryanodine receptor) or *CRC* (calcium channel of sarcoplasmatic reticulum of muscular cells) gene, controlling sensitivity of pigs to stress factors has already been studied for three decades. The gene was mapped to the chromosome region 6q12 (Chowdhary *et al.*, 1994). It is well documented (Sellier, 1995; Pommier *et al.*, 1998) that *T* allele at *RYR1* locus, corresponding to recessive HAL^n allele, is positively associated with increased proportion of lean meat in the carcass and inferior quality of pork (PSE meat).

Growth hormone (*GH1*) gene was mapped to the chromosome region 12p14 (Chowdhary *et al.*, 1994). Results of association studies of different variants of *GH1* gene with meat production are not consistent. Knorr *et al.* (1997) analysed associations of *GH1* genotypes (*Apa*I and *Hin*PI) in informative families and found a significant effect on eight traits of carcass quality of pigs. Nielsen and Sörensen (1998) studied polymorphism of two alleles of *GH1* gene promoter in TATA box and did not find any differences between homozygous genotypes. Pierzchala *et al.* (1999) studied associations of polymorphism of *GH1-Hae*II and *Msp*I loci. Analysed *GH1* genotypes as well as *Hae*II-*Msp*I haplotypes differed significantly in percentages of lean meat and in several traits of carcass fatness. Cheng *et al.* (2000) studied polymorphism of *GH1* (*Taq*I, *Dra*I) and intensity of growth in pigs of Duroc, Landrace and Tao-Yuan breeds. A significant effect of *GH1* gene was found only in Tao-Yuan breed.

Leptin encoded by *LEP* gene is expressed mainly in adipose tissue. It is expected that this gene controls feed intake and energy output. For this reason it represents a very interesting candidate gene for meat production. *LEP* gene was mapped to the chromosome region 18q13-q21 (Cepica *et al.*, 1999). Stratil *et al.* (1997) described polymorphism of this gene using the restriction enzyme *Hin*fI that is characterised by the substitution T3469C in the second exon. This is, however, a silent mutation (Jiang and Gibson, 1999). Hardge *et al.* (1998) found an association of *LEP* gene polymorphism with the meat to fat ratio in informative families derived from Berlin miniature pigs × Duroc. No effect of this gene on meat production was found in commercial lines. Jiang and Gibson (1999) studied (also with *Hin*fI) four types of genetic polymorphism of *LEP* gene and their associations with fatness in four breeds, including Duroc. Animals under study were classified according to the maximum and minimum backfat thickness estimated by ultrasound at the weight of 100 kg. These authors did not find any differences in frequencies of alleles in both selected groups; the only exception was the group of pigs related to the Large White breed. Hardge *et al.* (2000) analysed polymorphism of *LEP* gene in progeny of informative families. They corroborated significant associations of *LEP* - *Hin*fI locus with parameters of fatness; however, the evidence for linkage by means of quantitative transmission disequilibrium test did not account for the significant association between LEP gene variants and different backfat measurements. Kulig *et al.* (2001) investigated effects of *LEP-Hin*fI locus on growth intensity and parameters of carcass quality in pigs of Landrace breed. Significant differences between genotypes were found for lean meat content and average daily gains. Kennes *et al.* (2001) analysed four types of *LEP* polymorphism in Yorkshire, Landrace and Duroc breeds. Their results showed that in pig populations under study these polymorphisms were of low frequency or were absent. In Landrace breed, two types of polymorphism were highly significantly associated with feed intake and growth intensity.

MYC (MYC protooncogene protein [*C-MYC*]) encodes a nuclear phosphoprotein, i.e. a transcription factor the key importance of which was described in association with adipogenesis, myogenesis and follicle-genesis. *MYC* gene was mapped to the chromosome region 4p14 (Musilova *et al.*, 2000). Recent studies indicate the existence of associations between *MYC* genotypes and carcass quality and interaction among genotypes of *MYC* and *RYR1* genes (Reiner *et al.*, 1999).

The aim of this paper was to study associations of *RYR1*, *GH1*, *LEP*, and *MYC* genes with parameters of meat and fat production in Duroc breed. A unified field test was used for this purpose.

MATERIAL AND METHODS

Experimental animals

The unified field fattening experiment involved 117 pigs of Duroc breed (57 boars and 60 gilts). The number of animals for individual traits varied due to missing records (n = 86–117). A predominant number of animals (83%) were tested with the purpose of estimating the breeding value of Duroc boars from a nucleus herd.

Field tests were carried out in one year for a period of 9 weeks ± 7 days. At the beginning of the experiment, the age of animals was 12 weeks ± 4 days. Only healthy and normally developed piglets were placed into pens one or two weeks before the beginning of the fattening test. There were 6–12 piglets of the same sex in each pen. The standard feed mixture Testa was fed *ad libitum* to animals during the whole experiment.

Meat production evaluation

Records were taken for birth weight, weight at the beginning and toward the end of fattening period. In young boars and gilts, average daily gains recorded since birth (ADG; g) and within the test period (ADGT; g) were adjusted to the weight of 100 kg and 90 kg, respectively. At the end of test period, ultrasound measurements of backfat thickness were carried out according to standard methodology (ČSN 46 6164) at two points T_1 and T_2 (mm) at the distance of 7 cm laterally from the middle of backbone in the loin region. Records were used for the calculation of average backfat thickness (ABF; mm); the calculated value was corrected to uniform body weight according to sex (like above). The percentage of lean meat (LM; %) and the area of *musculus longissimus lumborum et thoracis* (MLD; cm^2) were calculated on the basis of data obtained by means of the apparatus PIGLOG 105 with correction to 100 kg, both in boars and gilts.

Genotype determination

Genotyping of *RYR1* (Brening and Brem, 1992), *GH1* (Schellander *et al.*, 1994), *LEP* (Stratil *et al.*, 1997), and *MYC* (Reiner *et al.*, 2000) was performed by means of PCR-RFLP technique.

Statistical methods

Genetic equilibrium of analysed population was evaluated on the basis of χ^2 test. Associations of candidate gene genotypes with phenotypic parameters of production traits were analysed by means of the GLM procedure (SAS, 2000) using a model equation with fixed and random effects:

$$y_{ijklm} = \mu + SEX_i + GHHAE_j + GHMSP_k + LEP_l + MYC_m + b.W_{ijklm} + e_{ijklm}$$

where: y_{ijklm} = *ijklm* observation
μ = mean of population
SEX_i = effect of *i*th sex (i = 1, 2)
$GHHAE_j$ = effect of *j*th genotype of *GH1-Hae*II (j = 1, 2, 3)
$GHMSP_k$ = effect of *k*th genotype of *GH1-Msp*I (k = 1, 2, 3)
LEP_l = effect of *l*th genotype of *LEP* (l = 1, 2, 3)
MYC_m = effect of *m*th genotype of *MYC* (m = 1, 2, 3)
$b.W_{ijklm}$ = regression of *ijklm*th observation on standard weight
e_{ijklm} = residual effects

The observed associations of candidate gene genotypes with meat and fat production traits were evaluated for individual genotypes using LSM ± SE (least squares means ± standard error) and significance of their differences at $P \leq 0.05$; $P \leq 0.01$ and $P \leq 0.001$.

RESULTS AND DISCUSSION

Allele and genotype frequencies of four polymorphic loci (*GH1-Hae*II, *GH1-Msp*I, *LEP* and *MYC*) in 117 animals of the Duroc breed are presented in Table 1. Genotype frequencies at all four polymorphic loci followed Hardy-Weinberg equilibrium ($P \leq 0.001$).

Frequencies of genotypes and alleles at *GH1-Hae*II and *GH1-Msp*I loci were estimated earlier (Křenková *et al.*, 1999) in hybrid pigs (Large White × Landrace and boars Large White or Large White × Piétrain). For loci *GH1-Hae*II and *GH1-Msp*I, the allele frequencies were + = 0.65 ± 0.04 and – = 0.35 ± 0.04 and + = 0.81 ± 0.03 and – = 0.19 ± 0.03, respectively.

Frequencies of alleles at *LEP* gene were previously studied in our laboratory in a hybrid population of pigs (Křenková *et al.*, 1999) with the following result: $T = 0.91 \pm 0.03$ and $C = 0.09 \pm 0.03$. Kennes *et al.* (2001) found a very low frequency of *C* allele in Duroc breed.

Reiner *et al.* (1999) studied polymorphism of *MYC* gene in 308 and 325 hybrids of F_2 generation from two informative families (Meishan × Piétrain and Wild Boar × Piétrain, respectively) and found the following frequencies of *A* and *B* alleles: $A = 0.53 \pm 0.02$, $B = 0.47 \pm 0.02$ and $A = 0.57 \pm 0.02$, $B = 0.43 \pm 0.02$, respectively. In the population under study *RYR1* gene was monomorphic with *C* allele fixed. This is in agreement with data published previously for allele frequencies at *HAL* locus (Webb, 1980). Contrary to it, Dvořák (personal communication) also found allele *T* with frequencies 0.29 and 0.12, respectively, in two groups of Duroc pigs kept in the Czech Republic. This discrepancy can be explained by possible crossing of Duroc in some herds kept in the Czech Republic with other breeds, probably with Piétrain, with the goal to improve meatiness.

The results of GLM analyses are presented in Table 2. For individual effects, the values of coefficients of determination ranged from 9.9% for ABF to 71.6% for ADGT.

A highly significant effect of sex was observed in the case of ADG, MLD and LM. The effect of sex on parameters of meat production is generally acknowledged and many authors suggest separated fattening according to sex to reach a higher efficiency.

With the exception of ADG ($P < 0.098$), neither of *GH1* loci under study (*GH1-Hae*II and *GH1-Msp*I) showed any effect on the variability of evaluated parameters of meat production in Duroc. *LEP* gene contributed ($P \leq 0.04$) to ADG, backfat thickness at T_2 and percentage of LM. Genotypes of *MYC* showed an effect on both ADG ($P \leq 0.001$) and ADGT ($P \leq 0.08$).

The observed significant associations of individual genotypes of marker genes with phenotypic parameters of meat and fat production are presented in Table 3. Differences ($P \leq 0.05$) between genotypes *GH1-Msp*I +/+ and +/– were found for ADG (582.44 ± 7.02 g/d and 599.85 ± 8.54 g/d, respectively). Associations observed in our earlier study (Křenková *et al.*, 1999) in 95 hybrid pigs (Large White × Landrace) × Large White and (Large White × Landrace) × (Large White × Piétrain) were not corroborated in this experiment.

Highly significant differences were found between *LEP* genotypes *TT* (578.55 ± 10.73 g/day) and *TC* (597.39 ± 11.27 g/day) for ADG. In the population under study, differences ($P \leq 0.05$) in LM between genotypes *TT* (59.88 ± 0.42%) and *TC* (60.36 ± 0.45%) and genotypes *TT* and *CC* (60.91 ± 0.52%) were determined. Highly signifi-

Table 1. Genotype and allele frequencies of candidate genes in Duroc pig population

Gene	Genotype frequencies			Allelic frequencies	
*GH1-Hae*II	++	+ –	– –	+	–
	0.28	0.51	0.21	0.54 ± 0.03	0.46 ± 0.03
*GH1-Msp*I	++	+ –	– –	+	–
	0.72	0.26	0.02	0.85 ± 0.02	0.15 ± 0.02
LEP	*TT*	*TC*	*CC*	*T*	*C*
	0.40	0,49	0.11	0.65 ± 0.03	0.35 ± 0.03
MYC	*AA*	*AB*	*BB*	*A*	*B*
	0.69	0.27	0.04	0.82 ± 0.02	0.18 ± 0.02

Table 2. GLM analysis – determination coefficients (R^2) and significant values (P) of the effects

Meat parameters	n	Model						
		R^2 (%)	SEX P	*GH1-Hae*II P	*GH1-Msp*I P	*LEP* P	*MYC* P	W P
ADG	117	47.7	**<0.0001**	0.5011	*0.0981*	**0.0412**	**0.0007**	**<.0001**
ADGT	109	71.6	0.3017	0.5033	0.1454	0.3800	*0.0821*	**<.0001**
ABF	117	9.9	0.9779	0.9352	0.4161	0.2894	0.9554	**0.0463**
T1	86	34.6	0.0796	0.7934	0.9186	0.2330	0.2405	**<.0001**
T2	86	18.7	0.2700	0.2026	0.1923	**0.0463**	0.9813	**0.0341**
MLD	86	42.9	**0.0077**	0.8392	0.5687	0.8826	0.6870	**<.0001**
LM	116	22.8	**0.0081**	0.7211	0.9991	**0.0476**	0.9479	**0.0153**

ADG = average daily gain (g); ADGT = average daily gain in test (g) (from 30 to 100 kg live weight); ABF = average backfat thickness (mm); T1, T2 = backfat thickness at two points (mm); MLD = area of *musculus longissimus lumborum et thoracis* (cm^2); LM = lean meat (%); W = regression on standard weight

cant differences ($P \leq 0.01$) in T_2 values were found between genotypes *TT* (9.04 ± 0.52 mm) and *TC* (8.03 ± 0.54 mm). Kulig *et al.* (2001) detected significant differences between individual genotypes of Landrace breed in percentage of LM and in ADG. Contrary to that Kennes *et al.* (2001) reported insignificant differences between *LEP-Hin*fI genotypes in growth rate and fatness for Duroc breed. The results published by Jiang and Gibson (1999) were not conclusive either.

For *MYC* the differences between genotypes *AA* and *AB* were found in ADG (*AA* = 594.82 ± 9.78 g per day vs. *AB* = 565.22 ± 10.79 g/d; $P \leq 0.001$) and the difference between genotypes *AB* and *BB* (608.66 ± 19.28 g/d; $P \leq 0.01$). As far as the values of ADGT were concerned, a difference ($P \leq 0.01$) was found between genotypes *AA* (966.93 ± 19.94 g per day) and *AB* (929.87 ± 21.96 g/d). Reiner *et al.* (1999) found highly significant differences between genotypes *AA*, *AB* and *BB* in backfat weight and

Table 3. Associations of the genotypes of candidate genes with meat parameters of pigs (least-squares means LSM ± standard error SE)

Gene	Genotypes		
*GH1-Msp*I	++	+ –	– –
ADG	582.44^{a} ± 7.02	599.85^{a} ± 8.54	586.41 ± 26.67
LEP	*TT*	*TC*	*CC*
ADG	578.77^{A} ± 10.73	597.39^{A} ± 11.27	592.53 ± 14.54
LM	59.88^{ab} ± 0.42	60.36^{a} ± 0.45	60.61^{b} ± 0.52
T2	9.04^{A} ± 0.52	8.03^{A} ± 0.54	8.66 ± 0.69
MYC	*AA*	*AB*	*BB*
ADG	594.82^{A} ± 9.78	565.22^{Ab} ± 10.79	608.66^{b} ± 19.28
ADGT	966.93^{A} ± 19.94	929.87^{A} ± 21.96	959.24 ± 42.88

Values with the same exponents show significant differences in rows: ^{a} = $P \leq 0.05$; ^{A} = $P \leq 0.01$; ^{A} = $P \leq 0.001$. ADG = average daily gain (g); ADGT = average daily gain in test (g) (from 30 to 100 kg live weight); ABF = average backfat thickness (mm); T1, T2 = backfat thickness at two points (mm); MLD = area of *musculus longissimus lumborum et thoracis* (cm^2); LM = lean meat (%)

ham fat weight in three nucleus F_2 populations originating from Meishan, Piétrain, and wild boar.

The results presented here indicate the existence of significant associations between the polymorphisms of *GH1-Msp*I, *LEP, and MYC* genes on the one hand and growth rate and fat deposition on the other in Duroc pigs. As the *LEP-Hin*fI mutation is silent, it seems to be probable that linkage disequilibrium with another mutation explains the observed significant associations. Knorr *et al.* (1997), however, mentioned that in commercial populations these associations require further studies.

The results presented here were obtained on a relatively small number of animals. Their verification needs further study performed in a larger population.

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Corresponding Author

Dr. Ing. Tomáš Urban, Mendelova zemědělská a lesnická univerzita, Zemědělská l, 613 00 Brno, Česká republika
Tel. +420 545 133 182, e-mail: urban@mendelu.cz

Effect of early feed restriction on growth in broiler chickens, turkeys and rabbits

Vliv rané restrikce na růst brojlerových kuřat, krůt a králíků

E. Tůmová[1], M. Skřivan[1], V. Skřivanová[2], L. Kacerovská[1]

[1]Czech University of Agriculture, Prague, Czech Republic
[2]Research Institute of Animal Production, Prague-Uhříněves, Czech Republic

ABSTRACT: The effect of quantitative feed restriction was studied in broiler chickens, turkeys and rabbits. Day-old male and female broiler chickens were split into 3 groups. The chickens of control group (group 1) were fed *ad libitum*, in group 2 they were restricted from 7 to 14 days of age (8 g per day/chick), and group 3 was restricted from 7 to 11 days of age (6 g per day/chick). Sexed poults were divided into 3 groups: group 1 was fed *ad libitum*, group 2 was restricted from 8 to 21 days of age (20 g per day/poult), and group 3 was restricted from 8 to 17 days of age (15 g per day/poult). Broiler rabbits were also split into 3 groups: group 1 was fed *ad libitum*, group 2 was restricted from 35 to 42 days of age (50 g per day/rabbit) and group 3 was restricted from 42 to 49 days of age (65 g per day/rabbit). Following the restriction period the animals were fed *ad libitum*. Compensatory growth was observed in broiler chickens (cockerels and pullets). At the end of the experiment full-fed cockerels weighed 2 079 g, and restricted ones 2 090 g and 2 150 g, respectively. Restricted pullets were insignificantly ($P > 0.05$) heavier (1 920 g and 1 911 g) than those fed *ad libitum* (1 852 g). In tom-turkeys compensatory growth occurred in the second half of the growth period and restricted tom-turkeys had higher live weight (9 461 g and 9 089 g) than unrestricted ones (9 032 g). Broiler rabbits compensated growth for the whole realimentation period. Restricted female turkeys had lower live weight (3 704 g and 3 742 g) than control turkeys fed *ad libitum* (3 907 g).

Keywords: restriction; growth; feed conversion; chicken; turkey; rabbit

ABSTRAKT: Byl sledován vliv kvantitativní restrikce na růst brojlerových kuřat, krůt a králíků. V pokusu 1 byli kohoutci a kuřičky rozděleni do tří skupin: skupina 1 byla krmena *ad libitum*, skupina 2 byla restringována mezi 7. až 14. dnem věku (8 g krmiva na kus a den) a skupina 3 měla restrikci mezi 7. až 11. dnem věku (6 g krmiva na kus a den). V pokusu 2 se sexovanými krůťaty byly tři skupiny: skupina 1 krmená *ad libitum*, skupina 2 restringovaná v období od 8 do 21 dnů věku (20 g krmiva na ks a den) a skupina 3 byla restringována od 8. do 17. dne věku (15 g krmiva na ks a den). V pokusu 3 s brojlerovými králíky byly také tři skupiny: skupina 1 krmená *ad libitum*, skupina 2 s restrikcí mezi 35. a 42. dnem věku (50 g krmiva na ks a den), skupina 3 byla restringována mezi 42. až 49. dnem věku (65 g krmiva na ks a den). Po skončení restrikce následovalo krmení *ad libitum*. Kompenzace růstu po restrikci byla zaznamenána u brojlerových kuřat a krocanů ve druhé polovině výkrmu a u králíků od skončení restrikce do konce výkrmu. Nerestringonaní kohoutci vážili na konci pokusu 2 090 g resp. 2 150 g zatímco kohoutci krmení *ad libitum* 2 079 g. Také restringované kuřičky byly na konci pokusu nesignifikantně ($P > 0,05$) těžší – 1 920 g a 1 911 g než kuřice krmené *ad libitum* (1 852 g). U krocanů restrikce zvýšila živou hmotnost na konci výkrmu (9 461 g a 9 089 g) proti krocanům krmeným *ad libitum* (9 032 g). Brojlerové krůty do 84 dnů věku živou hmotnost nevykompenzovaly; měly živou hmotnost nižší (3 074 g a 3 742 g) ve srovnání s krůtami krmenými *ad libitum* (3 907 g).

Klíčová slova: restrikce; růst; konverze krmiva; kuře; krůta, králík

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Feeding strategy in growing broiler chickens, turkeys and rabbits should be to produce animals with maximum lean body mass, highest feed conversion ratio and maximum body weight. Continuous genetic selection and improvement in nutrition have led to a very fast growth rate in modern strains. The early-life fast growth rate is accompanied by a number of problems, namely increased body fat deposition, high incidence of metabolic disorders, high mortality, and high incidence of skeletal diseases. To tackle with these problems early nutrient restriction programmes were used (Plavnik and Hurwitz, 1985, 1988, 1991; Yu and Robinson, 1992; Skřivan and Tůmová, 1991, 1995; Dunnington and Siegel, 1998; Lipens *et al.*, 2000; Mazzuco *et al.*, 2000; Lee and Leeson, 2001). Limiting feed intake depresses growth during the period of restriction, but reduced growth can be later compensated by realimentation (Plavnik and Hurwitz, 1985, 1988; Acar *et al.*, 1995; Zubair and Leeson, 1996; Govaerts *et al.*, 2000). During the period of compensatory growth feed efficiency can be improved (Washburn, 1990; Plavnik and Hurwitz, 1991; Susbilla *et al.*, 1994), and body fat can be reduced (Washburn, 1990; Plavnik and Hurwitz, 1988; Ferket and Sell, 1990). Plavnik and Hurwitz (1985), Jones and Farrel (1992) reported that restricted chickens did not show a decrease in abdominal fat content. Effects of restricted feeding on growth, feed efficiency and fatness depend on a number of factors such as market age, intensity of restriction, sex and strain.

Compensatory growth has been studied in a number of animals. The phenomenon of accelerated growth following a period of feed restriction was originally observed by Osborne and Mendel (1915). Bohmann (1955) defined compensatory growth as growth that is faster than normal after a period of nutrient restriction. Since that time many studies have reported the occurrence of compensatory growth in broiler chickens (Plavnik and Hurwitz, 1985, 1988, 1991; Jones and Farrel, 1992; Zubair and Leeson, 1996; Mazzuco *et al.*, 2000). Plavnik and Hurwitz (1985) found out in their studies that broiler chickens restricted in energy intake for 6 days, starting at 1 week of age, resulted in birds with similar body weights at 8 weeks of age. A number of papers confirmed the original study (Plavnik and Hurwitz, 1988, 1989, 1991; Rosebrough *et al.*, 1988; Skřivan and Tůmová, 1995; Lipens *et al.*, 2000; Mazzuco *et al.*, 2000). Male broilers have a greater ability to exhibit compensatory growth following a period of undernutrition than females (McMurtry *et al.*, 1988; Plavnik and Hurwitz, 1991).

The phenomenon of compensatory growth was observed in turkeys after moderate protein restriction during early development. Auckland and Morris (1969, 1971a,b) administered 70% of protein required for a maximum growth rate to medium-sized tom-turkeys for 6 weeks after hatching and found out that subsequent body weight gain and feed efficiency were improved in comparison with full-fed control. Moran (1979) reported that compensatory growth during 5 to 8 week of age corrected gain and fleshing while additional finish continued. Compensatory growth after protein restriction was described by Hester *et al.* (1990), Ferket and Sell (1990), Plavnik and Hurwitz (1990), Skřivan and Tůmová (1995). Compensatory growth in turkeys reduced feed intake and increased feed efficiency (Plavnik and Hurwitz, 1990; Ferket and Sell, 1990; Skřivan and Tůmová, 1995). In turkeys, early feed restriction did not affect carcass fat at marketing age (Ferket and Sell, 1990, Plavnik and Hurwitz, 1990).

As a consequence of favourable experience in other animal species and poultry studies on the application of restricted feeding were also initiated in rabbits (Osman, 1991; Osman and Tawfik, 1994; Schlolaut and Lange, 1990; Tawfeek, 1996; Jerome *et al.*, 1998). Restricted feeding induced compensatory growth and improved feed efficiency (Maartens and Peeters, 1988; Szendro *et al.*, 1989; Schlolaut and Lange, 1990; Perrier and Ouhayoun, 1996), reduced body fat (Perrier and Ouhayoun, 1996; Jerome *et al.*, 1998; Perrier, 1998) and did not affect mortality (Osman, 1991; Osman and Tawfik, 1994).

In the present study quantitative feed restriction was used in male and female broiler chickens, turkeys and rabbits. Experiments described the effects of early-life feed restriction on performance and growth. The experiments were carried out in the period from 1993 to 2000.

MATERIAL AND METHODS

Experiment 1

Commercial male and female, day-old broiler chickens (ROSS 208) were wing banded and assigned into 24 separate floor pens with 20 birds per

Table 1. Feed formulation and analyses (%)

Ingredient	Chickens		Turkeys				Rabbits
	days of age						
	1–21	22–49	1–28	29–63	64–84	84–140	35–84
Fish meal	1.5	1	9.4	4.5	1.5	–	–
Meat and bone meal	2.75	2	3.8	3	–	1.2	–
Yeasts	1.75	1	5.24	2	1	0.8	–
Blood meal	–	–	–	–	0.4	0.32	–
Blood flakes	–	–	–	–	1.6	1.28	–
Soybean meal	23	20	33.6	25.5	21.5	13.4	3
Sunflower meal	–	–	–	–	–	–	17
Corn	20	23.5	25	25	35	40	–
Wheat	46	47.5	19	36	34	39	–
Barley	–	–	–	–	–	–	8
Oats	–	–	–	–	–	–	9
Lucerne meal	–	–	–	–	–	–	30
Wheat bran	–	–	–	–	–	–	22.5
Sugar-beet pulp	–	–	–	–	–	–	6
Rapeseed oil	–	–	–	–	–	–	1.5
Vitamin supplement	4[a]	4[b]	1[c]	1[d]	1[e]	1[e]	1[f]
Mineral supplement	1[g]	1[g]	3[h]	3[h]	4[h]	3[h]	–
Ground limestone	–	–	–	–	–	–	1
Dicalcium phosphate	–	–	–	–	–	–	0.5
Feeding salt	–	–	–	–	–	–	0.5
Chemical composition (%)							
Dry matter	88.18	89.50	90.96	94.02	93.58	93.76	91.45
Crude protein	21.80	18.84	27.4	23.23	20.34	17.53	17.52
Fat	1.82	3.58	4.11	3.27	2.52	2.99	2.62
Fibre	2.8	3.41	2.3	3.21	2.74	2.27	19.39
Ash	7.81	6.52	10.06	6.28	5.93	4.86	8.02
Ca	1.01	0.91	1.46	1.06	0.87	0.70	–
P	0.52	0.67	0.50	0.86	0.76	0.58	–
ME (MJ/kg)	11.2	11.7	11.4	11.6	11.7	12.0	–

[a]Composition of vitamin supplement: vitamin A 2 000 000 i.u., vitamin D_3 400 000 i.u., vitamin B_1 400 mg, vitamin B_2 800 mg, vitamin B_6 800 mg, vitamin B_{12} 4 mg, vitamin E 2 000 mg, vitamin K_3 400 mg, niacin 4 000 mg, calcium pantothenate 20 000 mg, choline-chloride 50 000 mg, methionine 50 000 mg, neox 20 000 mg, lerbek 100 000 mg, vehiculum ad 1 kg

[b]Composition of vitamin supplement: vitamin A 1 600 000 i.u., vitamin D_3 160 000 i.u., vitamin B_2 600 mg, vitamin B_{12} 4 mg, vitamin E 2 000 mg, vitamin K_3 400 mg, methionine 200 000 mg, neox 20 000 mg, cygro 100 000 mg, vehiculum ad 1 kg

pen. The experiment was split into 3 groups, each group included 4 replications with 20 cockerels or pullets. The chickens, 16 individuals per m^2, were housed on wood shavings litter in a room maintained at 32°C with gradual reduction in temperature to 20°C by 28 days of age. Continuous lighting was provided. The chickens of all groups had 5 cm of feeding space and 3 cm of watering space. They were watered *ad libitum*.

The experiment was terminated at 49 days of chicken age. All chickens received commercial broiler diets, one diet from 1 to 21 days, the other from 22 to 49 days of age. The composition of feed mixtures is given in Table 1. The chickens of control group (group 1) were fed *ad libitum*, in group 2 they were restricted from 7 to 14 days of age (8 g per day/chick), and group 3 was restricted from 7 to 11 days of age (6 g per day/chick). Following the restriction period, the chickens were fed *ad libitum*.

The chickens were weighed individually at week intervals. Feed intake on a group basis was also recorded at that time. Mortality was recorded in groups over the whole period of fattening.

Experiment 2

A total of 360 sexed day-old turkey poults of medium type, Hybrid Heavy Medium, were placed in 18 littered boxes (each box contained 20 poults). Three boxes formed one group. Turkeys were housed on wood shavings litter, 5 individuals per m^2. The temperature was maintained at 38°C with gradual reduction to 20°C by 42 days of age. Light was provided for 24 h each day. Turkeys of all groups had 4 cm of feeding space and 3 cm of watering space. Watering was *ad libitum*.

Turkey-hens were fattened to 12 weeks and tom-turkeys to 20 weeks of age. The experiment was conducted in four periods – period 1: up to 4 weeks of age, period 2: up to 9 weeks, period 3: up to 12 weeks, period 4: up to 20 weeks of age. All birds received commercial diets for turkeys. The composition of feed mixtures is given in Table 1. Group 1 was fed *ad libitum*, group 2 was restricted from 8 to 21 days of age (20 g per day/poult), and group 3 was restricted from 8 to 17 days of age (15 g per day/poult). Following the restriction period the turkeys were fed *ad libitum*.

The growth of turkeys was checked by individual weighing at week intervals, feed consumption in groups was recorded also weekly. Mortality was recorded in groups during the whole experiment.

Experiment 3

Thirty male and female Hyplus rabbits of weaning stage (35 days of age) were used in this experiment. The rabbits were placed in individual cages, and given 0.15 m^2 per pen. The temperature of 16°C and relative humidity 55% were maintained for the whole period of fattening. A twelve-hour photoperiod was used. Water was available *ad libitum*.

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[c] Composition of vitamin supplement: vitamin A 1 600 000 i.u., vitamin D_3 320 000 i.u., vitamin B_2 500 mg, vitamin B_{12} 2 mg., vitamin E 3 000 mg, vitamin K_3 200 mg, niacin 6 000 mg, calcium pantothenate 1 500 mg, choline-chloride 7 500 mg, nitrovin 1 200 mg, neox 20 000 mg, dimetridazol 15 000 mg, stenaval 50 000 mg, vehiculum ad 1 kg

[d] Composition of vitamin supplement: vitamin A 1 600 000 i.u., vitamin D_3 320 000 i.u., vitamin B_2 600 mg, vitamin B_{12} 2 mg, vitamin E 4 000 mg, vitamin K_3 200 mg, niacin 4 500 mg, methionine 50 000 mg, calcium pantothenate 1500 mg, neox 20 000 mg, vehiculum ad 1 kg

[e] Composition of vitamin supplement: vitamin A 1 000 000 i.u., vitamin D_3 200 000 i.u., vitamin E 4 000 mg, choline-chloride 10 000 mg, manganese carbonate 2 000 mg, vehiculum ad 1 kg

[f] Composition of mineral supplement: mineral supplement II 10%, fodder limestone 18%, dicalcium phosphate 16%, feeding salt 3%, wheat flour 51%

[g] Composition of mineral supplement: mineral supplement MD II 10%, fodder limestone 28%, dicalcium phosphate 42%, feeding salt 5%, wheat flour 15%

[h] Composition of vitamin and mineral supplement: vitamin A 1 200 000 i.u., vitamin D_3 200 000 i.u., alpha tocopherol 5 000 mg, vitamin K_3 100 mg, vitamin B_1 200 mg, vitamin B_2 700 mg, vitamin B_6 400 mg, vitamin B_{12} 2 mg, niacin 5 000 mg, calcium pantothenate 2 000 mg, choline 60 000 mg, biotin 20 mg, folic acid 50 mg, antioxidant 10 000 mg, Diclazuril 100 000 mg, DL-methionine 100 000 mg, L-lysine HCl 25 000 mg, cobalt 30 mg, copper 800 mg, iron 2 700 mg, iodine 50 mg, manganese 1 900 mg, zinc 4 400 mg, selenium 7 mg

The rabbits were fattened to 84 days of age. The rabbits were divided into 3 groups (10 rabbits per group); group 1 was fed *ad libitum*, group 2 was restricted from 35 to 42 days of age (50 g per day per rabbit) and group 3 was restricted from 42 to 49 days of age (65 g per day/rabbit). Following the restriction period the rabbits were fed *ad libitum*. All rabbits received a commercial diet, its composition is given in Table 1.

The growth and feed consumption were measured individually in a week interval. Mortality was recorded in groups over the whole period of fattening.

Statistical analysis

Data were analysed by one-way analysis of variance using the ANOVA procedure of SAS (SAS Institute 1989). The means were compared by Scheffe's test ($P < 0.05$), where appropriate.

RESULTS AND DISCUSSION

Experiment 1

Daily weight gain in cockerels (Figure 1) was reduced about 50–70% during the restriction period. Feed restriction resulted in accelerated growth and at the age of 21 days daily weight gain was similar in restricted and full-fed cockerels. In the second half of the growth period, from the age 35 days, daily weight gain of restricted chickens was higher about 15% than in full-fed. Compensatory growth resulted in a minimisation of the difference in body weight between restricted and control birds at 49 days of age (Table 2). The present study confirms previous observations (Plavnik and Hurwitz, 1985, 1988, 1989; Leeson *et al.*, 1991; Acar *et al.*, 1995; Mazzuco *et al.*, 2000) that the period of restriction did not affect market body weight. In group 3, shorter restriction, growth compensation was higher than in group 2. This results supported the study of Plavnik and Hurwitz (1991) that in the mildest regimens, body weights reached slightly higher values than those of the *ad libitum* fed chickens. Jones and Farrell (1992), Lee and Leeson (2001) also considered that full body weight recovery could be realised more consistently if a number of short restriction periods were used instead of the long ones.

Growth of pullets (Figure 2) was similar to the growth of cockerels during restriction and realimentation periods. From the age of 21 days daily weight gain of restricted pullets was higher by 10% than in full-fed ones. At the age 49 of days restricted pullets were insignificantly ($P < 0.05$) heavier than full-fed ones (Table 2). Live weight at the age of 49 days was similar in both restricted groups. It seems that the responses of pullets to early-life feed restriction are less pronounced than those in coc-

Table 2. Fattening characteristics in chickens (mean ± SD)

Measurement	Treatmen/sex					
	ad libitum		restriction 7–14th day of age		restriction 7–11th day of age	
	cockerels	pullets	cockerels	pullets	cockerels	pullets
Live weight 1st day of age (g)	38.62 ± 0.33	38.14 ± 0.38	38.56 ± 0.39	38.50 ± 0.40	38.68 ± 0.36	38.42 ± 0.35
Live weight 49th day of age (g)	2079 ± 34.49	1852 ± 32.41	2090 ± 39.97	1920 ± 24.26	2150 ± 32.11	1911 ± 36.63
Weight gain 1–49th day of age (g)	41.84 ± 1.87	37.01 ± 1.23	41.86 ± 1.11	38.39 ± 1.63	43.09 ± 2.02	38.22 ± 1.80
Feed intake (per day/chicken) (g)	82.45 ± 3.38	80.21 ± 3.70	77.86 ± 1.79	76.37 ± 0.96	76.12 ± 2.25	73.01 ± 1.44
Feed conversion (kg)	1.95 ± 0.09	2.14 ± 0.08	1.84 ± 0.11	2.00 ± 0.10	1.78 ± 0.08	1.91 ± 0.09
Mortality	5	3	2	1	2	1

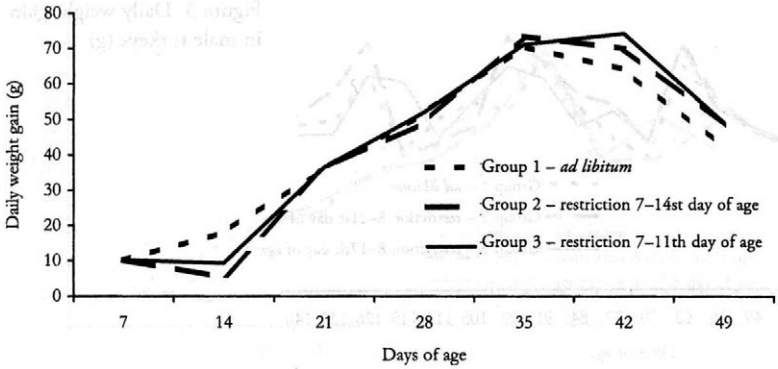

Figure 1. Daily weight gain in cockerels (g)

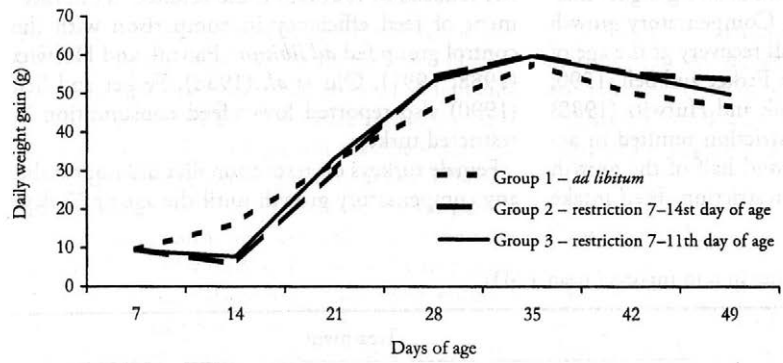

Figure 2. Daily weight gain in pullets (g)

kerels. Plavnik and Hurwitz (1991) suggested that cockerels have greater ability to exhibit compensatory growth following the period of undernutrition than pullets.

Restricted cockerels and pullets compensated weight gain during the first week following the restriction and at the age of 21 days weight gains of restricted and unrestricted chickens were the same. In the period from 22 to 35 days of age restricted and full-fed cockerels grew similarly, but restricted pullets had higher weight gain than those fed *ad libitum*. From 35 days of age restricted chickens of both sexes grew faster than full-fed chickens.

For both sexes, feed utilisation by restricted birds was better than by full-fed ones. Differences between the groups were not significant. Feed is the most expensive item in broiler production and a way of reducing this cost is to restrict feed in the early life of chickens (Plavnik and Hurwitz, 1985, 1988, 1989; Acar *et al.*, 1995; Tůmová, 1993; Skřivan and Tůmová, 1995; Lee and Leeson, 2001).

Feed restriction regimens can reduce mortality. In the present study, mortality was reduced in restricted groups of cockerels and pullets. Feed restriction slows down fast growth to reduce late mortality (Tůmová, 1993), including preascites and ascites (Acar *et al.*, 1995). Feed restriction decreased mortality caused by "sudden death syndrome" (Lippens *et al.*, 2000).

Experiment 2

Total body weight gain in tom-turkeys was not significantly changed by feeding regimens (Table 3, Figure 3). Weight gain in restricted tom-turkeys during the restriction period was lower about 20–60% than in tom-turkeys fed *ad libitum*. During the realimentation period growth accelerated. Compensatory growth enabled full recovery of body weight. At the age of 140 days body weight in restriction groups were higher than in the control group (group 1). Tom-turkeys in group 2 (longer

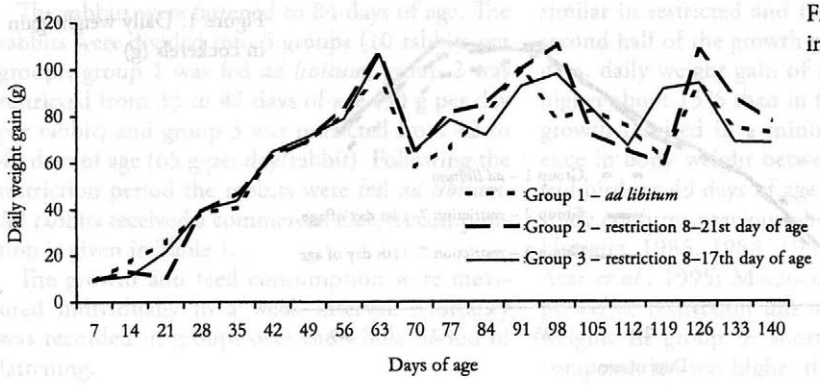

Figure 3. Daily weight gain in male turkeys (g)

restriction) had live weight about 400 g higher than in group 1, fed *ad libitum*. Compensatory growth after restriction achieved full recovery at the age of 20 weeks (Oju *et al.*, 1988; Ferket and Sell, 1990; Skřivan *et al.*, 1993). Plavnik and Hurwitz (1988) reported that early feed restriction resulted in accelerated growth in the second half of the growth period, several weeks after restriction. Feed intake was reduced by restriction, and resulted in improvement of feed efficiency in comparison with the control group fed *ad libitum*. Plavnik and Hurwitz (1988, 1991), Oju *et al.* (1988), Ferket and Sell (1990) also reported lower feed consumption in restricted turkeys.

Female turkeys on restriction diet did not exhibit any compensatory growth until the age of 77 days

Table 3. Fattening characteristics in tom-turkeys (mean ± SD)

Measurement	Treatment		
	ad libitum	restriction 8–21st day of age	restriction 8–17th day of age
Live weight 1st day of age (g)	50.9 ± 0.57	49.4 ± 0.54	49.8 ± 0.73
Live weight 140th day of age (g)	9032 ± 291.4	9461 ± 239.76	9089 ± 233.92
Weight gain 1–140th day of age (g)	64.15 ± 2.47	67.22 ± 2.61	64.57 ± 3.15
Feed intake (per day/turkey) (g)	171.97 ± 2.72	157.19 ± 8.45	157.20 ± 2.60
Feed conversion (kg)	3.03 ± 0.04	2.86 ± 0.02	2.85 ± 0.02
Mortality	3	2	1

Table 4. Fattening characteristics in female turkeys (mean ± SD)

Measurement	Treatment		
	ad libitum	restriction 8–21st day of age	restriction 8–17th day of age
Live weight 1st day of age (g)	48.5 ± 0.52	48.0 ± 0.78	48.2 ± 0.44
Live weight 84th day of age (g)	3907 ± 88.17	3704 ± 87.29	3742 ± 76.16
Weight gain 1–84th day of age (g)	45.61 ± 3.37	43.09 ± 2.92	43.97 ± 4.29
Feed intake (per day/turkey) (g)	119.45 ± 2.83	110.90 ± 9.10	113.58 ± 0.99
Feed conversion (kg)	2.36 ± 0.10	2.31 ± 0.19	2.32 ± 0.09
Mortality	2	1	1

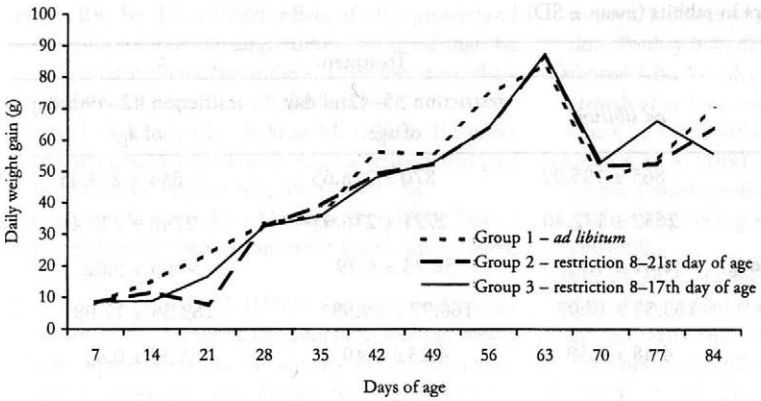

Figure 4. Daily weight gain in female turkeys (g)

(Figure 4). Restricted female turkeys weighed less at 84 days of age (Table 4). Ferket and Sell (1990) reported a significant reduction in body weight and feed during the first 10 weeks after restriction. It is possible that accelerated growth may be better expressed during the longer growing period (Plavnik and Hurwitz, 1991). In the realimentation period female turkeys consumed less feed. Feed efficiency was not affected by feeding regimens. In all groups and for both sexes daily weight gain was reduced when feed mixtures were changed.

In tom-turkeys in the period from 4 to 9 weeks of age growth in all groups was similar. A change in feed mixtures had a negative influence on growth in the first week after it was made. From the age of 9 weeks restricted tom-turkeys grew faster than full-fed ones. In females quantitative restriction resulted in an insignificant reduction in body weight. The lack of compensatory growth in female turkeys seemed to be limited by feed consumption.

Mortality in restricted tom-turkeys was lower than in those fed *ad libitum*, but in females it was not affected by feeding regimens. Ferket and Sell (1990) observed that mortality was not significantly influenced by dietary treatments.

Experiment 3

In rabbits during the restriction period daily weight gain was significantly ($P \leq 0.05$) reduced (Figure 5). Weight gain in restricted rabbits was about 60–70% lower that in full-fed rabbits. The next week after restriction weight gain was higher by 40% than in rabbits fed *ad libitum*. Maertens *et al.* (1988) reported high weight gain in the first two weeks after restriction. Compensatory growth following growth retardation resulted in insignificant differences in body weight at the end of experiment (Szendro *et al.*, 1989; Thwaites, 1989; Schlolaut

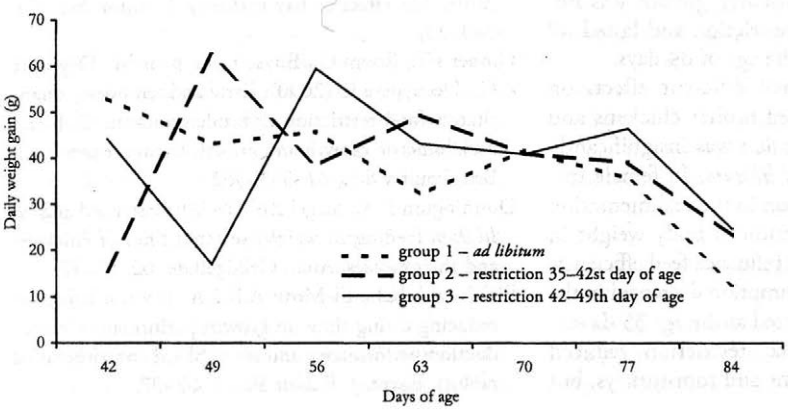

Figure 5. Daily weight gain in rabbits (g)

Table 5. Fattening characteristics in rabbits (mean ± SD)

Measurement	Treatment		
	ad libitum	restriction 35–42nd day of age	restriction 42–49th day of age
Live weight 35th day of age (g)	865 ± 105.99	870 ± 228.65	854 ± 213.45
Live weight 84th day of age (g)	2652 ± 172.40	2721 ± 276.67	2748 ± 222.41
Weight gain 35–84th day of age (g)	36.61 ± 4.15	38.23 ± 4.99	38.65 ± 3.82
Feed intake (per day/rabbit) (g)	163.53 ± 17.97	160.97 ± 19.59	163.34 ± 17.09
Feed conversion (kg)	4.48 ± 0.39	4.23 ± 0.40	4.50 ± 0.43
Mortality	1	1	2

and Lange, 1990; Perrier, 1998). At the age of 84 days restricted rabbits had higher body weight than control ones fed *ad libitum* (Table 5). Feed consumption and feed efficiency were not significantly affected by restriction treatments. It was observed by Ledin (1984), Scholaut and Lange (1990), El-Moty and El-Moty (1991), Perrier and Ouhayoun (1996), but Szendro *et al.* (1989), Jerome *et al.* (1998), Perrier (1998) reported lower feed consumption in restricted rabbits than in rabbits fed *ad libitum*. In group 2, where restriction started at the age of 35 days, feed consumption was lower than in other groups. Restriction did not affect mortality.

The present study confirms that feed restriction resulted in accelerated growth. Compensatory growth was observed in broiler chickens (cockerels and pullets) and in tom-turkeys in the second half of the growth period. Restricted female turkeys had lower live weight at the age of 84 days than full-fed ones. The fattening period for female turkeys was probably short to manifest compensatory growth. In broiler rabbits compensatory growth was observed immediately after restriction and lasted till the end of experiment at the age of 84 days.

Early feed restriction had different effects on feed efficiency. In restricted broiler chickens and tom-turkeys feed consumption was insignificantly lower than in birds fed *ad libitum*. In female turkeys lower feed consumption in the realimentation period resulted in a reduction of body weight in restricted birds and did not influence feed efficiency. In broiler rabbits feed consumption decreased in the group where restriction started at the age 35 days.

In our experiments feed restriction reduced mortality in broiler chickens and tom-turkeys, but did not affect mortality in female turkeys and in rabbits.

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Corresponding Author

Doc. Ing. Eva Tůmová, CSc., Česká zemědělská univerzita v Praze, 165 21 Praha 6-Suchdol, Česká republika

Tel. +420 224 383 048, e-mail: tumova@af.czu.cz

Fattening performance and carcass value of Awassi ram lambs, F_1 crossbreds of Romanov × Awassi and Charollais × Awassi in Jordan

Výkrmnost a jatečná hodnota beránků plemene Awassi, kříženců F_1 Awassi × Romanov a Awassi × Charollais v Jordánsku

M. Momani Shaker[1], A. Y. Abdullah[2], R. T. Kridli[2], J. Bláha[1], I. Šáda[1], R. Sovják[1]

[1]Institute of Tropical and Subtropical Agriculture, Czech University of Agriculture, Prague, Czech Republic

[2]Department of Animal Production, Faculty of Agriculture, Jordan University of Science and Technology, Irbid, Jordan

ABSTRACT: The goal of the study was to examine and evaluate the effect of lamb genotype on the growth, feed consumption, feed conversion and carcass value of Awassi ram lambs, F_1 crossbreds of Romanov × Awassi and Charollais × Awassi. Average daily weight gain and total weight gain during the trial were 199 ± 0.01 g and 12.33 ± 0.58 kg in pure Awassi ram lambs, 216 ± 0.01 g and 13.37 ± 0.71 kg in F_1 crossbreds A × Ch and 268 ± 0.01 g and 16.66 ± 0.58 kg in F_1 crossbreds A × R ($P \leq 0.01$). Statistically significant differences between the genotypes were found in diagonal body length, rump height and chest girth ($P \leq 0.01$). Evaluation of carcass by-products shows that the genotype affected the weight of full and empty digestive tracts, small intestine, heart, liver, intestinal fat, testicles, kidney and kidney fat ($P \leq 0.05 - 0.01$). The highest dressing percentage (including fat tail) in warm condition was 50.93 ± 1.11% in Awassi ram lambs and if compared with F_1 crossbred A × Ch 50.34 ± 1.36% and F_1 crossbreeds A × R 49.05 ± 1.11% no statistically significant difference was found. The highest percentage ratios of leg, loin and rack, which represent the prime meat of carcass, 57.08 ± 1.72% were in F_1 crossbreds A × Ch, 54.14 ± 1.40% in F_1 crossbreds A × R and 48.99 ± 1.40% in Awassi ram lambs ($P \leq 0.001$). The highest fat tail percentage 13.4 ± 1.06% was in Awassi ram lambs and the lowest 1.76 ± 1.06% in F_1 crossbreds A × R ($P \leq 0.001$). In general, the results of this study demonstrated that F_1 crossbreeds A × R and F_1 crossbreds A × Ch were superior to Awassi ram lambs in daily weight gain and total weight gain, feed conversion, lower costs per 1 kg meat gain and mainly in the carcass indicators.

Keywords: sheep; ram lambs; crossing; Awassi; Charollais; Romanov; fattening performance; carcass value

ABSTRAKT: Cílem práce bylo sledovat a vyhodnotit vliv genotypu jehňat na růst, spotřebu krmiva, konverzi živin a jatečnou hodnotu jehňat plemene Awassi a F_1 kříženců Awassi × Romanov a Awassi × Charollais. Do pokusu bylo zařazeno celkem 30 beránků ve věku čtyř měsíců a různého genotypu (Awassi = 11, kříženců F_1 Awassi × Charollais (A × Ch) = 7 a kříženců F_1 Awassi × Romanov (A × R) =12), která byla individuálně ustájena v kotcích po jednom kusu. Na začátku pokusu měli hmotnost: čistokrevní beránci plemene Awassi 27.50 ± 1.98 kg, kříženci F_1 A × Ch 31.14 ± 2.49 kg a kříženci F_1 A × R 35.91 ± 1.90 kg. Pokus byl zahájen po desetidenní adaptaci

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beránků. Všichni beránci dostávali stejnou krmnou směs po celou dobu pokusu. Beránci byli váženi v týdenních intervalech; denně byla evidována spotřeba všech krmiv po dobu trvání pokusu u jednotlivých beránků. Na konci pokusu, který trval 62 dnů, byla průměrná živá hmotnost beránků plemene Awassi 38.82 ± 2.31 kg, kříženců F_1 A × Ch 43.71 ± 2.89 kg a kříženců F_1 A × R 52.92 ± 2.21 kg. Dále bylo vybráno 16 beránků (Awassi = 6, kříženců F_1 A × Ch = 5 a kříženců F_1 A × R = 6) ke kontrolní porážce. Výběr byl proveden v rozsahu ±1 σ (směrodatná odchylka) od průměrné živé hmotnosti každé skupiny. Získané údaje byly zpracovány matematicko-statistickým programem – SAS podle modelové rovnice s pevným efektem metodou nejmenších čtverců. Nejlepší průměrný denní přírůstek a konverze živin (příjem sušiny na 1 kg přírůstku) byly zjištěny u kříženců F_1 Awassi × Romanov 268 g a 4.51, u kříženců F_1 Awassi × Charollais 216 g a 5.21 a u beránků plemene Awassi 199 g a 5.40. Rozdíly mezi jednotlivými genotypy byly významné ($P \leq 0.01$). Byly zjištěny významné rozdíly mezi jednotlivými genotypy v šikmé délce těla, výšce v kříži a obvodu hrudi ($P \leq 0.01$). Nejvyšší výtěžnost za tepla (50.93 %) měli beránci plemene Awassi a ve srovnání s beránky kříženců F_1 A × Ch (50.34 %) a beránky kříženců F_1 A × R (49.05 %) nebyl zjištěn významný rozdíl. Při hodnocení hmotnosti a podílů jednotlivých částí jatečného trupu beránků byly zjištěny významné rozdíly u procentických podílů kýty, kotlety, ledviny a ramena v závislosti na genotypu jehněte ($P \leq 0.05$). Nejvyšší podíl tučného ocasu z jatečného trupu byl zjištěn u beránků plemene Awassi 13.74 %, u beránků F_1 A × Ch 2.65 % a u beránků kříženců F_1 A ×R 1.76 %. Rozdíl byl vysoce statistický průkazný ($P \leq 0.001$). Při hodnocení délky plochy MLD, plochy MLD, tloušťky tuku nad plochou MLD, tloušťky masa s tukem mezi 12. a 13. hrudním obratlem ve vzdálenosti 110 mm, tloušťky tuku mezi 5. a 6. bederním obratlem a tloušťky tuku mezi 7. a 8. hrudním obratlem ve vzdálenosti 110 mm od páteře nebyl zjištěn průkazný rozdíl v závislosti na genotypu jehněte. Přes statistický neprůkazné rozdíly je patrné, že beránci kříženců měli lépe vyvinutý hřbet, široký a dlouhý MLD ve srovnání s čistokrevnými beránky plemen Awassi. Průměrná tloušťka tuku nad plochou MLD byla nejnižší (2.75 mm) u jatečných trupů kříženců F_1 A × Ch a nejvyšší (6.58 mm) u jatečných trupů beránků plemene Awassi, významný rozdíl však nebyl nalezen. Dosažené výsledky ukazují, že beránci kříženců F_1 A × R a beránci kříženců F_1 A × Ch vynikaly průměrným denním přírůstkem a absolutním přírůstkem, konverzí živin, nižšími náklady na 1 kg přírůstku masa a nižším podílem tučného ocasu ve srovnání s čistokrevnými beránky Awassi. Z výsledků konverze krmiv je patrné příznivé působení genotypu jehněte na výkrmnost beránků. U kříženců F_1 Awassi × Romanov bylo dosaženo nejvyšší konverze živin.

Klíčová slova: ovce; beránci; křížení; Awassi; Charollais; Romanov; výkrmnost; jatečná hodnota

Sheep belong to important farm animals in many countries. Jordan is one of them, where sheep breeding is the most significant part of animal husbandry. The Awassi breed can successfully be crossed only under adequate conditions of nutrition.

The studies of many materials and sources from Jordan show that the demand for high quality lamb meat gradually increases. Local sheep breeders are not able to meet this demand at present.

Besides the improvement of health conditions including preventive control of diseases and health programs, together with the genotype improvement, intensive fattening of lambs from 15 to 45 kg could also be used. This can lead to an increase in the local quality lamb production. This goal can be achieved by maximum daily weight growth and better conversion of nutrients during fattening. The methods how to improve sheep production characteristics by means of crossbreeding were studied by Emler *et al.*, 2000; Altinel *et al.*, 2000; Lipecka and Kedrak, 2000; Jakubec *et al.*, 2001.

Kaczor and Ciuryk (2000) reported that F_1 crossbreds of long-woolled Polish ewes with Suffolk sires had about 19% higher daily weight gain and about 10 % higher dressing percentage than long-woolled Polish lambs.

A lot of authors describe the priority of the lamb fattening system *ad libitum* as the best method, especially for meat production (Jones and Forbes, 1982; Hassan *et al.*, 1983; Yacoub and Kashmoula, 1988; Momani Shaker *et al.*, 1997).

The methods how to improve yield characteristics, cost reduction and application of a profitable system of lamb rearing and fattening were studied by Yacoub and Kashmoula, 1988; Momani Shaker *et al.*, 1996.

According to the authors the most important indicator, besides the direct influence on effective fattening, is the daily average growth that is in positive correlation with indicators of quality (muscle formation and low fat deposition). Horák (1999) concluded that the high growth ability of lambs is not possible without concentrate feed. Yacoub and Kashmoula (1988) reported that an *ad libitum* regime was suggested to be used for fattening of Karadi lambs after weaning but this regime resulted in more carcass fat in comparison with restricted feeding regime.

Momani Shaker *et al.* (1997) mentioned the fact of higher dressing percentage in the time of higher slaughter body weights.

Many authors published a finding that from the slaughter point of view, the most important indicator is the weight of leg, which is about two thirds of prime meat in joints. At the same time the leg is an indicator of wholesale carcass meatiness Slaná (1987), Momani Shaker *et al.* (1997)).

The effective influences on meat quality and quantity were discussed by Momani Shaker *et al.* (1997), Yacoub and Kashmoula (1988), Al-Kabi and Yacoub (1988).

The goal of this study was to examine and evaluate the influence of lamb genotype on the growth, feed consumption, feed conversion and carcass value in Awassi ram lambs, F_1 crossbreds of Romanov × Awassi and Charollais × Awassi.

MATERIAL AND METHODS

The study was carried out on the Awassi sheep breed and their crossbreds with Charollais and Romanov breeds kept at the Agricultural Center for Research and Production at Jordan University of Science and Technology, Irbid. The campus is located at 36° north and 590 m above sea level. The average rainfall sum is about 220–230 mm/year.

The study was based on selection of 30 ram lambs, 4 months old and from different genotypes (Awassi (A) = 11, F_1 crossbreds of Awassi × Charollais F_1 (A × Ch) = 7 and F_1 crossbreds of Awassi × Romanov F_1 (A × R) =12) that were housed in individual closed pens. At the beginning of the study, the average live weight of Awassi lambs was 27.50 ± 1.98 kg, F_1 crossbreds A × Ch 31.14 ± 2.49 kg and F_1 crossbreds A × R 35.91 ± 1.90 kg. The study was started after 10 days adaptation of lambs to assess concentrate mixture. All lambs were individually fed on the same concentrate mixture and water *ad libitum* for 62 days (Table 1). Live

Table 1. Composition of experimental diets

Ingredient	Proportion (%)	Dry matter* (g)	Crude protein* (g)	Ether extract * (g)	Crude fiber * (g)	ME * (MJ/kg)
Barley	55.00	478.50	66.00	11.55	27.50	7.32
Soybean meal	13.50	120.15	67.50	1.76	8.10	1.66
Wheat bran	12.50	111.25	19.00	2.25	40.25	1.38
Alfalfa	5.50	47.85	5.23	3.08	1.82	0.80
Wheat straw	12.50	116.25	3.75	1.63	45.00	0.69
DCP	0.45	–	–	–	–	–
Vitamin-mineral premix	0.10	–	–	–	–	–
Salt	0.45	–	–	–	–	–
Total	100	874.0	161.48	20.3	122.67	11.85
Analyzed nutrient content	–	880,1	164.4	20.5	121.20	10.92

*table value according to Harb *et al.* (1995)

weight (LW) was recorded once weekly, administered feed and feed refused by individual lambs were recorded daily.

At the end of the study which took sixty-two days, the average live weight of rams of A breed was 38.82 ± 2.31 kg, F_1 crossbreds (A × Ch) 43.71 ± 2.89 kg and F_1 crossbreds (A × R) 52.92 ± 2.21 kg.

Seventeen ram lambs were chosen (6 Awassi ram lambs, 5 F_1 crossbreds A × Ch and 6 F_1 crossbreds A × R) for control slaughter. The choice followed the range ±1 σ (standard deviation) with respect to the average live weight of each genotype.

Before slaughter the following body measurements were recorded: height at withers, height at back, height at rump, diagonal body length, chest girth and cannon-bone girth.

The animals were slaughtered after 18-hour fasting. After slaughter the weight of lungs with heart and liver, full and empty digestive tract, testicles and skin weight were recorded. Carcasses were weighed and chilled for 20 hours at 5°C, weighed again and some carcass dimension were measured according to Kadim *et al.*, 1989: body length, leg length, gigot width, width behind shoulder, maximum shoulder width and carcass fatness and meatiness were also subjectively classified by a five-score scale.

Carcasses were as cut into standardized wholesale cuts (Kadim *et al.*, 1989):

1. leg – hind limbs divided into back between the 5th and 6th lumbar vertebra.
2. loin – back proportion including the 13th thoracic vertebra and 1st to 5th lumbar vertebra.
3. rack – back proportion including the 7th and 12th thoracic vertebra.
4. shoulder – fore trunk carcass proportion including neck, middle neck and fore shank divided between the 6th and the 7th thoracic vertebra.

All carcass cuts were weighed, recorded and other measured characteristics were as follows:

- *musculus longissimus dorsi* (MLD) was determined planimetrically between the 12th and 13th thoracic vertebra
- depth and width of MLD area
- fat thickness on loin between the 12th and 13th thoracic vertebra at 110 mm from the backbone
- fat thickness with meat on loin between the 12th and 13th thoracic vertebra at 110 mm from the backbone
- fat thickness on the leg between the 1st and 2nd lumbar vertebra
- fat thickness over shoulder between the 7th and 8th pectoral vertebra

The obtained data were processed by a mathematical and statistical program (SAS) according to the model equation with fixed effect by the least squares method:

$$Y_i = \mu + G_i + e_i$$

where: Y_i = live weight of lamb
μ = overall mean
G_i = effect of the ith genotype of lambs (i = A, A × Ch and A × R)
e_i = residue

RESULTS AND DISCUSSION

The main characteristics of fattening performance and carcass value of ram lambs of different genotypes are presented in Tables 2 to 8.

Fattening performance traits of all ram lambs (n = 30) included in this study are shown in Table 2. The results show that F_1 crossbred lambs A × R and F_1 crossbreds A × Ch were better in total weight gain (WG) during the study, average daily weight gain (DWG), feed conversion and cost of 1 kg weight gain as compared with the Awassi ram lambs. The statistically significant difference was found at $P \leq 0.05 - 0.01$.

The results of fattening performance traits of ram lambs chosen (n = 17) for control slaughter are presented in Table 3. Average daily weight gain and total weight gain during the trial were 199 ± 0.01 g and 12.33 ± 0.58 kg in pure Awassi ram lambs, 216 ± 0.01 g and 13.37 ± 0.71 kg in F_1 crossbreds A × Ch and 268 ± 0.01 g and 16.66 ± 0.58 kg in F_1 crossbreds A × R, respectively. Differences between the individual genotypes were highly significant ($P \leq 0.01$). These results were in accordance with those reported by Mavrogenis and Louca (1979), who studied the effect of breed on live weight and daily weight gain after weaning in lambs of pure breeds Chios and Awassi and in crossbreds of Chios × Awassi. These authors reported that the crossbreeds had faster growth and higher live weight at 140 days of age in comparison with purebred lambs.

The best daily dry matter intake and feed conversion (kg DM intake/kg WG) were 1.19 ± 0.06 kg; 4.51 ± 0.43 kg in F_1 crossbreds A × R, 1.12 ± 0.08 kg; 5.21 ± 0.53 kg in F_1 crossbreds A × Ch

Table 2. Fattening performance traits of all ram lambs included in this study

Indicators	Awassi $n = 11$	Awassi x Charollais $n = 7$	Awassi x Romanov $n = 12$	F value
Initial live weight (LW) (kg)	27.50 ± 1.98^{b}	31.14 ± 2.49^{ab}	35.91 ± 1.90^{a}	4.71*
Final live weight (kg)	38.82 ± 2.31	43.71 ± 2.89	52.92 ± 2.21	10.09***
Total weight gain (WG) (kg)	12.80 ± 0.87^{b}	14.53 ± 1.09^{ab}	19.29 ± 0.84^{a}	15.75***
Average daily weight gain (DWG) (g)	207 ± 0.01^{b}	234 ± 0.01^{ab}	311 ± 0.01^{a}	15.70***
Feed conversion	6.21 ± 0.44^{b}	5.78 ± 0.55^{ab}	4.39 ± 0.42^{a}	4.73*
Feed intake per head/day (kg)	1.19 ± 0.05	1.29 ± 0.06	1.34 ± 0.04	2.31
Dry matter intake per head/day (kg)	1.05 ± 0.04	1.14 ± 0.05	1.18 ± 0.04	2.33
Feed conversion (kg DM intake/kg weight gain)	5.46 ± 0.38^{b}	5.08 ± 0.48^{ab}	3.86 ± 0.37^{a}	4.72*
Cost of 1 kg weight gain (JD)	0.68 ± 0.04^{b}	0.63 ± 0.06^{ab}	0.48 ± 0.04^{a}	4.73*

*$P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$, JD = Jordan Dinar

Table 3. Fattening performance traits of ram lambs

Indicators	Awassi $n = 6$	Awassi x Charollais $n = 5$	Awassi x Romanov $n = 6$	F value
Initial live weight (LW) (kg)	28.67 ± 3.26	30.25 ± 3.99	35.25 ± 3.26	1.09
Final LW (kg)	41.00 ± 3.47	43.63 ± 4.25	51.92 ± 3.47	2.64
Total weight gain (WG) (kg)	12.33 ± 0.58^{b}	13.37 ± 0.71^{ab}	16.66 ± 0.58^{a}	14.75***
Average daily weight gain (DWG) (g)	199 ± 0.01^{b}	216 ± 0.01^{ab}	268 ± 0.01^{a}	14.71***
Feed conversion	6.13 ± 0.37	5.91 ± 0.45	5.12 ± 0.37	1.99
Feed intake per head/day (kg)	1.20 ± 0.07	1.27 ± 0.089	1.32 ± 0.072	1.00
Dry matter intake per head/day (kg)	1.06 ± 0.06	1.12 ± 0.08	1.19 ± 0.06	1.01
Feed conversion (kg DM intake/kg weight gain)	5.40 ± 0.43	5.21 ± 0.529	4.51 ± 0.43	1.14
Cost of 1 kg weight gain (JD)	0.67 ± 0.05	0.65 ± 0.07	0.56 ± 0.05	1.24

*$P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$, JD = Jordan Dinar

and 1.06 ± 0.06 kg; 5.40 ± 0.43 kg in Awassi ram lambs, however the difference between the genotypes was not significant.

The feed conversion 5.40 ± 0.37 kg obtained in this trial in ram lambs of Awassi breed is worse than that found by Al Jassim *et al.* (1991) in their study on Awassi ram lambs, but better than the results reported by Yacoub and Kashmoula (1988) on Karadi ram lambs. In contrast Goot *et al.* (1982) reported that in a fattening experiment with all-concentrate ration on five Romanov x Awassi F_2 crossbred lambs of the initial age 67.6 days and

Table 4. Fasting body weights and body measurements of ram lambs before slaughtered

Indicators	Awassi $n = 6$	Awassi × Charollais $n = 5$	Awassi × Romanov $n = 6$	F value
Live weight after fasting (kg)	38.47 ± 3.26 ^{b}	40.70 ± 3.99^{ab}	48.57 ± 3.26^{a}	3.59*
Height at withers (cm)	72.25 ± 1.51	72.25 ± 1.85	75.25 ± 1.51	1.23
Height at back (cm)	74.92 ± 1.82	75.63 ± 2.23	77.42 ± 1.82	0.49
Height at rump (cm)	73.50 ± 1.70 ^{b}	75.50 ± 2.08^{ab}	79.67 ± 1.70^{a}	3.39*
Diagonal body length (cm)	55.17 ± 2.57^{b}	70.25 ± 3.16^{ab}	73.67 ± 2.57 ^{a}	14.17***
Chest girth (cm)	79.67 ± 4.42^{b}	94.25 ± 5.41^{ab}	98.33 ± 4.42^{ab}	4.80*
Cannon-bone girth (cm)	8.30 ± 0.16	8.63 ± 0.21	8.83 ± 0.17	2.51

*$P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$

Table 5. Average weights of by-products of slaughtered ram lambs

Indicators	Awassi $n = 6$	Awassi × Charollais $n = 5$	Awassi × Romanov $n = 6$	F value
Weight of skin (kg)	4.51 ± 0.39	5.09 ± 0.49	5.57 ± 0.40	1.77
Weight of full digestive tract (kg)	4.66 ± 0.50 ^{b}	4.75 ± 0.61^{b}	6.56 ± 0.50 ^{a}	4.35*
Weight of empty digestive tract (kg)	1.10 ± 0.06^{b}	1.22 ± 0.07^{ab}	1.39 ± 0.06 ^{a}	6.80**
Weight of small intestine (kg)	0.68 ± 0.04^{ab}	0.85 ± 0.05^{a}	0.76 ± 0.04 ^{b}	3.71*
Weight of large intestine (kg)	0.88 ± 0.14	0.92 ± 0.17	1.28 ± 0.14	2.42
Weight of heart (kg)	0.147 ± 0.010^{ab}	0.153 ± 0.013 ^{b}	0.194 ± 0.010 ^{a}	5.83**
Weight of spleen (kg)	0.077 ± 0.014	0.062 ± 0.018	0.076 ± 0.014	0.26
Weight of liver(kg)	0.568 ± 0.03^{ab}	0.653 ± 0.05 ^{b}	0.749 ± 0.04^{a}	5.14**
Weight of lungs (kg)	0.425 ± 0.03	0.495 ± 0.04	0.516 ± 0.03	2.62
Weight of fatty tissue (kg)	0.342 ± 0.166^{ab}	0.399 ± 0.203 ^{b}	0.955 ± 0.156 ^{a}	3.97*
Weight of testicles (kg)	0.205 ± 0.03^{ab}	0.303 ± 0.04 ^{b}	0.389 ± 0.03 ^{a}	8.31**
Weight of kidney (kg)	0.100 ± 0.005^{ab}	0.110 ± 0.006 ^{b}	0.128 ± 0.005 ^{a}	7.83**
Weight of kidney fat (kg)	0.202 ± 0.072^{ab}	0.271 ± 0.088^{ab}	0.473 ± 0.072 ^{a}	3.72*

*$P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$

weight 16.1 kg, the final weight after 84 days was 50.7 kg on average, daily gain 412 g, dry matter intake 1.5 kg a day and feed conversion 3.6 kg of dry matter per 1 kg of weight gain. Another important criterion that influences the economy of fattening is cost of 1 kg weight gain. Table 3 shows that the lowest cost of 1 kg weight gain 0.56 ± 0.05 Jordanian Dinar (JD) was achieved in F_1 crossbreds A × R, 0.65 ± 0.07 JD in F_1 crossbreds A × Ch and 0.67 ± 0.05 JD in Awassi ram lambs; however, no

Table 6. Average measurements of hanging carcass and subjective classification

Indicators	Awassi $n = 6$	Awassi × *Charollais* $n = 5$	Awassi × Romanov $n = 6$	F value
Body length (cm)	98.58 ± 1.97^{ab}	102.50 ± 2.41^{b}	106 ± 1.97^{a}	4.13*
Leg length (cm)	20.92 ± 0.36^{b}	20.75 ± 0.45^{b}	22.82 ± 0.36^{a}	9.20**
Leg width (cm)	16.28 ± 0.67^{ab}	18.63 ± 0.82^{b}	19.25 ± 0.67^{ab}	5.33*
Chest width (cm)	15.60 ± 0.78	16.38 ± 0.96	16.12 ± 0.78	0.22
Max. chest width (cm)	16.30 ± 0.92	18.25 ± 1.13	18.05 ± 0.92	1.24
Fatness of carcass (scores)	3.17 ± 0.29	3.00 ± 0.35	3.33 ± 0.29	0.27
Meatiness of carcass (scores)	3.33 ± 0.33	4.25 ± 0.41	4.00 ± 0.33	1.76

*$P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$

Table 7. Average weights and proportions of wholesale cuts including and excluding fat tail

Indicators	Awassi $n = 6$	Awassi × Charollais $n = 5$	Awassi × Romanov $n = 6$	F value
Carcass weight in warm condition (kg)	19.68 ± 2.01	20.65 ± 2.47	23.93 ± 2.01	1.17
Dressing percentage in warm condition (%)	50.93 ± 1.11	50.34 ± 1.36	49.05 ± 1.11	0.88
Carcass weight without fat tail (kg)	16.94 ± 1.87^{ab}	20.09 ± 2.29^{b}	23.50 ± 1.87^{a}	3.05*
Percentage carcass weight without tail (%)	86.26 ±1.06^{ab}	97.35 ± 1.29^{b}	98.24 ± 1.06^{a}	37.71***
Fat tail weight (kg)	2.74 ± 0.27^{a}	0.56 ± 0.33^{b}	0.43 ± 0.27^{b}	22.15***
Fat tail percentage (%)	13.74 ± 1.06^{ab}	2.65 ± 1.30^{b}	1.76 ± 1.06^{b}	37.71***
Leg weight (kg)	5.92 ± 0.63	6.73 ± 0.77	7.34 ± 0.63	1.28
Leg percentage (%)	31.67 ± 0.82^{b}	34.91 ± 1.01^{a}	32.98 ± 0.82^{ab}	3.10*
Loin weight (kg)	1.60 ± 0.32	2.48 ± 0.39	2.45 ± 0.32	2.27
Loin percentage (%)	8.47 ± 0.88^{ab}	12.71 ± 1.08^{a}	10.84 ± 0.88^{b}	4.27*
Rack weight (kg)	1.66 ± 0.22	1.84 ± 0.27	2.31 ± 0.22	2.32
Rack percentage (%)	8.86 ± 0.24^{b}	9.47 ± 0.29^{b}	10.31 ± 0.24^{a}	9.34**
First quality parts weight	9.18 ± 1.129	11.05 ± 1.383	12.10 ± 1.129	1.70
First quality parts (%)	48.99 ± 1.40^{ab}	57.08 ± 1.72^{a}	54.14 ± 1.40^{b}	7.17**
Shoulder weight (kg)	6.74 ± 0.68^{ab}	7.95 ± 0.83^{b}	9.28 ± 0.68^{a}	3.51*
Shoulder percentage (%)	35.81 ± 0.71^{ab}	41.57 ± 0.87^{b}	42.02 ± 0.71^{a}	22.43***

*$P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$

Table 8. Average MLD area and measurements of separable fat in carcass

Indicators	Awassi $n = 6$	Awassi × Charollais $n = 5$	Awassi × Romanov $n = 6$	F value
Width of MLD area (mm)	55.83 ± 2.70^{ab}	63.12 ± 3.30^{b}	65.00 ± 2.70^{a}	3.13*
Length of MLD area (mm)	26.08 ± 1.59	29.38 ± 1.95	28.58 ± 1.59	1.02
MLD area (cm^2)	12.15 ± 1.18	15.01 ± 1.45	14.44 ± 1.18	1.45
Fat thickness over MLD (mm)	6.58 ± 1.60	2.75 ± 1.96	4.08 ± 1.60	1.26
Thickness of meat with fat over loin between 12th and 13th ribs at a distance of 110 mm from the backbone (mm)	14.33 ± 2.07	18.87 ± 2.53	17.41 ± 2.07	1.08
Fat thickness over loin between 12th and 13th ribs at a distance of 110 mm from the backbone (mm)	9.58 ± 1.36	9.25 ± 1.66	9.50 ± 1.36	0.01
Fat thickness on the leg between 5th and 6th lumbar vertebra (mm)	11.50 ± 2.01	10.62 ± 2.46	11.50 ± 2.01	0.05
Fat thickness over shoulder between 7th and 8th pectoral vertebra (mm)	4.83 ± 0.91	6.56 ± 1.11	5.41 ± 0.91	0.72

*$P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$

statistically significant differences in costs between the genotypes were found. The same cost value was found by Yacoub and Kashmoula (1988) in their study of lambs of Karadi breed.

For the economic evaluation of lamb meat production both the final weight before slaughter and the dressing percentage have an importance.

Fasting body weight and body measurements of ram lambs before slaughter are presented in Table 4. The highest fasting live weight 48.57 ± 3.26 kg was found in F_1 crossbreds A × R, 40.70 ± 3.99 kg in F_1 crossbreds A × Ch and 38.47 ± 3.26 kg in Awassi ram lambs, and statistically significant differences between the genotypes were determined ($P \leq 0.05$).

When evaluating the body measurements before slaughter (Table 4), significant differences were found between the genotypes in diagonal body length, rump height and chest girth ($P \leq 0.01$). In the other indicators of body measurements before slaughter no statistically significant differences were established in dependence on the genotype of lambs. Lower values of body measurements before slaughter were reported by Momani Shaker *et al.* (1995) in Charollais lambs at 35.20 kg slaughter weight with daily gain 293 g.

The results of by-product weights in slaughtered ram lambs are presented in Table 5. Evaluation of carcass by-products shows that the genotype affected the weight of full and empty digestive tracts, small intestine, heart, liver, intestinal fat, testicles, kidney and kidney fat ($P \leq 0.05 - 0.01$).

The highest testicles weight 0.389 ± 0.03 kg was found in F_1 crossbreeds A × R, the lowest 0.205 ± 0.03 kg in Awassi ram lambs, the difference between the genotypes was highly significant. The other indicators of by-products were not affected by the genotype (weight of skin, head and limbs, spleen, large intestine and lungs). Similar results were reported by Kuchtík *et al.* (1997) for different breeds and crossbreds.

When evaluating the hanging carcass measurements and subjectively classifying (Table 6) in dependence on the genotype, statistically significant differences were found in body length, leg length and leg width ($P \leq 0.05$). The carcasses of crossbred lambs were longer than those of Awassi ram lambs of similar age and rearing conditions.

Leg lengths of hanging carcasses were 22.82 ± 0.36 cm in F_1 crossbreds A × R, 20.75 ± 0.45 cm in F_1 crossbreds A × Ch and 20.92 ± 0.36 cm in Awassi breed.

Subjective evaluation of fatness and meatiness of hanging carcasses did not show any statistically significant differences in the carcasses of all genotypes.

For mutton production the weight and proportions of carcass cuts is of great importance. The average weights and proportions of wholesale cuts in carcass including and excluding fat tail are shown in Table 7.

In dressing percentage based on the warm carcass weight, the Awassi males exceeded both F_1 crossbreds A × R and A × Ch owing to their heavy fat tails. But the crossbreds surpassed the pure bred Awassi in the dressing percentage of the carcass without fat tail.

The highest dressing percentage (including fat tail) in warm condition was 50.93 ± 1.11% in Awassi ram lambs and when compared with F_1 crossbreds A × Ch 50.34 ± 1.36% and F_1 crossbreeds A × R 49.05 ± 1.11% no statistically significant difference was found. Our results are similar to findings of Alwash *et al.* (1983), Yacoub and Kashmoula (1988), who found the values ranging from 48.87 to 49.22% for fat tailed lambs of Awassi and Karadi breeds. Momani Shaker *et al.* (1997) also reported that in a control slaughter of eight pure Charollais ram lambs the average slaughter weight was 42.1 kg, average carcass weight in warm condition was 21.96 kg and average dressing percentage 52.45.

When evaluating the percentage proportions of individual cuts of lamb carcass, statistically significant differences between the genotypes were found in the percentage of leg, loin and rack, which represent the prime meat cuts, and in shoulder percentage ($P \leq 0.05$).

When evaluating carcass percentage without fat tail, dependence on the male genotype proves that statistically significant differences were found ($P \leq 0.001$).

As compared with Awassi ram lambs, the weight of crossbreds without tail was reduced by 2.18 kg in F_1 crossbreds A × Ch and by 2.31 kg in F_1 crossbreds A × R, which coincides with consumer interest. The highest fat tail percentage 13.4 ± 1.06% was in Awassi ram lambs and the lowest 1.76 ± 1.06% in F_1 crossbreds A × R. The difference was statistically significant ($P \leq 0.001$). Similar results were reported by Yacoub and Kashmoula (1988) in lambs of Karadi breed.

The highest percentage proportions of leg, loin and rack, which represent the prime quality of the carcass, 57.08 ± 1.72% were in F_1 crossbreds A × Ch, 54.14 ± 1.40% in F_1 crossbreds A × R and 48.99 ± 1.40% in Awassi ram lambs ($P \leq 0.001$).

The lowest leg percentage 31.67 ± 0.82% was found in Awassi ram lambs and the highest 34.91 ± 0.82% in F_1 crossbreds A × Ch, the difference was statistically significant. Similar results were reported by Kuchtík *et al.* (1997) in different breeds and crossbreds.

The most important factors of carcass value are meatiness and fatness. Both factors are mutually related because the fat proportion influences sensory characteristics of meat.

The results of measurements of separable fat in carcass cuts are presented in Table 8. The MLD area and fat thickness over MLD muscle displayed no statistically significant differences between the genotypes. The average fat thickness over MLD obtained in this study was 6.58 ± 1.60 mm in pure Awassi ram lambs, 2.75 ± 1.96 mm in F_1 crossbreds A × Ch and 4.08 ± 1.60 mm in F_1 crossbreeds A × R. However, differences between the genotypes were not significant. Similar results were reported by Yacoub and Kashmoula (1988) in Karadi ram lambs. But Bayindir (1980) suggested that fat thickness over MLD was significantly and positively correlated with slaughter weight, and it increased as slaughter weight increased.

The results show that the crossbreds had well-developed loin, greatest MLD width and depth in comparison with purebred Awassi ram lambs.

In general, the results of this study document that F_1 crossbreds A × R and F_1 crossbreds A × Ch were better than Awassi ram lambs in daily weight gain and total weight gain, feed conversion, lower cost of 1 kg meat gain and mainly in the carcass indicators.

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Corresponding Author

Dr. Ing. Mohamed Momani Shaker, Česká zemědělská univerzita, Institut tropického a subtropického zemědělství, 165 21 Praha 6-Suchdol, Česká republika
Tel. +420 224 382 503, fax +420 220 921 363, e-mail: momani@itsz.czu.cz

Honey and its physical parameters

Med a jeho fyzikální parametry

A. Přidal[1], L. Vorlová[2]

[1]Department of Zoology and Apiculture, Faculty of Agronomy, Mendel University of Agriculture and Forestry, Brno, Czech Republic

[2]Department of Biochemistry and Biophysics, Faculty of Veterinary Hygiene and Ecology, University of Veterinary and Pharmaceutical Sciences Brno, Czech Republic

ABSTRACT: The aim of this study was to find how close relations exist between the results of microscopic analysis, optical rotation and electrical conductivity in 55 honey samples from the Czech Republic. The obtained results were to be interpreted in relation to the classification of honey samples according to their origin (honey groups: blossom, honeydew and compound honey). The relations were positive, very close ($r > 0.80$) and very highly significant ($P < 0.001$). Several analysed samples would have been inserted into honey groups wrongly if only conductivity had been measured. This fact and high correlation coefficients evidence that exact classification of honey must be carried out not only by measuring the conductivity but also on the basis of optical rotation and microscopic analysis – namely in transition intervals of conductivity between the particular honey groups.

Keywords: honey; quality evaluation; classification; specific rotation; pollen analysis; electrical conductivity

ABSTRAKT: Cílem práce bylo zjistit, zda existují závislosti mezi výsledkem mikroskopické analýzy medu a optickou rotací, elektrickou vodivostí a dalšími fyzikálními parametry u 55 vzorků medu z České republiky. Získané výsledky pak interpretovat pro použití při klasifikaci skupin medů (květový, medovicový a smíšený). Všechny uvedené závislosti mezi jmenovanými parametry byly kladné, velmi těsné ($r > 0,80$) a velmi vysoce průkazné ($P < 0,001$). Pokud by byla u analyzovaných vzorků používána ke klasifikaci medu jen konduktivita, některé z analyzovaných vzorků by bývaly byly zařazeny nesprávně do medných skupin. Tato skutečnost a těsné závislosti mezi sledovanými parametry dokazují, že přesnější zařazení medu není možné jen podle jeho vodivosti, ale současně s ohledem na jeho optickou rotaci a mikroskopickou analýzu (zejména v přechodných pásmech vodivosti mezi jednotlivými skupinami medu).

Klíčová slova: med; hodnocení jakosti; klasifikace; specifická rotace; pylová analýza; elektrická vodivost

Both European Honey Directive (1974) and Codex Alimentarius Standard for Honey (1993, 1998) specify criteria for honey quality and its classification. Both documents are revised now. Czech national criteria and other regulations for honey and other foods are laid down by Decree (1997, 2000).

Physical attributes belong to the main criteria of honey classification. Their measuring is comparatively simple and they have a good information value. The best-known and one of the most important honey characteristics is electrical conductivity. Optical rotation is a parameter that is discussed in relation to determination of botanical origin and adulteration of honey (Piazza *et al.*, 1991; Bogdanov *et al.*, 1997, 1999; Schuster *et al.*, 1998; Al-Khalifa and Al-Arify, 1999; Sanchez *et al.*, 2001). In some countries the rotation is applied to differentiation

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of honey groups – blossom, honeydew and compound honeys but the limit values have not been harmonised so far (Bogdanov *et al.*, 1997).

In Decree No. 334/97 the limit values for conductivity are determined as follows: blossom honey max. 55 mS/m, compound honeys 50–105 mS/m and honeydew honey 90–130 mS/m. Therefore, it is necessary to consider also other attributes for the determination of honey groups especially within transition intervals (i.e. 50–55 a 90–105 mS/m).

Microscopic analysis is another analytical method for the identification of botanical origin. Namely quantitative and also qualitative content of honeydew particles and pollen grains is studied for the identification of honey group and the blossom origin, respectively. On this account, the microscopic analysis is able to detect the botanical origin much more exactly than other analytical methods. However, it is difficult to correctly interpret results of melissopalynology and it needs a lot of experiences (Demianovicz, 1961; Kropáčová, 1969).

The aim of this study was to find how exactly it is possible to classify honey in relation to its botanical origin if pollen analysis and optical rotation are used. Therefore, it was needful to find how close relations exist between the results of microscopic analysis (i.e. pollen analysis), and the optical rotation, electrical conductivity and further physical parameters in 55 honey samples from the Czech Republic.

MATERIAL AND METHODS

Material

Samples of honey that came from the Czech market and different suppliers (n = 14) and samples directly from beekeepers, taken in the same year (2000), were used as the material. All of the honey samples were obtained by extraction. The samples were stored with authentic labels in eclipse at a laboratory temperature (22 ± 2°C) until the time of analysis.

Methods

Determination of moisture. Refractive index was determined by refractometer and equivalent content of water was found in the Table. Abbé refractometer AR 2 (fy A-Krüss Optronic, Germany) was used for such determination. Every sample was analysed in three parallel determinations. The determination of water content in honey was used for sample preparation to determine electrical conductivity of honey and to calculate specific rotation (Bogdanov *et al.*, 1997).

Determination of water activity (a_w). Water activity was determined by Pawkit AquaLab (fy Decagon, USA) instrument. Every sample was analysed in three parallel determinations.

Determination of electrical conductivity. Electrical conductivity of honey was determined from a honey solution containing 20% of honey dry matter in 100 ml distilled water (Bogdanov *et al.*, 1997). The measurement was carried out by help of thermostatic conductive cell and conductometer LF 315 (WTW GmbH, Germany). Every sample was analysed in three parallel determinations.

Determination of specific rotation. The angular rotation of a clear filtered aqueous solution was measured. The measurement was done on circular polarimeter 1000 (A-Krüss Optronic GmbH, Hamburg, Germany). Specific rotation was calculated from angular rotation, ray circuit length and grams of taken dry matter (Bogdanov *et al.*, 1997). Every sample was analysed in three parallel determinations.

Determination of botanical origin – pollen analysis (PA). Honey origin was verified by qualitative and quantitative microscopic pollen analyses (melissopalynology). The honey samples were divided according to their origin into several groups and subgroups (blossom origin) as follows:

a) blossom honey – 1. monofloral, 2. multifloral and 3. multifloral with predominance of some plant(s)
b) honeydew honey
c) compound honey (blend of honeydew and blossom honey)

The honeys belonging to a1) group originate mainly from nectar of only one plant species and proportions of the other nectars are fractional. All monofloral honeys had usual physical attributes and the result of their microscopic analysis was typical of the given monofloral origin (e.g. *Robinia* honeys did not crystallise). These honeys are not so called experimentally monofloral honeys gained from technically isolated growths as it was carried out e.g. by Demianowicz (1961). The mixture of nectars from different plant species is typical of honey samples belonging to a2) group. The honeys of a3) group also originate from the mixture of different nectars but one, two or three sources of nectar at maximum are obviously predominant. These

honeys did not have any usual physical attributes and the result of their microscopic analysis was not typical of any monofloral honey of the found predominant nectars. The methodology was consistent with the international methodology including their supplements and adaptations proposed by Louveaux *et al.* (1970, 1978).

Results were evaluated using the Microsoft EXCEL 2000 software. Methods: analysis of variance with multiplication comparison (confidence intervals for $P < 0.05$), regression analysis, correlation analysis and descriptive statistical characterisation.

RESULTS AND DISCUSSION

Table 1 shows the summarisation of results for some analysed honey samples. The following parameters were measured in each sample: moisture, water activity, electrical conductivity, specific optical rotation and microscopic analysis. In Table 2, the results of analysis for individual honey groups (honeys divided according to the result of microscopic analysis) are summarised and characterised by descriptive statistical data.

According to our former experience the conductivity of monofloral *Robinia* honeys is not higher than 12 mS/m. It was also found in samples No. 1–3. Samples No. 4–5 with conductivity above 12 mS/m did not crystallise either and their appearance was consistent with usual *Robinia* honey but the result of pollen analysis detected a greater portion of rape nectar (higher quantity of *Brassica* pollen grains). This fact can cause difficulties during consecutive honey technology. One of these two samples also had a higher number of pollen grains per 1 g of honey (above 2000), which is not typical of pure monofloral *Robinia* honeys.

Samples of honeys No. 29, 30 and 49 had very low conductivity with respect to the result of pollen analysis – compound honeys. Otherwise, these samples contained only a few honeydew particles but with reference to comparatively high rotation these samples were classified as a compound honey. In spite of the higher conductivity in sample No. 13 (similar to samples No. 29 and 30), sample No. 13 was a blossom honey because it was free of honeydew particles. Sample No. 49 was a typical example when honey bees were foraging equally on two sources; in this case on *Phacelia* and honeydew. *Phacelia* is a plant flowering usually during the period of honeydew appearance. Both sources are very attractive for foragers and according to our experience increasingly more honeys with higher portion of *Phacelia* nectar usually contain a higher or a lower amount honeydew. This sample contained a higher number of honeydew particles and, therefore, the sample was a compound honey in spite of low conductivity (under standard value 50 mS/m).

Sample No. 55 was another unusual honey – by honeydew honey this once. Conductivity of this sample was rather low and lay in the transition interval between compound and honeydew honeys. However, the sample contained many hon-

Table 1. Results of analysis of individual samples ordered according to honey group

Samples	Result of pollen analysis (honey group – blossom origin)	Moisture (g/100 g)	a_w	Conductivity (mS/m)	Rotation $(\alpha)^{20}_D$
1	monofloral – *Robinia*[C]	15.4	0.50	10.3	–13.9
2	monofloral – *Robinia*	15.3	0.50	10.4	–16.1
3	monofloral – *Robinia*[C]	16.7	0.51	11.3	–15.0
4	monofloral – *Robinia* (*Brassica*)	16.0	0.48	12.3	–16.9
5	monofloral – *Robinia* (*Brassica*)[C]	16.4	0.49	13.8	–16.0
13	Multifloral	15.6	0.47	43.4	–13.5
29	compound honey	14.9	0.49	45.8	–9.9
30	compound honey	15.4	0.48	41.0	–8.5
43	compound honey	16.2	0.48	109.8	–2.1
49	compound honey[C]	15.6	0.49	43.8	–7.7
55	honeydew honey	16.4	0.49	96.6	6.6

[C] sample of commercial honey

Table 2. Descriptive statistical characterisation of the individual physical parameters according to honey groups

	Moisture (g/100 g)	a_w	Conductivity (mS/m)	Rotation $(\alpha)^{20}$
Monofloral – *Robinia* (n = 5)				
Mean	16.0	0.49	11.6	–15.6
Minimum value	15.3	0.48	10.3	–16.9
Maximum value	16.7	0.51	13.8	–13.9
Standard deviation	0.6	0.01	1.5	1.1
Standard error	0.3	0.00	0.7	0.5
Coefficient of variation (%)	3.8	1.80	12.7	–7.3
Monofloral – others (n = 7)				
Mean	17.1	0.51	20.6	–15.2
Minimum value	15.1	0.47	13.3	–22.2
Maximum value	19.5	0.54	28.4	–12.0
Standard deviation	1.5	0.03	5.7	3.3
Standard error	0.6	0.01	2.2	1.2
Coefficient of variation (%)	9.0	5.20	27.9	–21.6
Multifloral (n = 16)				
Mean	16.5	0.52	26.0	–13.1
Minimum value	14.8	0.46	14.0	–18.9
Maximum value	18.5	0.59	43.9	–9.6
Standard deviation	1.1	0.04	9.2	2.5
Standard error	0.3	0.01	2.3	0.6
Coefficient of variation (%)	6.7	8.00	35.4	–19.3
Compound honey (n = 21)				
Mean	15.9	0.50	68.0	–4.2
Minimum value	14.0	0.41	41.0	–9.9
Maximum value	18.6	0.59	109.8	3.8
Standard deviation	1.1	0.04	18.5	4.0
Standard error	0.2	0.01	4.0	0.9
Coefficient of variation (%)	6.9	8.60	27.1	–97.4
Honeydew honey (n = 6)				
Mean	15.3	0.49	107.5	10.5
Minimum value	13.8	0.48	96.6	–1.0
Maximum value	16.5	0.50	111.6	20.4
Standard deviation	1.0	0.01	5.8	7.8
Standard error	0.4	0.00	2.4	3.2
Coefficient of variation (%)	6.8	1.80	5.4	74.5

eydew particles and a very low number of pollen grains (only 894 pollen grains per 1 g of honey). Furthermore, a major part of these pollen grains was represented by anemophile pollen or pollen from plants without nectar production as it is typical of honeydew honeys. On the other hand, sample No. 43 would have been classified as a honeydew honey if it had been classified only on the basis of conductivity. However, very low content of honeydew particles and very high content of pollen

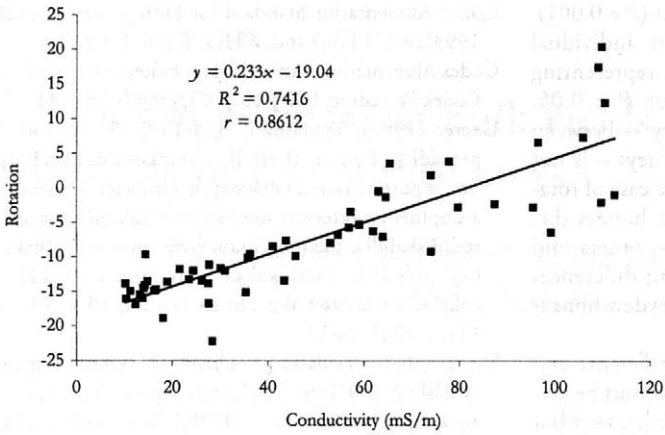

Figure 1. Regression line for conductivity and rotation

was found in this sample (10 049 PG/g – typical of honey with great portion of nectar source at least). Therefore sample No. 43 is a compound honey and this result corresponds with negative rotation.

Several closer relations were found between the physical attributes of analysed samples (Table 3). These are the relations between electrical conductivity, optical rotation and microscopic analysis that are the most important for honey classification and sorting into the individual honey groups. All mentioned relations are positive, very close ($r > 0.80$) and very highly significant. To calculate correlation coefficients between the individual honey groups (also blossom origin of honey) and other physical attributes, individual samples had to be numbered as follows: *Robinia* – 1, *Robinia* (*Brassica*) – 1.5, monofloral – 2, multifloral – 3, compound – 4 and honeydew honey – 5.

Regression line for rotation and conductivity is represented in Figure 1. Arithmetic means for conductivity and rotation of individual honey groups and blossom origin are shown in Figure 2.

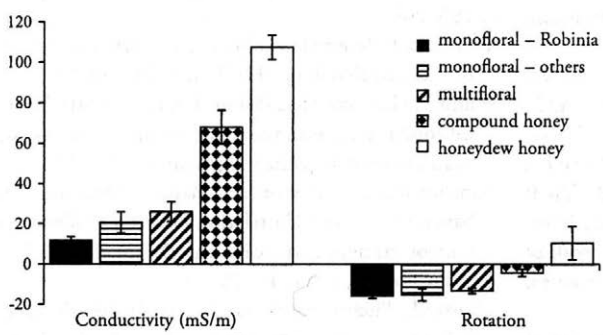

Figure 2. Average values of conductivity and rotation according to honey groups

Table 3. Coefficients of correlation between the physical parameters of honey

Parameter	PA	Moisture	a_w	Conductivity	Rotation
PA	1				
Moisture	–0.29*	1			
a_w	-0.09^{ns}	0.59***	1		
Conductivity	0.86***	0.23^{ns}	-0.08^{ns}	1	
Rotation	0.80***	–0.35**	-0.08^{ns}	0.86***	1

* $P < 0.05$;** $P < 0.01$;***$P < 0.001$; ns = no significance

Differences are very highly significant ($P < 0.001$). Significance of differences between individual groups is demonstrated by abscissas representing confidence intervals of reliability for $P < 0.05$. Only one difference in conductivity – between monofloral-others and multifloral honeys – is not significant, which was expected. In the case of rotation, only differences among blossom honeys (i.e. monofloral – *Robinia*, monofloral – others and multifloral honeys) are not significant; differences among blossom, compound and honeydew honeys are significant.

This fact and high correlation coefficients evidence that exact classification of honey must be carried out not only by measuring the conductivity but also in relation to optical rotation and microscopic analysis – namely in transition intervals of conductivity between the individual honey groups.

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Corresponding Author

Ing. Antonín Přidal, PhD., Ústav zoologie a včelařství, Agronomická fakulta, Mendelova zemědělská a lesnická univerzita, Zemědělská 1, 613 00 Brno, Česká republika
Tel. +420 545 133 248, e-mail: apridal@mendelu.cz

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