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Artificial propagation of African catfish (*Clarias gariepinus*): differences between reproduction effects after stimulation of ovulation with carp pituitary homogenate or GnRH-a and dopaminergic inhibitor

E. BRZUSKA

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ABSTRACT: The results of controlled reproduction of African catfish (*Clarias gariepinus*) females after ovulation stimulation with carp pituitary (4 mg/kg body weight) or with Aquaspawn preparation (complex of GnRH-a and domperidone) (0.5 ml/kg) were examined. It was found that after pituitary stimulation 100% and after Aquaspawn treatment 87.5% of females yielded eggs of satisfactory quality. In the group treated with the synthetic stimulator females yielded eggs of higher weight. The statistically significant ($P \leq 0.05$) higher weight of eggs was found if it was expressed in percentages of female body weight. After 12-, 24-, and 28-hour incubation the quality of eggs obtained after Aquaspawn treatment was better than that recorded in the case of pituitary application and differences between the results being statistically significant ($P \leq 0.05$). In the presented experiment the investigated material was composed of females from two categories determining their body weight, i.e. lighter females (average body weight of 4.89 ± 0.49 kg) and heavier females (average body weight of 6.96 ± 0.72 kg). No statistically significant differences were recorded between the investigated averages for any of the traits determining the weight or the quality of obtained eggs, however heavier females yielded eggs of higher weight expressed in grams.

Keywords: African catfish; artificial propagation; carp pituitary; Aquaspawn

In fish reproduction under controlled conditions attempts are made to obtain eggs of the highest weight possible and of the best quality, and hence to produce the highest possible numbers of good quality hatch. For this purpose various preparations stimulating ovulation are experimentally tested to find stimulators that would ensure such effects. It is obvious that appropriate maternal (and paternal) material should be used to obtain satisfactory results of stimulated fish breeding. With respect to African catfish (*Clarias gariepinus* Burchell 1822), the species of a well-grounded position in European fish culture (Huisman and Richter, 1987; Kuczyński *et al.*, 1999), such experiments were carried out by numerous authors (among others by Eding *et al.*, 1982; De Leeuw *et al.*, 1985; Richter *et al.*, 1985, 1987; Goos *et al.*, 1987; Kouřil *et al.*, 1992; Inyang and Hettiarchichi, 1994).

Up to 1995 in the Institute of Ichthyobiology and Fish Culture of the Polish Academy of Sciences

at Gołysz ovulation stimulation was carried out in this fish species using carp pituitary homogenate (Hogendorn and Vismans, 1980; Adamek, 1995). In later years within a program of investigations on the effects of reproduction after ovulation stimulation numerous experiments were carried out using various preparations (of both natural and synthetic origin) (Brzuska, 1998, 2002; Brzuska *et al.*, 1998a,b,c, 1999, 2000).

In the present paper the results of a successive experiment in the series are described, the tested stimulator being Aquaspawn. The Aquaspawn preparation used for ovulation and spermatation stimulation is the product of Spawnrite Ltd, Touws River in the Republic of South Africa. The preparation is a liquid ready for injection with two active ingredients: synthetic GnRH-a and domperidone. In 5 ml of Aquaspawn 100 µg of GnRH-a and 500 mg of dopamine receptor blocker – domperidone are contained in sterile physiologic saline. The

Table 1. Substances used as ovulation stimulators and their doses, method of application and number of females in group

Group	No. of females and range of body weight values (kg)		Ovulation stimulator	Dose*
I	4(4.70–5.40)	4(6.30–8.30)	carp pituitary	4 mg (i.p.)
II	4(3.90–5.30)	4(6.70–7.80)	Aquaspawn	0.5 ml (i.p.)
Σ	8	8		

Aquaspawn (Reg. No. G1957 Act 36/1947) was kindly provided by Mr L. V. Read Spawnrite Ltd Touws River, Republic of South Africa

*dose per 1 kg of female body weight: i.p. – intraperitoneally

formulation of Aquaspawn prevents overdosing. As Burton *et al.* (1998) claimed in the stimulated reproduction of fish the Aquaspawn preparation can also be applied orally.

As the Reports (kindly made available by L. V. Read) on the effects of Aquaspawn inform, this preparation can also be applied to fish as a slow-release pellet (cellulose/cholesterol mixture) implanted into the dorsal muscle. Experiments concerning the induction of spawning used this application method on the yellow fish (*Barbus copensis*). The results of these experiments show that Aquaspawn applied by implantation or injected as a liquid is not only an effective spawning agent but also it appears to have no adverse effects on the health of the treated fish. The reports show that after the application of Aquaspawn no side effects were observed on the breeders on which it had been used. The same fish were successfully induced to spawn in consecutive years. Particularly interesting results of the Aquaspawn preparation were obtained using this product successfully in getting difficult fish to breed (*Barbus andrewi*, *Barbus copensis*, *Myais copensis*). In the species mentioned above the only way to maintain or increase the present population is to induce them to breed under natural conditions. The above information was given in Spawnrite Ltd. Reports according to A. Bok (specialist scientist for Cape Nature Conservation in East London) and T. Pike (fisher expert at the National Parks Board in Pietermarithburg).

A very important detail of the information given in the Reports is that from the environmental aspect the product Aquaspawn is not considered to pose any threat to the environment when used to induce fish spawning. The product is considered safe for the environment due to low dosages used, rapid degradation within the fish's body by enzymes as well as very

short half-life. The synthetic decapeptide contained in Aquaspawn has never been shown to have any pathological effects and it is thus extremely unlikely to affect humans consuming flesh from fish that have been bred from parents receiving a single dose of this spawning agent. An interesting note in one Report is that Aquaspawn seems to have a good potential for artificial spawning in frogs.

For the ovulation stimulation in carp (*Cyprinus carpio* L.) females Aquaspawn was applied alone (at the dose given in the instruction; see References) and in combination with carp pituitary homogenate (Brzuska, 2001a). After the Aquaspawn treatment the obtained results of reproduction were very good (and better than after hypophysation), encouraging the author to undertake tests with ovulation stimulation in some fish species outside the Cyprinidae family.

The aim of the investigations presented here was to show the effects of reproduction in African catfish (*Clarias gariepinus*) females stimulated with Aquaspawn in comparison with the effects obtained after hypophysation. It was also attempted to determine whether the weight of females used in the experiment significantly affected the results of controlled reproduction.

MATERIAL AND METHODS

The investigation included 16 females of African catfish of the body weight 3.90–8.30 kg. The females were selected out of a greater population of spawners that were reared from eggs to maturity in the hatchery of the Institute of Ichthyobiology and Aquaculture in Gołysz, Polish Academy of Science. The fish were divided into two groups of eight females. In both groups a half of the indi-

viduals were characterized by a lower body weight (with the average of 5.05 kg in group I and 4.80 kg in group II). The other half included fish of higher body weight (with the average of 7.12 kg in group I and 6.95 kg in group II) (Table 1). The fish were placed in the hatchery in eight tanks 2.5 m³ in volume each. Two females, one heavier and one lighter were kept in each tank. During the experiment the temperature of water in the tanks ranged from 24 to 25°C. Ovulation was stimulated with two stimulators; in group I the females were treated with carp pituitary and in group II with Aquaspawn. The doses are given in Table 1. The control of ovulation started within 11 hours of the treatment with the two stimulators. The fish were checked for ovulation by gently pressing the abdomen (Richter *et al.*, 1987).

The eggs obtained from stripping each female were weighed and then fertilized with mixed milt obtained from macerated testes of three killed males. Eggs from each female separately were incubated in a Weiss glass in water at 24°C. After 12-h

incubation the percentage of fertilization and after 24 and 28 hours the percentage of live embryos were calculated for each female. After the hatch of larvae the percentage of deformed individuals was calculated. Statistical characteristics of the obtained data are given in Table 2.

Analysis of variance using the least-squares method was carried out to evidence the effect of the applied stimulator on the investigated traits. The traits were: weight of eggs in grams, weight of eggs in percentage of female body weight, and the percentage of fertilization and of live embryos after 24- and 28-hour incubation. Analysis of variance was carried out according to the following linear model:

$$Y_{ij} = \alpha + g_i + bW_{ij} + e_{ij}$$

where: α = theoretical general mean with the assumption that $W_{ij} = 0$

g_i = effect of group i ($i = 1 \dots 2$)

b = regression on female body weight

W_{ij} = body weight of a female

e_{ij} = random error associated with observation j

Table 2. Statistical characteristics of the data

Variable	Descriptive statistics					
	n	\bar{x}	S	min	max	SD
Weight of females (kg)						
Group I	8	6.20	0.43	4.70	8.30	1.21
Group II	8	5.75	0.48	3.90	7.50	1.29
Weight of eggs (g)						
Group I	8	532.50	95.71	120.00	800.00	270.71
Group II	7	679.28	53.33	485.00	860.00	141.10
Weight of eggs (% of female body weight)						
Group I	8	8.55	1.43	2.22	13.19	4.07
Group II	7	12.21	2.56	8.40	16.27	0.96
Fertilised eggs after 12-h incubation						
Group I	8	75.75	4.09	61.00	92.00	11.58
Group II	7	84.14	3.48	69.00	95.00	9.22
Live embryos after 24-h incubation (%)						
Group I	8	64.00	3.76	50.00	78.00	10.63
Group II	7	71.28	2.31	59.00	77.00	6.12
Live embryos after 28-h incubation (%)						
Group I	8	49.07	2.72	40.00	61.00	7.69
Group II	7	53.57	2.51	49.00	62.00	6.65

\bar{x} = arithmetical mean; S = standard error of the mean; SD = standard deviation

The significance of the effect of ovulation stimulator (group) on the investigated traits was checked using the *F*-test. The analysis allowed to estimate the least-squares constants and the least-squares means, this leading to the determination of deviations from the general means for the investigated traits within the main classification factor (Harvey, 1960, 1987).

The significance of differences between the arithmetical means for lighter and heavier females, calculated for the investigated traits, was checked using the *t*-test. The correlation between the investigated traits was computed for group I and group II separately. For each group separately the multiple regression equation was calculated using Statistica Version 5 (1997) to predict the percentage of live embryos after 24-h of incubation.

RESULTS

Ovulation time

In all the females of group I ovulation occurred 12 h after pituitary treatment. In fish of group II the synchronization of ovulation was also recorded in all the investigated individuals though the time of ovulation was later by one hour.

Percentage of females ovulating after hormonal stimulation

After hormonal stimulation eggs were obtained from all the females both in group I and in group II. In group II, i.e. in fish treated with Aquaspawn, one female gave eggs of a very poor quality (<30% fertilization), therefore in this case the recorded data were disregarded for the calculation.

Effect of ovulation stimulators on the weight and quality of eggs

The values of the least-squares means determining the weight of eggs obtained from the two groups of females distinctly show that in group II the weight of eggs was higher both if expressed in grams and in the percentage of female body weight (Table 3). However, the results of analysis of variance and the *F*-test allowed to determine a statistically significantly ($P \leq 0.05$) higher weight of eggs only if expressed as percentage of female body weight. The

respective values for groups I and II were 8.61% and 12.15% (Table 3).

In considering the values of the least-squares means for traits determining the quality of eggs it should be noted that after 12-, 24-, and 28-hour incubation the eggs yielded by females of group II manifested better quality (Table 3). It was determined that the effect of group on all three traits characterising the quality of eggs was statistically significant ($P \leq 0.05$).

Regression on female body weight was statistically significant ($P \leq 0.01$) only for the percentage of live embryos after 28-hour incubation of eggs.

Effect of body weight of females used for reproduction on the weight and quality of eggs

The mean body weight of lighter and heavier females used for reproduction and the values of arithmetical means for five investigated traits within the classification in which the body weight of fish is taken into consideration, are given in Table 4. The heavier females used for reproduction yielded eggs of higher weight than the lighter fish (the respective values being 666.00 g and 533.57 g), though the difference between the means was statistically insignificant. In calculating the weight of eggs as percentage of female body weight a higher (though statistically insignificant) value was obtained for lighter fish in comparison with the heavier ones (the respective values being 10.98% and 9.64%). Within this classification no statistically significant differences were recorded between the means determining the quality of eggs after 12-, 24-, or 28-hour incubation (Table 4).

Relations between the investigated traits

The values of correlation coefficients between the investigated traits calculated within groups I and II are given in Table 5.

In group I the body weight of females was positively correlated with all the other traits investigated, the correlation being statistically significant only between this trait and the percentage of live embryos after 28-h incubation. In this group a statistically significant ($P \leq 0.05$) correlation was determined between the percentage of egg fertilization and the percentage of live embryos both

Table 3. Constants (LSC) and least-squares means (LSM) estimated for investigated traits

Classification factor	Weight of eggs (g)			Weight of eggs as % of female body weight			Percentage of fertilized eggs after 12 h incubation			Percentage of live embryos					
										after 24 h incubation			after 28 h incubation		
	LSC	LSM	SE	LSC	LSM	SE	LSC	LSM	SE	LSC	LSM	SE	LSC	LSM	SE
α		607.13			10.38			80.00				67.68			51.78
Ovulation stimulator															
Carp pituitary (group I)	-91.91	515.22	72.01	-1.77	8.61	1.28	-4.95	75.05	3.59	-4.17	63.51	3.09	-2.69	49.09	2.02
Aquaspawn (group II)	91.91	699.03	77.07	1.77	12.15	1.37	4.95	84.94	3.84	4.17	71.85	3.31	2.69	54.47	2.16
Regression/body weight		83.61	44.68		-0.28	0.79		3.38	2.23		2.38	1.92		3.81	1.25

SE = standard error of least-squares means; α = theoretical general mean

after 24- and 28-h incubation (+0.87 and +0.77) and between the percentage of live embryos after 24- and 28-h incubation (+0.87).

In group II the highest value was found for the coefficient of correlation between the percentage of egg fertilization and that of live embryos after 24-h incubation (+0.87), the correlation between these traits being significant only within this group. A high correlation value (+0.75) was also determined between the weight of obtained eggs expressed in grams and the percentage of live embryos after 28-h incubation. In this group the weight of females was positively correlated with all the traits investigated except for the weight of eggs expressed as percentage of female body weight (Table 5).

Regression

The results of multiple regression are given in Table 6. The R^2 values given in this Table allow to determine whether the results of prediction obtained on the basis of the presented equations can be regarded as satisfactory.

For both groups the R^2 values show that the prediction of the percentage of live embryos after 24-h incubation based on these equations is satisfactory. Almost 88% for group I and 92% for group II of the variance are explained by these equations, but a statistically reliable R^2 is calculated for group II only.

Occurrence of deformed larvae

The occurrence of larvae with body deformations was found in both groups. In the investigated populations only several percentages of larvae with body deformations were recorded. No effect of the weight of females used for reproduction on the percentage of deformed larvae was observed.

DISCUSSION

The data obtained in the presented experiment show that in African catfish the treatment with the Aquaspawn preparation gave satisfactory results of reproduction effects. All the fish treated with this stimulator spawned, however one female yielded eggs of very poor quality. The synchronization of ovulation in fish after the application of this stimulator is a very important aspect. In the investigation

Table 4. Mean (\pm SD) body weight of lighter and heavier females of African catfish (*Clarias gariepinus* Burchell), mean weight of eggs (expressed in grams and as % of female body weight), mean percentage of fertilization after 12-hour incubation, and the mean percentage of live embryos after 24- and 28-hour incubation. Arithmetical means in the same row with different letters are significantly ($P \leq 0.05$) different

Investigated traits	Lighter fish $n = 8$	Heavier fish $n = 7$
Weight of females (kg)	4.89 \pm 0.49a	6.96 \pm 0.72b
Weight of eggs (g)	533.57 \pm 216.55a	666.00 \pm 230.48a
Weight of eggs (% of female body weight)	10.98 \pm 4.37a	9.64 \pm 3.46a
Fertilization of eggs after 12-h incubation (%)	77.43 \pm 7.91a	81.63 \pm 13.47a
Live embryos		
after 24-h incubation (%)	66.14 \pm 9.54a	68.50 \pm 9.62a
after 28-h incubation (%)	48.71 \pm 6.42a	50.13 \pm 7.31a

Table 5. Correlation between the investigated traits of females treated with carp pituitary – group I (above the diagonal) and Aquaspawn – group II (under the diagonal)

Variable	Weight of females (kg)	Weight of eggs (g)	Weight of eggs as percentage of female body weight	Percentage of fertilized eggs		Percentage of live embryos	
				after incubation			
				12h	24 h	28 h	
	1	2	3	4	5	6	
1		0.50	0.05	0.32	0.36	0.76*	
2	0.50		0.88*	0.68	0.56	0.66	
3	-0.37	0.59		0.60	0.42	0.32	
4	0.53	0.43	0.04		0.87*	0.77*	
5	0.33	0.34	0.05	0.87*		0.87*	
6	0.54	0.75	0.39	0.44	0.37		

* $P \leq 0.05$

Table 6. Results of multiple regression

Group	Regression equation	R^2	F
I	$y = 85.758 - 1.6x_1 + 3.59x_2 - 3.2x_3 + 0.846x_4$	0.875	5.26
II	$y = 24.816 - 0.73x_1 + 0.497x_2 - 0.54x_3 + 1.00x_4$	0.915	8.12*

Dependent variable: y = percentage of live embryos after 24-h incubation

Independent variables: x_1 = weight of females; x_2 = weight of eggs in grams; x_3 = weight of eggs as percentage of female body weight; x_4 = percentage of fertilized eggs after 12-h incubation

* $P \leq 0.05$

on the carp the synchronization of ovulation was also observed in all the females after the injection of Aquaspawn (Brzuska, 2001a). It should be stressed that the higher weight of eggs both expressed in grams and as the percentage of female body weight was obtained from African catfish females treated with Aquaspawn than from the hypophysed ones. It also seems important that in the group of fish treated with Aquaspawn no female yielded eggs of low weight while in the group after the carp pituitary application two females gave eggs of low weight, not exceeding 160 g.

The results of previously conducted studies showed that in general from females of the investigated fish species a higher quantity of eggs was obtained after the application of synthetic ovulation stimulators than after the treatment with stimulators of natural origin, such as carp pituitary or human chorionic gonadotropin (Biogonadyl) (Brzuska 2002; Brzuska *et al.*, 1998b,c, 1999, 2000).

It is interesting that the applied dose of des-Gly¹⁰ (D-Ala⁶)-Ethylamide did not affect the weight of obtained eggs and after the two doses (50 µg/kg and 20 µg/kg) the weight of obtained eggs was higher than that recorded after hypophysation (Brzuska *et al.*, 1998b, 1999).

The investigation on the use of Ovopel (a complex of a synthetic mGnRH analogue and metoclopramide; Horváth *et al.*, 1997) as an ovulation stimulator shows that the yield of eggs from fish treated with this preparation was higher than that from the hypophysed ones (Brzuska, 2002; Brzuska *et al.*, 1998c).

Kouřil *et al.* (1992) also reported that from females of this fish species treated with a synthetic ovulation stimulator (D-Ala⁶ GnRH ProNH₂Et) alone or with isofloxythepin (a dopaminergic inhibitor) the weight of obtained eggs expressed as percentage of female body weight exceeded that recorded after hypophysation. It should be stressed here that in the experiment reported by Kouřil *et al.* (1992) and in experiments described by Brzuska (2002) and Brzuska *et al.* (1998b,c, 1999) the dose of carp pituitary per 1 kg body weight of females was the same, amounting to 4 mg, as given by Hogendorn and Vismans (1980).

In discussing the results of the presented experiment it is worth stressing that the quality of eggs obtained from African catfish females treated with Aquaspawn was better (after 12, 24 and 28 hours of incubation) than after hypophysation. The investigation conducted on the carp of the Lithuanian line

B showed that the treatment with this preparation (at the dose recommended in the instruction and a lower one) ensured the yield of eggs of better quality than those obtained from hypophysed females (Brzuska, 2001a). Also in the investigation carried out by Brzuska *et al.* (2000) and Brzuska (2002) on African catfish females a better quality of eggs was recorded after Ovopel application in comparison with the effects of hypophysation. On the other hand, the results of studies described by Brzuska *et al.* (1998b, 1999) showed that the application of Des-Gly¹⁰[D-Ala⁶] LHRH Ethylamide did not effect the yielding of better quality eggs than the pituitary treatment.

A very important point is that the application of Aquaspawn to females of African catfish did not increase the numbers of deformed larvae in comparison with the number of larvae hatched from eggs yielded by hypophysed fish. The application of Des-Gly¹⁰ [D-Ala⁶]-LHRH Ethylamide (irrespective of the dose) to African catfish females increased the percentage of deformed larvae in comparison with the groups of fish treated with stimulators of natural origin, i.e. the pituitary or HCG (Brzuska, 1998b, 1999). In herbivorous fish, the silver carp (*Hypophthalmichthys molitrix* Val.) and the grass carp (*Ctenopharyngodon idella* Val.) the application of Des-Gly¹⁰[D-Ala⁶]-LHRH Ethylamide also induced a higher percentage of deformed larvae than the carp pituitary homogenate.

The experiments conducted by De Leeuw *et al.* (1985) on African catfish (*Clarias gariepinus*) with the use of Des-Gly¹⁰[D-Ala⁶] Ethylamide showed that the percentages of deformed larvae hatched from eggs yielded by individual females greatly varied. Hogendoorn and Vismans (1980) gave the percentage of deformed larvae of African catfish in relation to the time from hypophysation to stripping at three different temperatures.

In the present experiment an interesting observation was made concerning the percentage of larvae with body deformations that did not depend on the body weight of females. In earlier studies carried out on European catfish (*Silurus glanis* L.) body deformations were observed only among larvae hatched from eggs yielded by heavy females (of the body weight exceeding 9.3 kg) irrespective of the ovulation stimulator applied (Brzuska, 2000, 2001b).

The problem taken into consideration in the present work concerning the dependence between the body weight of females and the effects of reproduction is also interesting from the aspect

of fish culture practice. In earlier studies of this problem the investigated material was European catfish (Brzuska, 2000, 2001b) and African catfish (Brzuska, 2002). In the present experiment the average body weight of lighter and heavier females used for the reproduction differed by about 2 kg only and no statistically significant differences were found between the means for traits determining the weight and quality of eggs. However, the obtained results distinctly show that from lighter females a lower weight of eggs was obtained only if it was expressed in grams.

In the present investigation the percentage of live embryos was determined not only after 24-hour incubation but also additionally after additional four hours. The aim of this control was to determine whether during these four hours a rapid decline of larvae occurred due to the application of preparation Aquaspawn to African catfish for the first time in conditions of our hatchery. The obtained results showed that in relation to the group of hypophysectomized females no intensified death of larvae occurred after the Aquaspawn treatment. Brzuska and Adamek (1999) recorded a considerable number of dead larvae in the last phase of incubation of eggs obtained from European catfish (*Silurus glanis* L.) females treated with Des Gly¹⁰ [D-Ala⁶] LHRH Ethylamide.

In summing up the obtained results it can be stated that after the application of Aquaspawn at the dose of 0.5 ml/kg of body weight to African catfish females the effects of reproduction were satisfactory, exceeding those recorded after pituitary treatment at the dose of 4 mg/kg. A very significant point is that the above preparation is applied in the form of one injection. The producer suitably prepares this inducing ovulation agent and its application to fish is really easy. In the ovulation stimulation one injection of the stimulator reduces the handling, post-breeding mortality, and stress to females of this very sensitive fish species. The synchronization of ovulation in all the females treated with Aquaspawn, satisfactory weight and quality of eggs, and a more precise prediction of the percentage of live embryos justify further tests with this preparation in African catfish (*Clarias gariepinus*).

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ABSTRAKT

Umělý výtěr sumečka afrického (*Clarias gariepinus*): výsledky reprodukce po stimulaci ovulace kapří hypofýzou a přípravkem obsahujícím analog GnRH a dopaminergní inhibitor

Byla provedena umělá reprodukce sumečka afrického (*Clarias gariepinus*), k dosažení ovulace byly jikernačky stimulovány pomocí kapří hypofýzy (4 mg/kg hmotnosti ryb) a přípravku Aquaspawn (GnRH-a a domperidon);

0,5 ml/ g). Při použití hypofýzy bylo dosaženo ovulace u 100 % jikernaček, při použití přípravku Aquaspawn u 87,5 % jikernaček, získané jikry byly uspokojivé kvality. U skupiny jikernaček ošetřených syntetickým přípravkem byla získána vyšší hmotnost vytřených jiker. Byla zjištěna statisticky signifikantní ($P \leq 0,05$) závislost hmotnosti vytřených jiker v procentech na hmotnosti jikernaček. Po 12, 24, a 28 hodinách inkubace byla zjištěna vyšší kvalita jiker při použití přípravku Aquaspawn ve srovnání s použitím hypofýzy, rozdíl byl statisticky signifikantní ($P \leq 0,05$). K pokusu byly použity jikernačky dvou hmotnostních kategorií, lehčí jikernačky (průměrná hmotnost $4,89 \pm 0,49$ kg) a těžší jikernačky (průměrná hmotnost $6,96 \pm 0,72$ kg). Nebyly zjištěny statisticky významné rozdíly mezi hodnotami hmotnosti jikernaček a kvality jiker, i když od jikernaček s vyšší hmotností byly získány jikry o větší hmotnosti.

Klíčová slova: sumeček africký; umělý výtěr; kapří hypofýza; Aquaspawn

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The effect of fibrolytic enzymes on dry matter, ADF and NDF ruminal disappearance and intestinal digestibility

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ABSTRACT: Two non-lactating cannulated Jersey cows in a 2 × 2 Latin square were used to determine the effect of fibrolytic enzyme supplementation on dry matter, NDF and ADF ruminal disappearance from wheat straw (WS) and total mixed ration (TMR) and on dry matter intestinal digestibility. An enzyme complex containing 8 000 carboxymethyl cellulase and 20 000 xylanase units per 1 kg dry matter was added in powder form to a diet consisting of barley based concentrate and meadow hay. Ruminal disappearance was measured by *in situ* method and intestinal digestibility by a mobile bag technique. The addition of exogenous enzymes had minimal effects on the effective degradability of DM, NDF and ADF from WS and TMR. Fibrolytic enzymes increased DM, NDF and ADF disappearance after 4 and 6 hours of incubation, but decreased it after a longer incubation of 12 and 24 hours. The use of enzymes improved the intestinal digestibility of TMR and WS dry matter, but no statistical differences were determined ($P < 0.05$).

Keywords: fibrolytic enzymes; ADF; NDF; ruminal disappearance

Enzymes are used to improve the nutritive value of feeds for nonruminants and as silage additives, but they are not commonly used for feeding adult ruminants. Fibrolytic enzymes are typically cellulases that degrade cellulose or xylanases that act on hemicellulose (Beauchemin *et al.*, 1995). Enzymes applied to forages immediately before incubation enhance the digestion of DM and NDF (Feng *et al.*, 1996) suggesting that fibrolytic enzymes applied at feeding can improve digestion in ruminants. Nussio *et al.* (1997) found that the addition of enzyme mixture just prior to feeding was as effective as forage treatment 1 to 3 days before feeding. Hristov *et al.* (2000) speculated that exogenous polysaccharide-degrading enzymes could potentially improve nutrient digestion of ruminants post-ruminally not only by modifying the feed but also enzyme resistance to proteolysis. Beauchemin *et al.* (1999) reported an increased total tract digestibility of organic matter (OM), ADF and NDF, but no differences were observed in ruminal OM digestibility, indicating that the effects of enzyme supplementation were mostly intestinal. Dairy

cows fed roughage treated with fibrolytic enzyme produced more milk by 4.2 kg and ate more feed by 2.0 kg DM (Stokes and Zheng, 1995). Pritchard *et al.* (1996) reported linear improvements of intake and gain in steers fed treated grass hay.

More detailed knowledge of exogenous enzyme interactions with feed, host and rumen microorganisms is necessary to apply this technology successfully (Morgavi *et al.*, 2000), but according to Beauchemin *et al.* (2000), there is no doubt that feed enzymes will be used routinely by the cattle industry in the not so distant future.

The objective of the study was to investigate the effects of fibrolytic enzyme supplement to TMR and wheat straw on ruminal disappearance of DM, ADF, NDF and intestinal digestibility DM.

MATERIAL AND METHODS

Two non-lactating Jersey cows weighing 475 kg fitted with ruminal and proximal duodenal cannulas were used in a 2 × 2 Latin square design. Cows

were kept in individual pens and fed a control diet without enzymes (CK) and a diet with fibrolytic enzymes (EN). 8 000 carboxymethyl cellulase and 20 000 xylanase units per 1 kg dry matter were applied to concentrate and meadow hay diet. A complex of fibrolytic enzymes was added to barley based concentrate in powder form. The diet consisted of 2 kg of concentrate (18% CP) and hay (4.3 kg) was fed in two equal parts at 7.00 and 19.00.

Two experimental periods of 21 d consisted of a 14-day adaptation phase followed by 7-day trial period to perform the nylon bag procedure. The effect of fibrolytic enzymes (FE) on dry matter, ADF and NDF disappearance was estimated for two feeds: wheat straw (WS) and total mixed ration (TMR). Four nylon bags (2 bags per cow) were filled with 5 g of 3.5 mm milled feed per cow and incubated for 4, 6, 12, 24 and 48 h in the rumen of cows' respective diet (CK or EN). Bags were made of Dacron. The bags (280 × 100 mm, pore size 46 µm) were attached to a semi-rigid stalk and in turn were attached to a swivel-connector inside the rumen fistula cap. Bags were placed simultaneously in the rumen just before the animals were offered the first meal in the morning (7.00 AM). After removal from the rumen, bags were washed with cold water and stored frozen. After thawing, bags were washed, and then the bags were dried at 50°C for 48 h and weighed.

The percentages of dry matter, ADF and NDF degraded at each incubation time were calculated and the rate of degradation was estimated using the non-linear regression (Ørskov and McDonald, 1979). Three constants were used to calculate effective ruminal degradability (dg) according to the equation $dg = a + (bc)/(c+k)$ with the outflow rate assumed to be 0.06/h.

Intestinal digestibility of dry matter undegraded in the rumen was measured by the mobile bag technique. Three mobile bags per feed/diet were filled with one gram of samples of the residue after 12 h ruminal incubation and inserted into mobile bags (80 × 25 mm, pore size 10 µm). The bags were incubated for 2 hours at 39°C in pepsin-HCl solution (100 mg pepsin-1: 10 000 l of 0.004 mol/l HCl solution, pH 2.4) as recommended by Madsen *et al.* (1995) and inserted into the intestine via duodenal fistula approximately one hour after feeding (8 bags per cow per 1 hour). The bags were recovered in the feces within 26 hours. Bags not recovered within 30 h were discarded. After recovery, the bags were washed, frozen, dried and weighed as described pre-

viously. Ruminal disappearance of DM from nylon bags was calculated as the difference between the initial and residual amounts remaining after an incubation for 12 hours. Intestinal digestibilities were estimated as follows: ruminally undegraded DM-residue after intestinal incubation – ruminally undegraded DM. Total tract digestibility was calculated as follows: DM degraded in the rumen after 12 h + (rumen DM in the rumen after 12 h incubation × intestinal digestibility of undegraded DM/100).

Data were analyzed in a 2 × 2 Latin square design using the procedure of general linear models:

$$Y_{ijk} = M + C_i + P_j + T_k + E_{ijk}$$

where: Y_{ijk} = observation
 M = overall mean
 C_i = cow effect
 P_j = period effect
 T_k = treatment effect
 E_{ijk} = random error

Effects were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Chemical composition of TMR and WS is presented in Table 1. The addition of FE to barley concentrate had no significant effect on effective degradability of dry matter, ADF and NDF of both tested feeds (Tables 2, 3). Cellulase and xylanase improved DM, ADF and NDF ruminal disappearance after a short time of incubation, 4 and 6 hours. Disappearance of dry matter, ADF and NDF of wheat straw in the rumen after 6 h increased by 3.9, 3.5, 3.9%, respectively. The disappearance DM, ADF and NDF of TMR incubated for 6 h in the rumen was also improved significantly ($P < 0.05$) by 7.2, 3.1 and 2.9%, respectively. Fibrolytic enzymes decreased ruminal degradability of TMR and WS after a longer time of incubation for 12 and 24 hours. The NDF disappearance of WS and TMR after 12 h incubation in the rumen decreased by 2.0 and 5.9%, respectively. Dawson and Tricarico (1999) also reported that the fibrolytic enzyme effect in *in-vitro* study was generally larger during the initial stages of digestion. In contrast, Lewis *et al.* (1996) found no effect of direct FE enzymes on *in situ* disappearance of DM, NDF and ADF after 8, 16 and 24 h incubation, but the enzymes increased DM and NDF disap-

Table 1. Mean content of TMR ingredients (%DM) and chemical composition of total mixed ration and wheat straw (%DM)

Items	TMR	WS
Corn silage	27	–
Alfalfa silage	12	–
Corn	12	–
Barley	22	–
Rapeseed meal	11	–
Soybean meal	13	–
Mineral mix*	3	–
Chemical: formulated diets (kg/DM)		
Crude protein	19.9	4.1
PDIE	10.5	3.9
PDIN	10.7	2.3
ADF	20.4	53.0
NDF	33.5	84.9
Crude fiber	15.2	42.4
Ca	0.78	0.19
P	0.53	0.33

*Mineral mixture contained (in 1 kg): 127 g Ca, 73 g P, 100 g Na, 39 g Mg, 3 200 mg Mn, 6 000 mg Zn, 20 mg Co, 80 mg I, 20 mg Se

Table 2. Ruminal disappearance and effective DM, ADF and NDF degradability and DM intestinal digestibility of wheat straw

Diet	Hours of incubation					Effective degradability (%)	Intestinal digestibility (%)	Total* digestibility (%)
	4	6	12	24	48			
DM								
CK	13.3 ^a	16.7 ^a	29.3	44.0	54.5	30.5	2.7	31.2
EN	14.9 ^b	20.6 ^b	27.3	39.8	57.9	30.1	3.0	29.5
s.e.	1.11	0.34	1.85	2.79	1.33	3.21	0.27	2.10
ADF								
CK	–5.4 ^a	3.1 ^a	16.5	36.7	50.3	19.2	–	–
EN	0.6 ^b	6.6 ^b	15.2	35.6	52.3	19.8	–	–
s.e.	0.07	0.14	2.34	2.14	1.54	1.79		
NDF								
CK	6.3	8.8 ^a	22.7	41.6	53.5	25.1	–	–
EN	5.9	12.7 ^b	20.7	38.3	57.2	24.6	–	–
s.e.	0.87	1.98	2.17	5.07	2.93	2.67		

^{a, b} $P < 0.05$; s.e. = standard error

*Total digestibility = rumen disappearance after 12 h incubation + (100–rumen disappearance after 12 h incubation × intestinal digestibility/100)

Table 3. Ruminal disappearance and effective DM, ADF and NDF degradability and DM intestinal digestibility of TMR

Diet	Hours of incubation					Effective degradability (%)	Intestinal digestibility (%)	Total* digestibility (%)
	4	6	12	24	48			
DM								
CK	55.6 ^a	55.5 ^a	71.5 ^a	79.6	82.7	67.6	16.4 ^a	76.3
EN	48.5 ^b	62.7 ^b	67.3 ^b	78.8	81.8	65.9	20.7 ^b	74.1
s.e.	2.02	1.11	3.31	0.41	1.22	1.44	1.78	3.41
ADF								
CK	0.0 ^a	6.7 ^a	29.0 ^a	45.8	51.3	24.1	–	–
EN	3.6 ^b	9.8 ^b	22.6 ^b	42.9	47.3	24.3	–	–
s.e.	0.12	1.06	1.43	3.56	4.01	0.86		
NDF								
CK	17.7	21.4 ^a	39.9 ^a	55.3	61.8	37.2	–	–
EN	16.9	26.3 ^b	34.0 ^b	53.2	58.7	34.8	–	–
s.e.	2.11	1.04	1.13	1.02	4.12	3.25		

^{a, b} $P < 0.05$; s.e. = standard error

*Total digestibility = rumen disappearance after 12 h incubation + (100-rumen disappearance after 12 h incubation × intestinal digestibility/100)

pearance after 32, 40 and 96 hours of incubation. They speculated that the increase after a long incubation could result from enhanced colonization and digestion of the slowly degradable fiber fraction by ruminal microorganisms. Feng *et al.* (1996) also found higher DM disappearance in an enzyme treated grass substrate incubated in the rumen for 24 and 48 hours. A high outflow rate and a short retention time is typical of feeding high-yielding cows consuming more than 20 kg DM daily, therefore the structural carbohydrate disappearance after 4 and 6 h seems to be especially important. Rode *et al.* (1999) suggested that the beneficial effect of exogenous enzymes on animal performance is likely to be highest in ruminants with negative energy balance, such as cows in early lactation. A number of studies showed positive responses to fibrolytic enzymes (Beauchemin *et al.*, 1995; Lewis *et al.*, 1995; Yang *et al.*, 1999). Pritchard *et al.* (1996) found that a blend of xylanase and cellulase is more effective than cellulase alone. Fontes *et al.* (1995) reported that many fungal and bacterial cellulases and xylanases are glycosylated, can partially protect complementary actions with ruminal enzymes and changes in the site of digestion. Feng *et al.* (1996)

found that digestion of DM and NDF was enhanced for dry grass treated with an enzyme complex, but not for fresh or wilted grass. Beauchemin *et al.* (1995) reported that much higher fibrolytic effects were observed when enzymes were applied to dry rather than to wet forages. Beauchemin *et al.* (1999) suggested that the application of enzymes to dry feed enhances the binding of the enzyme with the substrate, which can increase the resistance of the enzymes to proteolysis and prolong their residence time within the rumen. Kung *et al.* (2000) speculated that treatment of feeds with enzymes just prior to feeding can improve digestibility via a number of different mechanisms including direct hydrolysis, enhanced microbial attachment, changes in gut viscosity, complementary actions with ruminal enzymes, changes in the site of nutrient digestion and improvements in palatability and changes in patterns of feed consumption could also occur.

In the present study enzyme supplementation improved intestinal digestibility of TMR dry matter by 4.3%, and had no effect on intestinal digestibility of wheat straw. Total digestibility (calculated as the sum of ruminal disappearance after 12 h incubation and intestinal digestibility measured by the

mobile bag technique) of wheat straw and TMR was not significantly affected by fibrolytic enzyme supplementation.

Hristov *et al.* (1997) demonstrated that some exogenous enzyme supplements are relatively stable in the rumen and remain active in the small intestine. Morgavi *et al.* (2001) suggested that enzyme feed additives were stable in the ruminal fluid and resistant to microbial degradation for a time sufficiently long to act in the rumen and ruminal stability seems not to be a limiting factor for the activity of feed enzyme. Treacher *et al.* (1997) found that enzymes are apparently more effective when added to the diet prior to feeding than when dosed into the rumen via rumen cannula.

In our study there was no effect of enzyme supplementation on the intestinal digestibility of wheat straw. Fibrolytic enzymes improved dry matter digestibility, ADF and NDF intestinal digestibility of TMR indicated that the enzymes were partly resistant to proteolysis in the rumen and remained active in the intestine. Hristov *et al.* (2000) found a linear increase in fibrolytic activities in duodenal digesta as a result of increased ruminal levels of xylanase and glucanase but digestibilities of DM, NDF and crude protein were not affected by the enzyme addition. In our experiments the use of an exogenous fibrolytic enzyme mixture promotes ruminal fiber digestion only for a short time of incubation, which would be particularly beneficial for high-yielding cows in the first part of lactation because these cows have a fast outflow rate of rumen.

CONCLUSION

A complex of fibrolytic enzymes applied in powder form to hay and barley based concentrate diet improved the disappearance of ADF and NDF from TMR and wheat straw in the early hours of rumen digestion, but there was no effect on effective DM, ADF and NDF degradability and total DM digestibility measured by *in situ* and mobile bag techniques.

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ABSTRAKT

Vliv fibrolytických enzymů na ruminální a intestinální stravitelnost sušiny, ADF a NDF

Pro stanovení vlivu přídatku fibrolytických enzymů na ruminální stravitelnost sušiny, NDF a ADF z pšeničné slámy a celkové smíšené krmné dávky a na intestinální stravitelnost sušiny jsme v pokusu uspořádaném jako latinský čtverec 2 × 2 použili dvě nelaktující dojnice plemene jersey, jimž byly zavedeny kanyly. Enzymový komplex obsahující 8 000 jednotek carboxymethylcelulázy a 20 000 jednotek xylanázy na 1 kg sušiny jsme přidali ve formě prášku do krmné dávky, kterou tvořil koncentrát na bázi ječmene a luční seno. Ruminální stravitelnost jsme měřili metodou *in situ* a intestinální stravitelnost metodou „mobile bag“. Příklad exogenních enzymů měl minimální vliv na skutečné odbourávání sušiny, NDF a ADF z pšeničné slámy i z celkové smíšené krmné dávky. Fibrolytické enzymy zvýšily stravitelnost sušiny, NDF a ADF po 4 a 6 hodinách inkubace, ale snížily ji po inkubaci trvajících 12 a 24 hodin. Použití enzymů zlepšilo intestinální stravitelnost sušiny z pšeničné slámy a celkové smíšené krmné dávky, ale statistické rozdíly nebyly zjištěny ($P < 0,05$).

Klíčová slova: fibrolytické enzymy; ADF; NDF; ruminální stravitelnost

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The effect of changed pH values of feed in isophosphoric diets on chicken broiler performance

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ABSTRACT: In a comparative trial with 2 400 sexed chicks of ROSS 208 hybrid the effect and efficiency of acidifiers FA 30 (phosphoric acid and citric acid) and FA 31 (phosphoric acid) on husbandry parameters were studied using the same nutrition levels – levels of each nutrient were identical. Feed rations were produced without using meat and bone meal. BRI diet was fed in the form of dry mash with large particles till the 14th day of age. BRII and BRIII diets were pelleted, BRII was fed till the 35th day of age and BRIII was fed till the 42nd day of age. The experimental period was from hatching to the 42nd day of age. Chicks were weighed on the day of filling the production facility, at 14 days of age 60 chicks were randomly selected from each group, marked and weighed, the same chicks were weighed on day 28 again and all chicks were weighed on day 42. The highest weight gain was achieved by males receiving the acidifier FA 30 ($2\,394.91 \pm 257.83$ g), compared to the control group that achieved the weight gain of $2\,353.21 \pm 260.40$ g; the difference was 1.77%. The highest weight gain in females was also achieved with the acidifier FA 30 ($2\,121.56 \pm 229.56$ g), compared to the control group that achieved the weight gain of $2\,035.63 \pm 189.40$ g; the difference was 4.22%. The females of control group showed the lowest mortality 0.50%, the two treated groups had the same mortality 1.13% regardless of sex. Regardless of sex, feed conversion was 1.83 kg/kg in the control group, 1.80 kg/kg in the group treated with FA 30, and 1.77 kg/kg in the group treated with FA 31. Lower pH values of the crop and gizzard contents were found in the treated groups than in the control group. Differences in performance between the treated groups and the control were not statistically significant ($P > 0.05$).

Keywords: chicks; acidifiers; feed additives; phosphoric acid; pH; feed conversion

Acidification is a method of eliminating the high occurrence of pathogens in the poultry environment. Because very high stocking densities are used in poultry production, the susceptibility of animals to diseases has increased and nowadays we cannot rely only on antibiotics used at subtherapeutical doses for the improvement of health status, weight gains and feed conversion. These products are not in accordance with the public perception of feed additives, and last but not least, they affect the microflora of animals as a whole.

A favourable effect of a decreased pH value caused by feed acidification on the alimentary tract microflora was reported (Smith, 1965). Some

researches also demonstrated a favourable effect on the hygiene of feed and feeding water (Smith, 1965; McDougall *et al.*, 1967; Van den Broek, 1999). Both inorganic (Pritzl and Kienholz, 1973) and organic acids and their salts have been used (Cave, 1984; Eidelsburger and Kirchgessner, 1994; Samanta and Biswas, 1995; Waldroup *et al.*, 1995).

Lin and Chen (1995) described a trial investigating the effect of phosphoric acid on growth inhibition in fungi of the genera *Fusarium*, *Aspergillus* and *Penicillium*, isolated from poultry feed. Phosphoric acid was compared with other fungicidal substances. Doses of 1 g and 5 g/kg were used. The order of

efficiency of the used substances differed according to the fungus strain. Phosphoric acid showed an effect on all the strains under study. The experimental results suggest that phosphoric acid can be an efficient fungicidal agent for a use in poultry feed. In a comparative trial (Van den Broek, 1999) the effect of hydrochloric acid and several organic acids or their blends on *Salmonella* sp., *Escherichia coli* and *Campylobacter* sp. was investigated. Hydrochloric acid did not produce such a significant response as the blend of organic acids.

Organic acids show an enormous bactericidal effect and they are readily absorbed through the bacterial cell wall (Langhout, 2000). On the other hand, inorganic acids such as phosphoric acid can exert a bacteriostatic effect due to a dramatic decrease in pH value. In many studies acidifiers showed the strongest effect in the first 4 weeks of chick's life (Versteegh and Jongbloed, 1999).

The information about the use of phosphoric acid as a feed additive to broiler diets was published a long time ago, and this is the reason for the use of

Table 1. Composition of BRI diet (%)

Composition	Experimental groups		
	Control	Group 1	Group 2
Maize	30.00	30.00	30.00
Wheat	29.234	28.152	28.431
Soybean meal	33.00	33.00	33.00
Fish meal	2.00	2.00	2.00
Salt	0.15	0.15	0.15
Limestone	1.915	1.929	1.913
Monocalcium phosphate	0.541	0.509	0.546
Oil	1.00	1.00	1.00
Methionine 20% premix	0.16	0.16	0.16
Lysine 20% premix	1.00	1.00	1.00
Premix	1.00	1.00	1.00
FA 30	–	1.10	–
FA 31	–	–	0.80
Total	100	100	100
DM (g/kg)	882.37	882.37	882.37
AME (MJ/kg)	11.36	11.36	11.36
Crude protein (g/kg)	225.1	225.1	225.1
Methionine (g/kg)	4.8	4.8	4.8
Sulphur AA (g/kg)	8.8	8.8	8.8
Threonine (g/kg)	8.4	8.4	8.4
Calcium (g/kg)	12.0	12.0	12.0
Phosphorus (g/kg)	5.8	5.8	5.8
Sodium (g/kg)	1.1	1.1	1.1
Magnesium (g/kg)	1.7	1.7	1.7
Manganese (mg/kg)	187	187	187
Zinc (mg/kg)	155	155	155
TKK 3 (ml HCl/kg)	298.2	300.3	300.2

DM = dry matter; AME = apparent metabolizable energy; Methionine 20% premix = content of 198 g DL-methionine/kg; Lysine 20% premix = content of 156 g L-lysine/kg; TTK3 = titrimetric capacity of feed (pH 3)

this acid in a new genetic material that can achieve better growth performance and feed conversion ratio.

MATERIAL AND METHODS

A trial was conducted at a testing station of the Agricultural Joint-Stock Company, Krucebnurk, the centre Ždírec nad Doubravou, in an experimental hall with controlled environmental conditions. 2 400 chicks of ROSS 208 hybrid were used.

The experimental hall was divided into 12 pens, 200 chicks per pen, i.e. 2 experimental groups with one replication, divided according to sex into 2 male groups and 2 female groups.

The composition of BRI and BRII diets and the calculated nutrient contents are given in Table 1 and 2, the contents of feed supplements in BRI and BRII diets are listed in Table 3. All the used diets were free of meat and bone meal. The BRI compound feed was administered in the form of mash with large particles till the 14th day of age. BRII was fed in pelleted form till the 35th day

Table 2. Composition of BRII and BRIII diets (%)

Composition	Experimental groups		
	Control	Group 1	Group 2
Maize	30.00	30.00	30.00
Wheat	37.643	37.281	37.495
Soybean meal	25.00	25.00	25.00
Fish meal	2.00	2.00	2.00
Salt	0.15	0.15	0.15
Limestone	1.583	1.248	1.216
Monocalcium phosphate	0.464	0.46	0.479
Oil	1.00	1.00	1.00
Methionine 20% premix	0.16	0.16	0.16
Lysine 20% premix	1.00	1.00	1.00
Premix	1.00	1.00	1.00
F 30	–	0.70	–
F 31	–	–	0.50
Total	100	100	100
DM (g/kg)	879.9	879.9	879.9
AME (MJ/kg)	11.705	11.71	11.70
Crude protein (g/kg)	200.86	200.86	200.86
Methionine (g/kg)	4.28	4.28	4.28
Sulphur AA (g/kg)	7.96	7.96	7.96
Threonine (g/kg)	7.31	7.31	7.31
Calcium (g/kg)	10.5	10.5	10.5
Phosphorus (g/kg)	5.38	5.38	5.38
Sodium (g/kg)	1.1	1.1	1.1
Magnesium (g/kg)	1.64	1.64	1.64
Manganese (mg/kg)	178	178	178
Zinc (mg/kg)	141	141	141
TKK 3 (ml HCl/kg)	285.0	293.5	293.8

DM = Dry matter; AME = apparent metabolizable energy; Methionine 20% premix = content of 198 g DL-methionine/kg; Lysine 20% premix = content of 156 g L-lysine/kg; TKK3 = titrimetric capacity of feed (pH 3)

Table 3. Composition of BRI, BRII and BRIII premixes (in 1 kg of premix)

	Units	BRI	BRII	BRIII
Vitamin A	IU	1 250 000	1 250 000	1 250 000
Vitamin D ₃	IU	350 000	250 000	250 000
Vitamin E	mg	5 000	3 500	3 500
Vitamin K	mg	300	250	250
Vitamin B ₁	mg	200	200	200
Vitamin B ₂	mg	500	500	500
Vitamin B ₆	mg	450	300	300
Vitamin B ₁₂	mg	2.5	2	2
Niacin	mg	4 000	2 500	2 500
Calcium pantothenate	mg	1 250	1 000	1 000
Biotin	mg	10	10	10
Folic acid	mg	100	100	100
Choline	mg	30 000	20 000	20 000
Antioxidant	mg	10 000	10 000	10 000
Amino acids				
DL-methionine	mg	200 000	180 000	180 000
L-lysine	mg	200 000	185 000	185 000
Coccidiostatic				
Halofuginone	mg	30	–	–
Na-salinomycin	mg	–	6 000	–
Trace elements				
Cobalt	mg	40	40	40
Copper	mg	800	800	800
Iron	mg	6 000	5 500	5 500
Iodine	mg	90	90	90
Manganese	mg	8 000	7 500	7 500
Zinc	mg	6 000	5 500	5 500
Selenium	mg	20	20	20

of age, followed by BRIII without anticoccidics (the same composition as BRII). Acidifiers were mixed into BRI, BRII and BRIII rations in the form of three times mixed premix according to Table 4.

Parameters under study

Live weight – when filled into the production facility, on the 1st day of age 200 chicks from each group were weighed on an electronic scale to the nearest 1g. At 14 days of age 60 average chicks were randomly chosen from each group out of the total

of 200 individuals, numbered and marked with paint. These chicks were weighed at the age of 14 and 28 days. At 42 days of age all chickens of each group were weighed.

Feed consumption – was monitored simultaneously with live weight for each group by weighing uneaten feed and leftovers in a feeder to the nearest 10 g.

The evaluation of results using European Efficiency Factor – the following equation was used for the evaluation:

$$\text{IEU} = (\text{livability} \times \text{live weight in kg/length of fattening period in days} \times \text{FCR}) \times 100$$

Table 4. Scheme of trial

Groups/Acidifier	BRI	BRII, BRIII
	dosage	dosage
Control	0.0%	0.0%
FA 30	1.1%	0.7%
FA 31	0.8%	0.5%

Specifications of acidifiers:

FA 30 – mineral acidification supplement composed of phosphoric acid (35%) supplemented with citric acid (2.4%) and an inert insoluble carrier of diatomaceous origin. Properties – brownish granulate, particle size 0.2–1.0 nm, phosphorus content 11%, pH 2.1–2.3 (in 1% water solution), loose specific gravity 870 kg/m³, packed specific gravity 940 kg/m³

FA 31 – loose acidity regulator. It contains phosphoric acid (52.5%) adsorbed to a silicate carrier. Properties: white powder, particle size <0.1 mm, phosphorus content 16.9%, pH 1.6–2.0 (in 1% water solution), loose specific gravity 840 kg/m³, packed specific gravity 940 kg/m³

The evaluation of microclimatic parameters – was performed with a stationary device AHLBORN (measuring air temperature, humidity and air circulation). Air temperature, air humidity, air circulation, dew point, concentration of harmful gases (CO₂ and NH₃) and light intensity were evaluated in the animal zone in each pen. The measurements were always carried out before weighing so that they would not be biased due to stress and changed conditions of the environment because of handling chicks during weighing.

Health status – the number of chicks was accurately recorded every day. At the beginning of the trial, at the delivery, the chicks were examined by cloacal smears for the presence of salmonellae. Deaths were recorded in the registration chart placed on each cage and in the registration diary; documents were provided by a veterinarian for each death with the analyses of causes.

The digestive tract examination – was carried out on the 41st day of age in 6 slaughtered females from each treated group and control group. pH values in the crop, gizzard, duodenum, caecum and large intestine were measured with a digital pH meter equipped with a probe for measuring pH values in tissues and tissue fluids. Caecal smears were carried out to be bacteriologically examined for the presence of *Salmonella enteritidis*.

Analytical examination of feed rations – samples were taken during the production process according to the appropriate methodology (Kacarovský *et al.*, 1990). Analysis of the results – was carried out using mathematical and statistical methods (Snedecor and Cochran, 1969) with the ANOVA programme.

RESULTS AND DISCUSSION

Live weight of chicks

At the beginning of the trial live weight was fairly homogeneous and ranged on average from 37.5 g to 44.2 g, differences between the groups were not considered as statistically significant ($P > 0.05$). In this trial commercial chicks were used that were only sexed, whereas Eidelsburger and Kirchgessner (1994) worked with more homogeneous, selected material with live weight ranging from 37 ± 1 g to 39 ± 1 g. In the experimental phase after the first third of the fattening period, i.e. at 14 days of age, the results are in Table 5, the females receiving FA 31 showed by far the lowest live weight values – 284.96 ± 17.65 g, i.e. 95.43%, when compared with the control group. In males the lowest values were observed in FA 31, only 91.66% when compared with the control. When taking into account both sexes, the control group with the average live weight of 305.88 ± 20.15 g (100%) and the FA 30 group with 308.56 ± 18.89 g (100.87) were nearly identical, the FA 31 group achieved only 289.03 ± 17.53 g (94.49%). The analysis of statistical significance of mean values in the groups did not give any significant results ($P > 0.05$). Cave (1984) did not observe any statistically significant values in broiler chicks in this period of age either. Many authors (Waldroup *et al.*, 1995; Versteegh and Jongbloed, 1999) assessed growth parameters after a longer period of time, not already within 14 days.

There were more pronounced differences in the live weight of chicks at 28 days of age. Regardless of sex, the control chicks achieved the average value of 1 107.01 ± 84.48 g. A similarly intensive growth was observed in the FA 31 group, the average live weight of chicks at 28 days of age was 1 090.89 ± 96.81 g (98.54%). The highest live weight of treated chicks was observed in the FA 30 group – 1 100.11 ± 101.62 g (99.37%) which corresponds with the results of Pritzl and Kienholz (1973). Cave (1984) reported a decrease by 3% in live weight in

Table 5. Characteristics of live weight (in g) of broilers

Treatment	Weight of hatched chicks	Weight of chicks on day 14	Standard error on day 14	Weight of chicks on day 28	Standard error on day 28	Weight of chicks on day 42	Standard error on day 42
Females							
Control	39.85	298.58	16.92	1 049.19	77.80	2 035.63	189.40
Index	100.00	100.00		100.00		100.00	
FA 30	39.54	310.31	16.59	1 072.92	90.13	2 121.56	229.56
Index	99.22	103.92		102.26		104.22	
FA 31	39.39	284.96	17.65	1 057.89	100.98	2 059.97	203.45
Index	98.84	95.43		100.82		101.19	
Males							
Control	39.82	313.18	23.39	1 164.84	91.16	2 353.21	260.40
Index	100.00	100.00		100.00		100.00	
FA 30	39.86	306.82	21.19	1 127.30	113.11	2 394.91	257.83
Index	100.10	97.96		96.77		101.77	
FA 31	39.71	287.09	17.42	1 123.89	92.64	2 350.79	262.40
Index	99.72	91.66		96.48		99.89	
Females and Males							
Control	39.83	305.88	20.15	1 107.01	84.48	2 194.42	224.90
Index	100.00	100.00		100.00		100.00	
FA 30	39.70	308.56	18.89	1 100.11	101.62	2 258.23	243.70
Index	99.67	100.87		99.37		102.90	
FA 31	39.55	289.03	17.53	1 090.89	96.81	2 205.38	232.92
Index	99.29	94.49		98.54		100.49	

the period from 22 to 29 days of age while using 1.0% of propionic acid supplement. The analysis of statistical significance of mean value differences showed that there were not any statistically significant differences between the groups ($P > 0.05$).

At the end of the trial, on the 42nd day of age, regardless of sex, live weight was $2\,258.2 \pm 243.70$ g (102.90%) in the FA 30 group and $2\,205.4 \pm 232.92$ g (100.49%) in the FA 31 group. The average live weight in the control group amounted to $2\,194.4 \pm 224.90$ g (100%). In the statistical analysis no significant differences ($P > 0.05$) between the treatments with the highest growth rate and treatments with the lowest growth rate were found. Maheswari and Kadirvel (1993) demonstrated a favourable affect of malic acid on weight

gains, but they did not prove the effect of different levels either.

Feed consumption

The results of total feed consumption per chick are shown in Table 6; the highest feed intake was observed in control males and in F30 females, 3.87 kg (101.84%). Regardless of sex, the highest feed intake was recorded in the FA 30 group – 4.06 kg (100.99%). The FA 31 group had 3.90 kg (97.01%). The broilers with the highest growth rate – FA 30 and FA 31 and controls had a higher total feed consumption per chick. Versteegh and Jongbloed (1999) described a significantly higher

Table 6. Feed intake and mortality of broilers

Treatment	Mortality (%)	Feed intake	Feed intake	Feed intake	FCR	FCR	FCR
		per chick 0–14 days (kg)	per chick 0–28 days (kg)	per chick 0–42 days (kg)	0–14 days	15–28 days	29–42 days
Females							
Control	0.50	0.43	1.66	3.80	0.43	1.24	2.14
Index	100.00	100.00	100.00	100.00	100.00	100.00	100.00
FA 30	0.75	0.41	1.65	3.87	0.41	1.24	2.22
Index	150.00	95.34	99.39	101.84	95.34	100.00	103.73
FA 31	0.75	0.39	1.60	3.71	0.39	1.21	2.11
Index	150.00	90.69	96.38	97.63	90.69	97.58	98.59
Males							
Control	1.25	0.42	1.81	4.23	0.42	1.40	2.42
Index	100.00	100.00	100.00	100.00	100.00	100.00	100.00
FA 30	1.51	0.46	1.80	4.24	0.46	1.33	2.44
Index	120.80	109.52	99.44	100.23	109.52	95.00	100.82
FA 31	1.50	0.39	1.71	4.09	0.39	1.32	2.38
Index	120.00	92.85	94.47	96.69	92.85	94.28	98.34
Females and Males							
Control	0.88	0.42	1.74	4.02	4.02	1.32	2.28
Index	100.00	100.00	100.00	100.00	100.00	100.00	100.00
FA 30	1.13	0.44	1.73	4.06	0.44	1.29	2.33
Index	128.40	104.76	99.42	100.99	104.76	97.72	102.19
FA 31	1.13	0.39	1.65	3.90	0.39	1.26	2.24
Index	128.40	92.85	94.82	97.01	92.85	95.45	98.24

feed intake only in the period of 0–4 weeks of age but the weight gain determined in the period of 0–6 weeks was not significant any more. This conclusion has not been confirmed.

As to feed consumption per 1 kg live weight gain in females, (Table 7) there was a noticeable decrease in feed consumption per 1 kg live weight gain in the high growth rate groups FA 30 and FA 31, i.e. 1.82 kg/kg (97.32%) and 1.80 kg/kg (96.25%), respectively. A similar trend of markedly low values of feed consumption per 1 kg live weight gain was also observed in males, – 1.74 kg/kg (98.33%) and 1.77 (96.66%), the control males 1.80 kg/kg. The analysis of feed consumption per 1 kg weight gain, regardless of sex, indicated very good feed conversion values in groups 1 and 2 – 1.80 kg/kg and 1.77 kg/kg, respec-

tively, which is 98.36% in group 1 and 96.72% in group 2 when compared with the controls.

Table 7 shows the above results of chicken growth until 42 days of age, livability and feed consumption per 1 kg weight gain expressed as European Efficiency Factor.

Microclimatic parameters

The measured values of air temperature and humidity corresponded with the requirements listed in a management guide to the ROSS 208 hybrid combination. In most cases, the levels of carbon dioxide and ammonia (CO₂, NH₃) did not exceed maximum permissible concentrations for the whole

Table 7. Feed conversion and EEf of broilers

Treatment	Feed conversion (kg feed/kg weight gain)	European efficiency factor
Females		
Control	1.87	258.34
Index	100.00	100.00
FA 30	1.82	274.84
Index	97.32	106.38
FA 31	1.80	270.06
Index	96.25	104.53
Males		
Control	1.80	307.80
Index	100.00	100.00
FA 30	1.77	317.22
Index	98.33	103.06
FA 31	1.74	316.88
Index	96.66	102.94
Females and Males		
Control	1.83	282.70
Index	100.00	100.00
FA 30	1.80	295.68
Index	98.36	104.59
FA 31	1.77	293.57
Index	96.72	103.84

Table 8. pH of the digestive tract of broilers at 41 days of age

Treatment	pH crop	pH gizzard	pH duodenum	pH caecum	pH colon
Control	5.03	3.42	5.69	6.10	5.88
FA 30	4.73	3.07	5.67	6.38	5.94
FA 31	5.01	2.22	5.81	6.15	5.98

fattening period. No increase in moisture content of droppings was observed. Pritzl and Kienholz (1973) did not observe any effects on litter quality after addition of 0.1 M phosphoric acid, only the pH value of dropping decreased from pH 6.7 to pH 5.7. These data were not determined in this trial.

Health status

During the experimental period the health status of the chicks was relatively good. When the chicks were filled into the production facility, a bacterial

infection with *Salmonella enteritidis* was found. This infection was suppressed by a routine preventative medication of the breeding stock. Enrofloxacin and the probiotic LBC P35 were used. Mortality (Table 6) during the fattening period was low, the average mortality of experimental groups regardless of sex was 1.13%, and 0.88% in the control group.

Examination of the digestive tract

On the 41st day of age, i.e. a day before the end of the trial, the digestive tract of 6 females from

each treatment and control group was examined and pH values were determined; the caeca were examined bacteriologically. The results in Table 8 show a very pronounced acidifying effect of both treatments in the crop and especially in the gizzard: the average pH value of the gizzard content dropped below pH 3.0. In the posterior segments of the digestive tract (duodenum, caecum and large intestine) the conclusion of Smith (1965) was confirmed. The determined values were very similar to physiological values. In the bacteriological examination the occurrence of *Salmonella enteritidis* was not detected, which confirmed the data by Van den Broek (1999) and conclusions by Lin and Chen (1995) and Langhout (2000) on the bacteriostatic effect of phosphoric acid.

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ABSTRAKT

Vliv změny pH krmiva v izofosforečných dietách na užitek kuřecích brojlerů

Ve srovnávacím pokusu s 2 400 sexovanými kuřaty hybridu ROSS 208 byl sledován vliv a účinnost okyselujících přípravků FA 30 (kyselina fosforečná a kyselina citronová) a FA 31 (kyselina fosforečná) na zootechnické ukazatele při stejné úrovni výživy – hladiny všech živin byly totožné. Krmné směsi byly vyrobeny bez použití masokostní moučky. Směs BRI byla hrubě šrotována a byla zkrmována v sypkém stavu do 14. dne věku. Směsi BRII a BRIII byly granulované, BRII byla zkrmována do 35. dne věku a směs BRIII byla zkrmována do 42. dne věku. Pokus probíhal od vylíhnutí kuřat až do věku 42 dnů. Kuřata byla vážena v den naskladnění, ve věku 14 dní bylo z každé skupiny náhodně vybráno, označeno a zváženo 60 kuřat, následně stejná kuřata byla zvážena 28. den a 42. den byla zvážena všechna kuřata. Nejvyššího přírůstku bylo dosaženo u kohoutků s okyselujícím přípravkem FA 30 ($2\,394,91 \pm 257,83$ g) v porovnání s kuřaty kontrolní skupiny, která dosáhla přírůstku $2\,352,21 \pm 260,40$ g, při rozdílu 1,77 %. Nejvyššího přírůstku bylo dosaženo u slepiček s okyselujícím přípravkem FA 30 ($2\,121,56 \pm 229,56$ g), v porovnání s kuřaty kontrolní skupiny, která dosáhla přírůstku $2\,035,63 \pm 189,40$ g, při rozdílu

4,22 %. Nejnižší úhyn byl zjištěn u kuřic kontrolní skupiny 0,50 %, u kuřat pokusných skupin bez rozdílu pohlaví byl zjištěn úhyn 1,13 %. Konverze krmiva byla u kuřat kontrolní skupiny bez rozdílu pohlaví 1,83 kg/kg, ve skupině s přípravkem FA 30 byla konverze 1,80 kg/kg a ve skupině s přípravkem FA 31 byla 1,77 kg/kg. U pokusných skupin bylo zjištěno nižší pH obsahu volete a žaludku v porovnání s kontrolní skupinou. Rozdíly v uživatelnosti mezi pokusnými a kontrolními skupinami nebyly průkazné ($P > 0.05$).

Klíčová slova: kuřata; okyselovací přípravek; krmná aditiva; kyselina fosforečná; pH; konverze krmiva

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Retention of protein and fat in meat of turkeys fattened to higher age

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ABSTRACT: Turkey females (F) and males (M) of BUT Big 6 hybrid combination were slaughtered in one-week intervals from 10th to 18th and 10th to 25th weeks of age, respectively. In breast meat (BM) and thigh meat (TM), the content of protein and fat were investigated. With increasing age, BM percentage in live weight increased linearly ($P < 0.01$), TM and drumstick meat yield did not change ($P > 0.05$) either in F or in M. The content of protein in BM did not change in F, the dependence on age in M was expressed by the parabola equation with a maximum on Day 102. The protein content of TM increased linearly in F ($P < 0.05$) during the whole experimental period while in M no changes were observed ($P > 0.05$). The lipid content in TM was higher than in BM both in F and M ($P < 0.01$). F deposited more fat at the same age than M in TM ($P < 0.05$) but not in BM ($P > 0.05$). In F and M, the weight of BM, TM and the amount of protein and fat in BM and TM increased faster than their live weight by 18; 12; 18; 244; 15; and 36% and by 17; 7; 13; 234; 10; and 45%, respectively.

Keywords: turkey; sex; age; duration of fattening; turkey meat; meat yield; meat composition

Yield and quality of poultry products are common goals in the commercial poultry industry. An increase in the market demand for value added products brings about the growth of demand for turkeys fattened to higher live weights.

If the fattening period is extended, feed conversion and yield of the body parts change. The percentage of breast meat in live weight increases with the age of turkeys (Larsen *et al.*, 1986; Blair *et al.*, 1989; Adams and Stadelman, 1991). The increase in the thigh meat yield is smaller than that of breast meat (Leeson and Summers, 1980). In a study conducted between 15 and 26 weeks of age in male turkeys, Peng *et al.* (1985) calculated allometric coefficients b expressing the relationship between the growth rate of breast, thighs, drumsticks and dissectible fat and the growth of carcass to be 1.38, 0.93, 0.81, and 3.06, respectively.

Salmon (1974) found three times more fat in thigh meat than in breast meat (2.4 and 0.7 per cent, respectively). In an experiment performed by Tůmová and Skřivan (1993) the fat content of breast and thigh meat in 20-week-old male tur-

keys ranged from 1.26 to 1.47 and from 4.35 to 4.92 per cent, respectively. The content of crude protein (N*6) ranged from 23.2 to 24.1 and from 19.3 to 19.5 per cent, respectively. Female carcasses contain higher concentrations of lipids, especially when analysed at the same slaughter age as males (Oju *et al.*, 1988; Wood, 1989).

The objectives of the present study were to determine chemical composition of meat and to quantify basic production parameters of female and male turkeys fattened to different age; the knowledge of these facts is essential for the development of production systems and processing of poultry.

MATERIAL AND METHODS

Turkeys of BUT Big 6 hybrid combination were used in the experiment. Birds were kept in cages until the age of six weeks and thereafter on floor bedding. Female and male groups, each of them involving 51 animals, were kept separately but fed *ad libitum* on the same diet pertinent to the given age

Table 1. Composition of the diets (g/kg)

Ingredients	KR 1	KR 2	KR 3	KR 4	KR 5	KR 6
	Weeks of fattening					
	1–3	4–6	7–9	10–13	14–17	18–25
Maize meal	350	390	400	400	400	400
Wheat meal	136.9	145.6	214.1	151.8	284.1	356.4
Soybean meal (protein 460 g/kg)	320	290	200	324	223	160
Heat-treated soybeans	40	20	30			
Rapeseed				40	50	50
Expeller rapeseed meal			25	20		
Fishmeal (protein 640 g/kg)	50	40	25			
Meat-and-bone meal (protein 500 g/kg)	70	70	60			
Sunflower oil		10	13	14		
Ground limestone	7	7	6	15	12	10
Mono- + dicalcium phosphate	15	14	13	22	20	15
Sodium chloride	1.5	2.0	1.2	2.9	2.4	2.5
DL-methionine	0.9	1.6	1.5	1.8	1.9	0.2
L-lysine	0.7	1.2	2.0	0.5	1.6	0.9
L-threonine		0.6	1.2			
Supplementary premix ¹ KR-START	8					
KR 1		8	8	8		
KR 2					5	
KR 3						5
Nutrient composition						
AME _n (calculated) (per kg diet) (MJ)	11.71	12.08	12.35	12.06	12.28	12.60
Crude protein (analysed) (per kg diet) (g)	282.4	260.7	228.4	195.6	175.7	159.6

¹Composition see Table 2

category. The composition of the diets including crude protein and energy content and of supplementary premixes is presented in Tables 1 and 2.

The live weight of turkeys, feed consumption and dry matter of the feed were recorded till the age of 22 days daily, thereafter in three-day intervals till the age of 42 days and in seven-day intervals till the end of experiment.

Turkeys were successively slaughtered after 12 hours of starvation in one-week intervals starting from the tenth week of age. Three females (F) and two males (M) were slaughtered each week. F were taken until the 18th week of age, M until the 25th week of age (altogether 26 and 34 birds, respectively). Breast, thigh and drumstick muscula-

ture without skin was dissected after cooling using a method described by Hahn and Spindler (2002). Skin was removed with subcutaneous fat. Visible external fat was removed while intermuscular fat remained in the muscle. *Musculus pectoralis profundus* (breast meat, BM) and *M. biceps femoris* + *M. semitendinosus* + *M. semimembranosus* (thigh meat, TM) were separated from the carcass of each bird. The separated tissues were homogenised and dry matter, nitrogen according to Kjeldahl and total lipids after extraction with diethyl ether were determined immediately using the methods specified by Decree No. 124/2001 of the Czech Ministry of Agriculture. Crude protein content was calculated using the factor 6.00 (N*6).

Table 2. Supplementary premix supplied (mg/kg diet)

Additives (mg)	Supplementary premix			
	KR-START	KR 1	KR 2	KR 3
Vitamins				
retinyl acetate	5.16	3.44	3.10	2.75
cholecalciferol	0.125	0.100	0.075	0.075
DL-alpha-tocopherol acetate	50	40	30	30
menadione	3	3	2	2
thiamine	5	3	2	2
riboflavin	8	6	6	6
pyridoxine	7	5	3.5	3
cyanocobalamin	0.025	0.02	0.02	0.02
nicotinic acid	75	50	40	40
calcium pantothenate	20	15	15	10
biotin	0.25	0.20	0.15	0.10
folic acid	3	2	1.5	1
choline chloride	350	300	300	200
betaine	75	75	50	50
Trace elements				
cobalt	0.45	0.45	0.45	0.45
copper	14	12	10	10
iron	50	45	40	40
iodine	2.40	2.25	2.25	1.00
manganese	120	100	100	100
zinc	100	75	70	70
selenium	0.2	0.2	0.2	0.2
Amino acids				
DL-methionine	1 800	1 400	1 400	
Coccidiostatics				
diclazuril	1			
sodium lasalocide		100	100	
Chemotherapeutics				
dimetridazole	90	90	90	
Other additives				
antioxidants	100	100	100	100
Growth promoters				
avilamycin	10	10	10	10

The regressions of determined values were calculated according to Snedecor and Cochran (1967).

To express the relationship between meat weight, dry matter, N*6 and fat retained in the meat and live weight of turkey a power function was used (Brody, 1945)

$$Y = aX^b$$

where: Y = content of the part in live weight in g,

X = live weight of turkey in g,

a = extrapolation of Y for $X = 1$,

b = allometric coefficient, ratio of the percentage change in Y to the corresponding percentage change in X

RESULTS AND DISCUSSION

The dependence of live weight in grams (Y_F – females and Y_M – males) on the age of turkeys in days (X) from hatching to Day 126 (F) and Day 175 (M) was expressed by the 3rd degree parabolas (Figure 1) with the inflection points on Day 82 (6 337 g) and Day 109 (13 328 g), respectively. At the age of 14 and 20 weeks (i.e. usual slaughter age), the average live weights of F and M were 8.50 kg and 19.36 kg, respectively.

The dependence of dietary dry matter consumption per unit of weight gain on the age of turkeys from hatch was described by the equations

$$Y_F = 0.86 + 0.0183 X; r = 0.984; P < 0.01 \text{ and}$$

$$Y_M = 0.89 + 0.0116 X; r = 0.968; P < 0.01.$$

When evaluating the period from 10 to 18 weeks and to 25 weeks of age for F and M, respectively, by means of linear regression, the daily increase in live weight was 114 and 178 g ($P < 0.01$), respectively. The increase in dietary dry matter consumption per unit of weight gain (FCR) was 0.0164 and 0.0165 ($P < 0.01$), respectively.

Similarly like in the experiments mentioned by Leeson and Summers (1980), Peng *et al.* (1985), Larsen *et al.* (1986), Blair *et al.* (1989) and Adams and Stadelman (1991), breast meat percentage in live weight increased linearly and highly significantly ($P < 0.01$) with the age in F and M; the corresponding values were 0.065 and 0.052 per day, respectively (Tables 3 and 4). Thigh and drumstick (i.e. leg) meat yields did not change with the increasing age ($P > 0.05$).

Fattening to higher weight brings benefits both to farmers and to the processing industry. A survey of weekly changes in basic production parameters of F and M turkeys is presented in Tables 5 and 6. For the time being, F and M are usually fed till the age of 14 and 20 weeks, respectively. F fattened to 18 weeks of age were 1.34-times heavier than those fattened to 14 weeks, and the feed conversion ratio was 1.13-times worse; however, the amount of BM and TM yield from each hatchling was 1.45-times and 1.40-times higher. As compared with 20-weeks-old M, the corresponding values for 25-week-old birds were 1.27, 1.21, 1.36 and 1.30, respectively.

When analysing the economic efficiency of a longer fattening period, it is necessary to consider

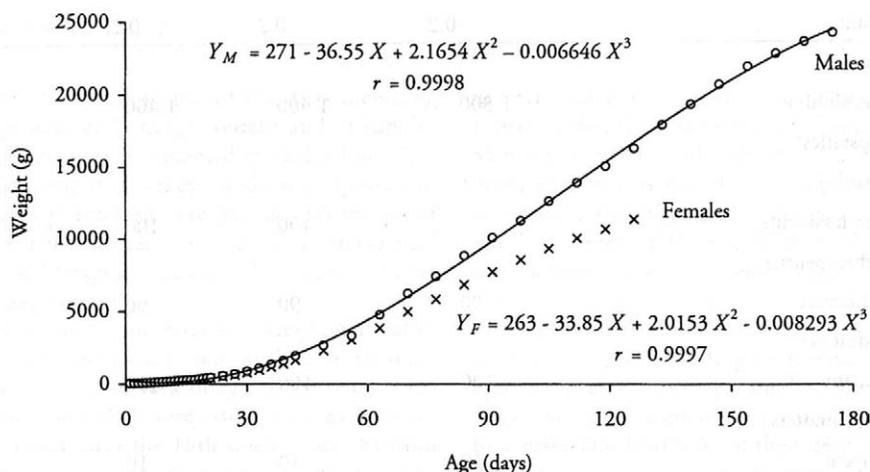


Figure 1. Live body weight of turkeys

Table 3. Dependence of meat yield characteristics on the age of females from 70 to 126 days

Regression equation		$Y = a + bX$			Mean \pm standard error of the mean
		a	b	r	
Breast meat	% of live weight	16.59	0.0649**	0.671	23.00 \pm 0.347
	dry matter (g/kg)	230.8	0.329**	0.846	263.3 \pm 1.39
	N*6 (g/kg)	230.8	-0.013	0.074	229.5 \pm 0.63
	fat (g/kg)	-19.9	0.312**	0.906	11.0 \pm 1.24
Thigh meat	% of live weight	7.62	0.0150	0.373	9.11 \pm 0.144
	dry matter (g/kg)	211.3	0.314**	0.678	242.3 \pm 1.66
	N*6 (g/kg)	178.0	0.106*	0.390	188.5 \pm 0.98
	fat (g/kg)	18.3	0.124	0.337	30.6 \pm 1.32
Drumstick meat	% of live weight	7.21	-0.0031	0.132	6.91 \pm 0.083
Leg meat	% of live weight	14.84	0.0120	0.223	16.02 \pm 0.192

X = age in days; r = correlation coefficients; a , b = parameters of equation

Significance of linear regression * $P < 0.05$, ** $P < 0.01$

Table 4. Dependence of meat yield characteristics on the age of males from 70 to 175 days

Regression equation		$Y = a + bX$			Mean \pm standard error of the mean
		a	b	r	
Breast meat	% of live weight	17.07	0.0518**	0.838	23.43 \pm 0.361
	dry matter (g/kg)	242.7	0.181**	0.763	264.8 \pm 1.38
	N*6 (g/kg)	243.7	-0.139**	0.680	226.7 \pm 1.19
	fat (g/kg)	-24.2	0.318**	0.889	14.9 \pm 2.09
Thigh meat	% of live weight	8.65	0.0067	0.301	9.47 \pm 0.129
	dry matter (g/kg)	205.7	0.278**	0.870	239.9 \pm 1.86
	N*6 (g/kg)	181.8	0.068	0.323	190.1 \pm 1.22
	fat (g/kg)	7.4	0.129**	0.577	23.2 \pm 1.30
Drumstick meat	% of live weight	6.84	0.0027	0.181	7.17 \pm 0.086
Leg meat	% of live weight	15.49	0.0093	0.289	16.64 \pm 0.188

X = age in days; r = correlation coefficients; a , b = parameters of equation

Significance of linear regression * $P < 0.05$, ** $P < 0.01$

Table 5. Basic production parameters of females fattened to different age

Age (days)	Live weight (g)	Feed conversion from hatching in dry matter	Feed conversion from 99th day in dry matter	Breast meat (g)	Thigh meat (g)	Drumstick meat (g)	Leg meat (g)	Breast meat in live weight (%)	Thigh meat in live weight (%)	Drumstick meat in live weight (%)	Leg meat in live weight (%)
70	4 924	2.218		1 041	427	329	772	21.13	8.67	6.67	15.68
77	5 819	2.334		1 256	511	401	917	21.59	8.78	6.90	15.76
84	6 724	2.445		1 482	597	474	1 066	22.04	8.88	7.05	15.85
91	7 622	2.551		1 715	685	544	1 214	22.50	8.99	7.13	15.93
98	8 495	2.651		1 950	772	607	1 361	22.95	9.09	7.15	16.02
105	9 327	2.747	3.877	2 183	858	662	1 502	23.40	9.20	7.09	16.10
112	10 101	2.837	4.099	2 410	939	704	1 635	23.86	9.30	6.97	16.18
119	10 798	2.922	4.303	2 625	1 016	732	1 757	24.31	9.41	6.78	16.27
126	11 404	3.002	4.359	2 824	1 084	743	1 865	24.77	9.51	6.52	16.35

Table 6. Basic production parameters of males fattened to different age

Age (days)	Live weight (g)	Feed conversion from hatching in dry matter	Feed conversion from 141st day in dry matter	Breast meat (g)	Thigh meat (g)	Drumstick meat (g)	Leg meat (g)	Breast meat in live weight (%)	Thigh meat in live weight (%)	Drumstick meat in live weight (%)	Leg meat in live weight (%)
70	6 043	1.632		1 251	551	425	975	20.70	9.12	7.03	16.14
77	7 261	1.711		1 529	666	512	1 177	21.06	9.17	7.05	16.21
84	8 541	1.792		1 830	787	604	1 390	21.42	9.21	7.07	16.27
91	9 868	1.876		2 150	914	699	1 612	21.78	9.26	7.09	16.34
98	11 230	1.961		2 487	1 045	798	1 842	22.15	9.31	7.10	16.40
105	12 613	2.049		2 839	1 180	899	2 077	22.51	9.35	7.12	16.47
112	14 003	2.138		3 203	1 316	1 000	2 315	22.87	9.40	7.14	16.53
119	15 386	2.229		3 575	1 454	1 102	2 554	23.23	9.45	7.16	16.60
126	16 749	2.323		3 952	1 590	1 203	2 791	23.60	9.49	7.18	16.66
133	18 078	2.418		4 331	1 725	1 301	3 024	23.96	9.54	7.20	16.73
140	19 359	2.516		4 709	1 856	1 397	3 251	24.32	9.59	7.22	16.79
147	20 579	2.615	3.923	5 080	1 983	1 489	3 469	24.68	9.63	7.24	16.86
154	21 724	2.717	4.161	5 441	2 103	1 576	3 676	25.05	9.68	7.26	16.92
161	22 780	2.820	4.555	5 788	2 216	1 657	3 870	25.41	9.73	7.27	16.99
168	23 734	2.926	5.149	6 117	2 320	1 731	4 047	25.77	9.78	7.29	17.05
175	24 572	3.033	5.522	6 422	2 414	1 797	4 206	26.14	9.82	7.31	17.12

the reduced costs of purchasing price of one-day-old hatchlings, losses due to mortality, different cost of feed mixtures, reduced energy consumption for heating, better use of halls and lower processing costs.

In F, the content of protein in BM did not change with increasing age while in M a highly significant decrease was observed ($P < 0.01$). In M, its dependence on age was expressed much better ($P < 0.01$)

by the concave parabola ($Y = 197.9 + 0.666 X - 0.003268 X^2$; $r = 0.821$) with the maximum on Day 102. On the other hand, in F the protein content of TM increased linearly during the whole experimental period ($P < 0.05$) while in M no changes were observed ($P > 0.05$). Crude protein content in BM and TM in 20-week-old males (22.4 and 19.1%, respectively) was slightly lower than in an experiment performed by Tůmová and Skřivan (1993).

Table 7. Allometric power functions in females from 70 to 126 days

Allometric function		$Y = aX^b$			
		a	b	I_{YX}	F -value
Breast meat	weight (g)	0.04648	1.178	0.985	777**
	dry matter weight (g)	0.00596	1.258	0.984	741**
	N*6 weight (g)	0.01076	1.177	0.983	699**
	fat weight (g)	6.5E-13	3.436	0.955	249**
Thigh meat	weight (g)	0.03035	1.122	0.970	376**
	dry matter weight (g)	0.00393	1.192	0.977	509**
	N*6 weight (g)	0.00443	1.150	0.965	325**
	fat weight (g)	0.00010	1.364	0.869	74**
Drumstick meat	weight (g)	0.07765	0.987	0.965	327**
Leg meat	weight (g)	0.09047	1.063	0.975	466**

X = age in days; a , b = parameters of equation; I_{YX} = index of correlation
Significance of I_{YX} ** $P < 0.01$

Table 8. Allometric power functions in males from 70 to 175 days

Allometric function		$Y = aX^b$			
		a	b	I_{YX}	F -value
Breast meat	weight (g)	0.04711	1.167	0.992	2 106**
	dry matter weight (g)	0.00739	1.222	0.992	2 028**
	N*6 weight (g)	0.01586	1.126	0.992	1 987**
	fat weight (g)	4.1E-13	3.343	0.950	294**
Thigh meat	weight (g)	0.04737	1.072	0.981	805**
	dry matter weight (g)	0.00491	1.160	0.984	946**
	N*6 weight (g)	0.00693	1.099	0.979	737**
	fat weight (g)	0.00003	1.454	0.900	136**
Drumstick meat	weight (g)	0.05544	1.027	0.981	831**
Leg meat	weight (g)	0.10077	1.052	0.986	1 100**

X = age in days; a , b = parameters of equation; I_{YX} = index of correlation
Significance of I_{YX} ** $P < 0.01$

As expected, the lipid content in TM was higher ($P < 0.01$) than in BM both in F and M. In F, the values calculated from particular regressions for the age of 98 days were 3.05% and 1.07% in TM and BM, respectively while in M the corresponding values for the age 140 days were 2.55% and 2.03%, respectively. However, each sex deposited total lipids in BM more than twice as intensely as in TM, as follows from a comparison of regression coefficients presented in Tables 3 and 4. The above calculated values for BM can be compared with data published by Decker and Cantor (1992) for an average lipid content in light turkey meat without skin, which was 1.6%. Tůmová and Skřivan (1993) reported an average lipid content in TM and BM of male turkeys slaughtered at the age of 20 weeks 4.64% and 1.37%, respectively, and Komprda *et al.* (2001) 2.45% and 1.47%, respectively.

As far as the comparison of sexes in the present experiment is concerned, according to findings by Wood (1989) and Oju *et al.* (1988) F deposited more of total lipids at the same age than M in TM ($P < 0.05$; based on linear regression equality test), but not in BM ($P > 0.05$).

When producing older turkeys, the value of the most valuable final product was markedly higher. Allometric coefficients b , expressing the relationship between BM weight, TM weight, dry matter, N*6 and fat retained in the meat on the one hand and live weight of turkeys on the other, are presented in Tables 7 and 8. In F, weights of BM, TM and amounts of protein in the BM and TM increased by 18; 12; 18; and 15% faster than their live weight. In M, the corresponding values were 17; 7; 13; and 10%, respectively. The increase in the fat content in breast meat of F and M was higher by 244 and 234%, respectively, than the growth rate of turkeys. The relative increase in fat content in TM was higher by 36% in F while in M it was higher by 45% than the relative growth rates of birds.

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ABSTRAKT

Retence bílkovin a tuku v masě krůt vykrmovaných do vyššího věku

Krůty (F) hybridní kombinace BUT Big 6 byly poráženy v týdenních intervalech ve věku 10 až 18 týdnů a krocani (M) ve věku 10 až 25 týdnů. V prsní svalovině (BM) a ve svalovině horního stehna (TM) byl zjišťován obsah bílkovin a tuku. Výťažnost BM se u F i M lineárně zvyšovala ($P < 0,01$), výťažnost TM a svaloviny dolního stehna se s věkem neměnila ($P > 0,05$). Obsah bílkovin v BM se u F neměnil, závislost na věku u M byla vyjádřena rovnicí paraboly s maximem ve 102. dni života. Obsah bílkovin v TM se během celého sledovaného období u F lineárně zvyšoval ($P < 0,05$) a u M se průkazně neměnil ($P > 0,05$). Obsah tuku byl v TM u F i M vyšší ($P < 0,01$) než v BM. Ve stejném věku ukládaly F v TM více ($P < 0,05$) tuku než M, v BM byl rozdíl neprůkazný ($P > 0,05$). Hmotnost BM, TM, množství bílkovin a tuku uložené v BM a TM se zvyšovalo u F o 18; 12; 18; 244; 15 a 36 % a u M o 17; 7; 13; 234; 10 a 45 % rychleji než jejich živá hmotnost.

Klíčová slova: krůty; pohlaví; věk; délka výkrmu; krůtí maso; výťažnost masa; složení masa

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Correlation between the thickness of breast muscles and meatiness in turkeys

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ABSTRACT: The experiment was performed on 240 white broad-breasted turkeys aged 16 weeks. Live measurements of the thickness of their breast muscles were carried out with an ultrasonic apparatus. A significant correlation ($r = 0.401\text{--}0.630$) between the weight and thickness of breast muscles measured at point P II was observed in both turkey-toms and turkey-hens of strains J-11, J-22 and J-44. Their thickness measured at this point can also be an indicator of total meat weight in the turkeys of both sexes that resemble those of strains J-11, J-22 and J-44. The thickness of muscles at point P IV can also be applied to indirect estimation of relative meatiness of some types of turkeys, as it shows a significant correlation ($r > 0.400$) with the analysed traits of meatiness.

Keywords: turkeys; thickness of breast muscles; musculature traits; coefficients of correlation

Carcass meatiness in poultry depends first of all on the content of breast and leg muscles. That is why selection is aimed at developing these groups of muscles. Body measurements can be useful in breeding work (Stiles and Brandt, 1971; Gillis *et al.*, 1973; Lewczuk, 1978; Bochno, 1982; Michalik and Bochno, 1986; Wawro and Bochno, 1986; Jankowski, 1989; Wawro and Wawro, 1989; Wawro, 1990; Wawro and Jankowski, 1990; Rymkiewicz and Bochno, 1998).

An analysis of various research results made by Bochno (1982) indicates the possibility of using measurements of breast muscle thickness in breeding work aimed at improving carcass meatiness in poultry. The studies by Bocksch (1979), Pingel and Hattenhauer (1982), Hattenhauer and Pingel (1985) show that these measurements can be applied to indirect estimation of breast part meatiness in turkeys, as there is a close correlation ($r > 0.7$) between the thickness and weight of breast muscles. Lewczuk (1978) reported a slightly less significant correlation ($r < 0.7$) between breast muscle thickness measured at different points and meat weight in carcasses of turkey broilers. Bochno and Michalik (1979) found out that the thickness of breast muscles measured intravitaly in adult

turkey-hens is significantly correlated with meat weight, and insignificantly with meat percentage.

The present studies were conducted due to the fact that the results obtained by various authors were ambiguous. Their aim was to determine the usefulness of live measurements of breast muscle thickness at different points for indirect estimation of meatiness in turkeys.

MATERIAL AND METHODS

The experimental material was 240 white broad-breasted turkeys of strains J-11, J-22, J-33 and J-44 (30 ♂ and 30 ♀ from each strain), selected for many generations at the Turkey Breeding Centre in Biesal near Olsztyn (Jankowski, 1989; Wawro, 1990; Faruga and Jankowski, 1996) using Hybrid 2200 turkeys imported from Canada to Poland in the years 1980–1981. In sire strains the selection was aimed at improving meatiness traits, and the index of reproduction was of secondary importance. The main aim of selection was to increase body weight and meatiness. Strain J-22 could be used as both paternal female or maternal male as these turkeys were characterised not only by high

body weights but also by a good egg yield (Faruga and Jankowski, 1996). In the maternal female strain (J-44) the index of reproduction played the most important role. These turkeys were of a light (mini) type. Their body weights and meatiness were low, but the average level of egg production was over 100 eggs. In the maternal male strain (J-33) the selection aims were to increase both these indices.

The studies were conducted on turkeys aged 16 weeks. Live measurements of the thickness of breast muscles (*musculus superficialis* and *musculus profundus*) were carried out with an ultrasonic apparatus, at four points: P I – 1.5 cm from the breast-bone crest and 4.0 cm to the right from its edge, P II – 3.0 cm and 4.0 cm, respectively, P III – 4.0 cm and 2.0 cm, respectively, P IV – 1.5 cm in front of the breast-bone crest and 3.0 cm to the right from its edge.

Eviscerated and chilled carcasses were subjected to detailed dissection. The weight of breast muscles, leg muscles, breast and leg muscles, and all muscles in the carcass (total meat weight) was analysed. The weight of these muscles was also expressed as percentage of body weight before slaughter.

A statistical analysis included arithmetic means (\bar{x}), coefficients of variation (v) of the traits examined and coefficients of correlation between the thickness of breast muscles and meatiness in turkeys.

RESULTS AND DISCUSSION

Turkeys of strains J-11 and J-22 were characterised by the thickest breast muscles, measured at point P I (\bar{x} ca. 5.0 cm). Breast muscles of turkeys (♂ and ♀) of strain J-44 were by 1 cm thinner (Table 1). This is consistent with the directions of their improvement (Jankowski, 1989; Jankowski *et al.*, 1996). Turkeys of sire strains were also characterised by much higher breast muscle thickness measured at points P II, P III and P IV than turkeys from the maternal female strain (J-44). Turkey-toms usually had somewhat thicker breast muscles than turkey-hens. J-22 hens were the only exception here.

Carcasses of the examined turkeys showed relatively good meatiness. The highest weight of breast and leg muscles, as well as the highest meat content, was observed in carcasses of toms of strains J-11 and J-22, whereas the lowest – in those of J-44 hens (Table 1). As concerns relative meatiness

(expressed as percentage of body weight before slaughter), it was better in females than in males. Similar tendencies were noted in previous studies by Lewczuk (1978), Jankowski (1989), Wawro and Jankowski (1990). Brenøe and Kolstad (2000) report that the meat and breast part content of carcasses is similar in both sexes up to 15 weeks of age. Lesson and Summers (1980) observed higher percentages of breast and leg muscles in carcasses of toms than in those of hens at the age of 16 weeks. Many authors (Clayton *et al.*, 1978; Larsen *et al.*, 1986; Jankowski, 1989; Wawro, 1990; Barbour and Lilburn, 1995, 1996; Brake *et al.*, 1995) agree that meatiness depends on the type, strain and age of turkeys to a large extent. Heavy turkeys and turkeys from sire strains are mostly characterised by higher weight of breast and leg muscles, higher total meat content and better relative meatiness than the medium-heavy ones and those from maternal strains.

Tables 2 and 3 present coefficients of correlation between breast muscle thickness measured at various points, and meatiness traits. The values of these coefficients depend not only on the point of measurement of muscle thickness but also on the strain and sex of birds.

There was a significant correlation ($r = 0.474$ to 0.630) between the weight and thickness of breast muscles measured at points P I, P II and P IV in both toms and hens of strain J-11 (Tables 2 and 3). In birds of both sexes of strain J-22 the weight of breast muscles was significantly correlated only with their thickness measured at point P II ($r =$ ca. 0.450), whereas in strain J-33 – at P III ($r_{\sigma} = 0.424$; $r_{\text{♀}} = 0.393$). In strain J-44 lack of correlation between the weight and thickness of breast muscles was found only in the case of measurement at point P I ($r < 0.362$). These results differ slightly from those obtained by Wawro and Salej (1997), who found out that breast muscle thickness measured at seven various points, including P I, shows a close correlation with breast muscle weight in males ($r = 0.8–0.9$); in females this correlation was much lower in the majority of 20 measurements taken at different points of the breast part.

The results of our own research show that the measurement of breast muscle thickness turned out to be useless for indirect estimation of the leg muscle content in turkeys of strains J-22 and J-33 – $r < 0.362$ (Tables 2 and 3). The thickness of these muscles, measured at four points, was significantly correlated with the weight and percentage of leg muscles in J-11 toms ($r =$ ca. 0.5) and

Table 1. Arithmetic means (\bar{x}) and coefficients of variation (v , %) of the analysed traits

Specification	Trait symbol	Statistics	Strain							
			J-11		J-22		J-33		J-44	
			♂	♀	♂	♀	♂	♀	♂	♀
Thickness of breast muscles measured at points (cm)										
1.5 × 4.0	P-I	\bar{x}	5.02	4.95	4.92	5.09	4.34	4.53	4.02	4.14
		v	11.02	8.52	9.56	7.08	11.78	12.40	13.19	11.15
3.0 × 4.0	P-II	\bar{x}	4.73	4.70	4.72	4.77	4.42	4.22	3.89	3.78
		v	8.58	9.40	8.87	6.26	7.70	8.94	12.49	7.83
4.0 × 2.0	P	\bar{x}	4.66	4.39	4.73	4.50	4.332	3.99	3.83	3.50
		v	9.16	8.82	11.15	6.43	7.66	7.57	9.18	9.06
1.5 × 2.0	IV	\bar{x}	4.19	3.99	4.33	4.12	4.00	3.70	3.53	3.19
		v	10.38	10.67	12.75	8.77	8.31	8.28	10.55	11.42
Weight of (kg)										
breast muscles	x_1	\bar{x}	2.11	1.46	2.14	1.49	1.78	1.25	1.39	0.92
		v	13.77	9.23	10.19	10.85	9.80	7.55	15.71	11.81
leg muscles	x_2	\bar{x}	1.80	1.19	1.73	1.22	1.47	1.03	1.18	0.77
		v	13.91	9.47	9.28	10.26	8.22	6.78	13.06	12.02
breast and leg muscles	x_3	\bar{x}	3.91	2.65	3.87	2.71	3.25	2.28	2.57	1.69
		v	12.76	8.45	8.69	9.65	8.66	6.51	13.05	11.32
total meat weight (kg)	x_4	\bar{x}	5.48	3.73	5.44	7.83	4.62	3.22	3.65	2.43
		v	11.84	7.97	8.26	8.61	8.64	6.22	11.55	10.48
Percentage of (body weight = 100%)										
breast muscles	x_5	\bar{x}	21.26	21.79	21.99	21.87	21.13	21.51	20.00	20.56
		v	6.40	6.33	6.51	7.73	4.94	5.02	5.94	6.11
leg muscles	x_6	\bar{x}	17.94	17.80	17.64	18.00	17.34	17.75	17.18	17.18
		v	5.53	4.72	5.52	4.43	3.71	3.96	5.51	4.04
breast and leg muscles	x_7	\bar{x}	39.20	39.59	39.63	39.88	38.48	39.26	37.18	37.74
		v	4.65	5.63	3.92	4.24	3.58	3.35	4.49	3.55
total meat content	x_8	\bar{x}	55.25	55.80	55.87	56.35	54.68	55.39	53.41	54.00
		v	3.91	3.39	2.60	3.39	3.07	2.31	3.07	3.05

– except for measurement at point P I – with the leg muscle content in J-44 turkeys of both sexes ($r = 0.428-0.677$).

The thickness of breast muscles at point P II can be important for indirect estimation of meatiness in turkeys. It shows a correlation with the total meat weight, both in toms and hens of strains J-11, J-22 and J-44 ($r = 0.402-0.571$) – Table 2. This was confirmed by Lewczuk (1978), who reported that

breast muscle thickness measured at this point was closely correlated with the meat weight in carcasses of 16-week-old toms ($r = 0.697$) and hens ($r = 0.513$).

Special attention should be paid to a significant correlation between the meat weight in carcasses of J-44 turkeys of both sexes and breast muscle thickness at points P III and P IV: $r = 0.504-0.695$ (Table 3). It seems that the selection pressure

Table 2. Coefficients of correlation between the thickness of breast muscles at points P I and P II, and meatiness traits

Meatiness trait symbol	Thickness of muscles at points	Strain							
		J-11		J-22		J-33		J-44	
		♂	♀	♂	♀	♂	♀	♂	♀
x_1^a	P I	0.486	0.494	0.345	0.278	0.032	0.244	0.136	0.292
	P II	0.630	0.524	0.451	0.465	0.283	0.328	0.401	0.597
x_2	P I	0.512	0.258	0.269	0.171	0.076	0.239	0.312	0.008
	P II	0.541	0.331	0.210	0.322	0.286	0.246	0.585	0.428
x_3	P I	0.505	0.427	0.333	0.254	0.053	0.267	0.283	0.180
	P II	0.613	0.481	0.482	0.489	0.299	0.324	0.567	0.579
x_4	P I	0.471	0.429	0.366	0.198	0.072	0.340	0.292	0.199
	P II	0.571	0.434	0.448	0.402	0.301	0.358	0.549	0.551
x_5	P I	0.304	0.320	0.188	0.254	-0.144	-0.040	0.178	0.344
	P II	0.616	0.367	0.200	0.261	0.207	0.180	0.426	0.459
x_6	P I	0.237	-0.041	-0.012	0.179	-0.357	-0.124	-0.325	0.360
	P II	0.316	0.144	0.088	0.282	0.013	0.005	0.527	0.146
x_7	P I	0.340	0.319	0.181	0.313	-0.160	-0.099	0.324	0.147
	P II	0.657	0.427	0.229	0.354	0.225	0.149	0.615	0.517
x_8	P I	0.186	0.245	0.277	0.186	-0.129	0.004	0.354	0.147
	P II	0.566	0.479	0.115	0.087	0.246	0.263	0.582	0.446

Critical values of r for $\alpha = 0.05$ –0.362

a – explanation of the symbol “x” is given in Table 1

put on meatiness in this strain (Jankowski, 1989; Jankowski *et al.*, 1996) did not cause any excessive development of breast muscles, which could lead to disproportions in the body structure of these turkeys. This is probably the reason for a significant correlation between breast muscle thickness and total meat weight, both in toms and hens of strain J-44.

A correlation between the thickness and quantity of breast muscles, expressed as percentage of body weight before slaughter, was slightly different from that concerning the weight of breast and leg muscles, and the total meat weight (Tables 2 and 3). The thickness of breast muscles was only in some cases significantly correlated with the analysed traits of meatiness. Measurements of muscle thickness at point P I turned out to be completely useless for estimation of the percentages of breast muscles, leg muscles and total meat content in turkeys

– $r < 0.362$ (Table 2). Similarly to this measurement (P I), breast muscle thickness measured at points P II, P III and P IV cannot be treated as reliable for estimation of relative meatiness in turkeys of strains J-22 and J-33 due to (mostly) insignificant coefficients of correlation. The lack of significant interdependence between breast muscle thickness and relative meatiness in J-22 and J-23 turkeys was probably caused by certain differences in their body conformation, compared with J-11 and J-44 birds. According to Faruga and Jankowski (1996), J-22 turkeys were characterised by higher body weights and lower breast width than J-11 birds. J-33 turkeys, classified to the medium (midi) type, showed higher body weights and meatiness, as well as slightly different body conformation, compared with light (mini) birds of strain J-44 (Jankowski, 1989; Faruga and Jankowski, 1996).

Table 3. Coefficients of correlation between the thickness of breast muscles at points P III and P IV, and meatiness traits

Meatiness trait symbol	Thickness of muscles at points	Strain							
		J-11		J-22		J-33		J-44	
		♂	♀	♂	♀	♂	♀	♂	♀
x_1^a	P III	0.668	0.189	0.330	0.516	0.424	0.393	0.488	0.698
	P IV	0.618	0.474	0.285	0.235	0.162	0.424	0.446	0.605
x_2	P III	0.616	0.116	0.029	0.239	0.339	0.200	0.533	0.485
	P IV	0.482	0.029	0.215	0.122	0.196	0.284	0.509	0.677
x_3	P III	0.668	0.172	0.299	0.432	0.409	0.344	0.594	0.654
	P IV	0.624	0.299	0.319	0.203	0.185	0.404	0.496	0.673
x_4	P III	0.620	0.143	0.291	0.422	0.419	0.359	0.586	0.637
	P IV	0.596	0.241	0.322	0.157	0.195	0.423	0.504	0.695
x_5	P III	0.614	0.117	0.109	0.328	0.307	0.305	0.577	0.545
	P IV	0.606	0.504	-0.025	0.169	0.107	0.246	0.161	0.228
x_6	P III	0.392	0.033	-0.165	-0.190	-0.049	-0.030	0.321	0.155
	P IV	0.446	-0.192	-0.067	0.014	0.048	-0.031	0.211	0.481
x_7	P III	0.602	0.277	-0.042	0.213	0.250	0.234	0.602	0.603
	P IV	0.653	0.387	-0.094	0.162	0.149	0.185	0.271	0.469
x_8	P III	0.483	0.040	-0.079	0.092	0.304	0.344	0.566	0.492
	P IV	0.585	0.415	-0.111	0.014	0.168	0.264	0.401	0.438

Critical values of r for $\alpha = 0.05$ – 0.362

a – explanation of the symbol “x” is given in Table 1

The thickness of muscles measured at points P II, P III and P IV can be of some importance for estimation of relative meatiness in the turkeys that resemble those of strains J-11 and J-44. Muscle thickness at point P II showed a significant correlation with the percentages of breast muscles, breast and leg muscles and total meat content in toms and hens of strains J-11 and J-44 ($r = 0.367$ – 0.657) – Table 2.

Measurement of breast muscle thickness at point P III can be useful in breeding work aimed at improving the meatiness of small-sized turkeys, resembling J-44 ones in constitution and body weight. This measurement shows a close correlation with the percentages of breast muscles ($r_{\sigma} = 0.577$, $r_{\Omega} = 0.545$), breast and leg muscles ($r > 0.600$) and total meat content ($r_{\sigma} = 0.566$, $r_{\Omega} = 0.492$) – Table 3. As regards the improvement of relative meatiness in turkeys resembling J-11 ones, breast muscle thickness measured at point P IV can be taken into consideration as it is significantly correlated ($r > 0.362$) with the examined traits of meatiness, both in toms and hens of this strain.

The localisation of the most reliable point of measurement of breast muscle thickness by means of ultrasonic waves is an important problem from the perspective of meatiness improvement in turkeys. According to Brenøe and Kolsted (2000), the tissue composition of live turkeys can be determined by computer tomography in future. However, it seems that its indirect estimation based on ultrasonography can still be an alternative to this expensive method.

CONCLUSIONS

The results of the studies allow to formulate the following conclusions:

1. The thickness of breast muscles measured at point P II (3.0 cm from the breast-bone crest and 4.0 cm to the right from its edge) can be useful for indirect estimation of breast muscle weight and total meat weight in turkeys resembling those of strains J-11, J-22 and J-44.

2. The thickness of breast muscles measured at points P II, P III and P IV can be applied to estimation of relative (expressed as percentage of body weight) meatiness of turkeys resembling J-11 and J-44 ones, since it is highly correlated (in both sexes) with the percentages of breast muscles and total muscles.

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ABSTRAKT

Korelace mezi tloušťkou prsní svaloviny a zmasilostí u krůt

Pokus jsme prováděli na 240 bílých širokoprsých krůtách ve věku 16 týdnů. Tloušťku prsní svaloviny jsme měřili na živých krůtách ultrazvukem. U krocánů i krůt linií J-11, J-22 a J-44 jsme zaznamenali významnou korelaci ($r = 0,401 - 0,630$) mezi hmotností a tloušťkou prsní svaloviny naměřenou v bodě P II. Tato tloušťka svaloviny zjištěná v daném bodě může být rovněž ukazatelem celkové hmotnosti masa u těch krůt obojího pohlaví, které jsou podobné krůtám linií J-11, J-22 a J-44. Tloušťku svaloviny v bodě P IV lze také použít k nepřímému odhadu relativní zmasilosti u některých typů krůt, jak to naznačuje významná korelace s analyzovanými znaky zmasilosti.

Klíčová slova: krůty; tloušťka prsní svaloviny; znaky svaloviny; korelační koeficienty

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