



Performance and behaviour of chickens with different growing rate reared according to the organic system

Cesare Castellini, Alessandro Dal Bosco,
Cecilia Mugnai, Marcella Bernardini

Dipartimento di Scienze Zootecniche. Università di Perugia, Italy.

Corresponding author: Prof. Cesare Castellini. Dipartimento di Scienze Zootecniche, Università di Perugia. Borgo XX Giugno 74, 06121 Perugia, Italy. Tel. +39-075-5857115 – Fax: +39-075-5857122 - E-mail: cesare@unipg.it.

Paper received October 3, 2002; accepted December 9, 2002

ABSTRACT

The performance and the behaviour of three different chicken strains, reared according to the EEC-Regulation 1804/1999 organic system, were compared. The strains had very slow (Robusta maculata), slow (Kabir) and fast (Ross) growing rates, respectively. The trial was carried out on 200 chickens (male and female) per strain. Rearing lasted 81 days as required by the EEC Regulations. At slaughter age, 20 birds per group were killed. Robusta maculata and Kabir chickens showed more intense walking activity and better foraging aptitude; their antioxidant capacity was also superior. Ross chickens had a good growth rate and feed conversion index, reaching an excellent body weight, but the mortality and the culling rate were high indicating that fast-growing strains do not adapt well to organic production. Robusta maculata showed the worst productive performance although the mortality was low and Kabir birds gave intermediate results. The carcass traits were the best in Ross and the poorest in Robusta maculata. Male chickens were heavier and leaner than females.

Key words: Chickens, Performance, Behaviour, Organic system

RIASSUNTO

PRESTAZIONI PRODUTTIVE E COMPORTAMENTO DI POLLI A DIVERSO RITMO DI CRESCITA ALLEVATI CON IL SISTEMA BIOLOGICO

Sono state valuate le prestazioni produttive e il comportamento di polli appartenenti a genotipi a lento (Robusta maculata) medio (Kabir) e rapido accrescimento (Ross) allevati con il sistema biologico. A tale scopo sono stati utilizzati 200 soggetti (maschi e femmine) per tipo genetico per un periodo di 81 giorni, macellando poi 20 soggetti per ceppo. I polli di Robusta maculata e Kabir hanno mostrato un'attività motoria più intensa ed una migliore attitudine al pascolamento; hanno inoltre presentato una capacità antiossidante superiore. I polli Ross hanno fornito un migliore indice di conversione alimentare e più elevati tassi di accrescimento, raggiungendo buoni pesi finali, ma elevati livelli di mortalità, tanto da ritenerli poco adatti per questo tipo di allevamento. La Robusta maculata ha mostrato le peggiori prestazioni produttive anche se la mortalità è stata molto bassa; il Kabir ha evidenziato risultati intermedi. Le caratteristiche della carcassa hanno evidenziato un andamento analogo. I maschi erano più pesanti e magri delle femmine.

Parole chiave: Pollo, Prestazioni produttive, Comportamento, Allevamento biologico.

Introduction

In Europe an increasing number of consumers are willing to pay higher prices for the guarantee of organically grown animal products (Bennet, 1996). The organic livestock system promises such guarantees due to the guidelines of EEC-Regulation 1804/1999 which provides specifications for housing conditions, nutrition, breeding and animal care, disease prevention and veterinary treatment.

In relation to the choice of breed the regulation states that "account must be taken of the capacity of animals to adapt to local conditions, their vitality, and their resistance to disease". In addition, specific health problems associated with some breeds or strains used in intensive systems should be avoided and slow-growing animals are recommended for the potential better adaptation to the outdoor environment and to a long rearing period (at least 81 d).

Despite these specifications, the reality of strains that are suitable for organic or free-range conditions is very different. Most birds originate from commercial suppliers, who furnish chickens that have been selected for high growth rate and good feed conversion under intensive conditions (Reiter and Bessei, 1996). Obtaining slow-growing strains is difficult and expensive and, therefore, many breeders use strains that have been selected for rapid growth rate and low feed conversion and which are extensively used in intensive production. In the organic system these genotypes can show muscular-skeletal problems induced by increased motor activity.

However, there are some slow-growing strains that have been selected for this type of rearing (Katz, 1995; Saveur, 1997) as well as some pure breeds, more suitable for extensive conditions. By using the latter ones, their extinction could be avoided.

Few scientific studies exist on the adaptation of different strains to the organic production system. Grashorn (1999) investigated the performance and meat quality of several strains reared under intensive, semi-extensive and extensive systems and found a progressive reduction of performance in birds reared extensively. Farmer *et al.*

(1997), in comparing Ross with ISA chickens reared under extensive system, found a faster body weight gain and a more efficient feed conversion ratio in Ross chickens that also showed lower motion activity and higher mortality.

So, the choice of a genotype requires attaining a balance between rusticity and productive performance, but it also depends on the final destination of the birds (integrated production, free market, restoration, etc).

The objective of this work was to compare behaviour, growing performance and carcass traits of three different chicken strains with different growth rates reared under organic system (EEC-Regulation 1804/1999).

Material and methods

Animals, housing and feeding

Six hundred 1-day-old chicks of both sexes from a very slow-growing (Robusta maculata), slow-growing (Kabir) and fast-growing (Ross 208) genotypes were reared separately (2 replications per sex and genotype) under a brooder lamp for the first 3 weeks of life on the experimental farm of the Animal Production Department (University of Perugia). The environmental temperature ranged from 20 °C to 25 °C and the relative humidity from 65 to 75%. Incandescent lamps (30 lux) placed at bird level were used for illumination. Chicks were vaccinated against Mareks and Newcastle disease and coccidiosis (Paracox®-8).

After 21-days of age the birds of each strain were put in 4 covered shelters (2 replications per sex) (0.10 m²/bird) with straw litter and access to a grass paddock (4 m²/bird); feeders and drinkers were available both outdoors and indoors.

The trial was carried out from April to June 2002.

Chickens were fed *ad libitum* the same starter (1-21 d) and finisher (22 d to slaughter) diets, containing more than 80% certified organic ingredients, bought from a national agency. Characteristics of the diets are presented in Table 1.

Individual body weights were recorded weekly, as well as the collective feed intake of each subgroup. The average feed consumption of the group was used to calculate the individual feed:gain

ratio. The number of culled and dead birds was recorded and animals were sent to the Istituto Zooprofilattico Sperimentale Umbria e Marche for diagnosis.

At 81 days, a sample of 20 birds per strain (10 males and 10 females), each weighing between

$\pm 10\%$ of the population mean, were slaughtered in the Department processing plant, 12 hours after feed withdrawal. Chickens were not transported and were electrically stunned (110 V; 350 Hz) before killing.

Grass samples were taken from 1 m² of paddock by cutting it at 3 cm above the ground for chemical analysis.

Table 1. Formulation (%), chemical composition (% d.m.) and energetic value (MJ kg⁻¹) of the diets.

	Starter	Finisher	Grass
Ingredients:			
Maize	52.0	46.0	
Full fat soybean	30.5	12.5	
Wheat	-	20.0	
Soybean meal ⁽¹⁾	9.0	14.0	
Alfalfa meal	2.8	2.8	
Gluten feed	3.0	2.0	
Vitamin-mineral premix ⁽²⁾	1.0	1.0	
Dicalcium phosphate	1.0	1.0	
Sodium bicarbonate	0.5	0.5	
NaCl	0.2	0.2	
Chemical composition:			
Dry matter	90.89	90.80	25.30
Crude protein	22.30	18.05	13.28
Ether extract	7.95	4.98	5.88
Crude fibre	4.67	4.01	23.25
Ash	5.76	5.59	7.86
NDF - Neutral Detergent Fibre	10.74	10.11	43.28
ADF - Acid Detergent Fibre	5.58	5.06	31.23
Cellulose	4.22	3.56	26.41
ADL - Acid Detergent Liquid	1.03	1.11	4.82
Hemicellulose	5.16	5.05	12.06
Metabolisable Energy*	12.54	12.98	5.78
Carotenoids mg kg d.m. ⁻¹		18.31	102.10
a-tocopherol mg kg d.m. ⁻¹		35.52	175.25

⁽¹⁾ From conventional crops.

⁽²⁾ Amounts per kg: Vit. A 11.000 IU; Vit. D₃ 2.000 IU; Vit. B₁ 2.5 mg; Vit. B₂ 4 mg; Vit. B₆ 1.25 mg; Vit. B₁₂ 0.01 mg; α -tocopheryl acetate 30 mg; Biotin 0.06 mg; Vit. K 2.5 mg; Niacin 15 mg; Folic acid 0.30 mg; Panthotenic acid 10 mg; Choline chloride 600 mg; Mn 60 mg; Fe 50 mg; Zn 15 mg; I 0.5 mg; Co 0.5 mg.

* estimated by Carre and Rozo (1990).

Behavioural observations

Behaviour observations were recorded at 7 and 11 weeks of age in the morning and afternoon, during two periods of three hours each according to the procedure used by Lewis *et al.* (1997). Twenty birds per strain were chosen at random and marked with different colours on the tip of the tail. The behavioural observations included: walking, standing, lying, eating (food and water) and others (preening, pecking and scratching the litter or the ground). The various behaviours were recorded on a purpose-designed table, and their respective frequencies were calculated as a percentage of the total observed behaviours. Since no differences were found between weeks and hours, all data were pooled to obtain a mean value.

The interest shown by the birds when the observer entered the pen and the time spent outdoors or indoors were registered for all birds.

At 81 days, just before slaughtering, twenty chickens from each of the three groups were subjected to a tonic immobility test for fear response, as described by Scott and Moran (1993). Each bird was manually inverted and restrained in a cradle for 10 sec. The time that needed for the bird to right itself was recorded (up to a maximum of 3 min).

Blood sample collection, analytical determinations and carcass dissection

Immediately before slaughter, blood samples were collected in heparinized vacutainers and centrifuged at 1,500 x g for 10 min at + 4 °C, to measure the *in vivo* antioxidant capacity by the Oxyadsorbent test produced by Diacron ® s.r.l. (Italy) (Cesarone *et al.*, 1999).

After killing, carcasses were plucked, eviscerated (non-edible viscera: intestines, proventriculus, gall bladder, spleen, oesophagus and full crop) and

Table 2. Behaviour pattern of chickens*.

Behaviour		Strain			SEM
		Kabir	Ross	Robusta maculata	
Initial interest	%	55b	31a	60b	8
Time spent outdoors	% total time	60b	35a	65b	10
Lying	"	55.0a	62.5b	54.0a	4.1
Walking	"	12.0b	8.0a	12.0b	3.2
Standing	"	16.5	16.0	18.5	8.0
Eating	"	8.0	8.5	7.5	5.3
Others	"	7.5b	5.0a	8.0a	1.2
Tonic immobility	sec	49a	110b	41a	42

N=20 per strain.

Means within rows bearing different superscript (A..B; a..b) differ significantly at $P<0.01$ and $P<0.05$.

* Observation done at 7 and 11th weeks of age.

stored for 24 hours at + 4 °C. Head, neck, legs, edible viscera (heart, liver, gizzard), and fat (perivisceral, perineal and abdominal) were removed in order to obtain the ready-to-cook carcass (ASPA, 1996).

The content of the crop without the grit was weighed and analysed to compare the feeding behaviour of the strains.

Chemical analyses of diet, grass and crop contents and carotenoids of the diet and grass were done according the AOAC methods (1995); the metabolisable energy was estimated with the equation of Carre and Rozo (1990).

Alpha-tocopherol in the diet, grass and crop contents was extracted with diethyl-ether (2:1) on 5 g of samples saponified with ethanol and KOH (50%). The homogenate was centrifuged (1,630 x g, 10 min) and the supernatant was transferred to a large test tube and dried to 0.5 ml under N₂ at 30-40 °C. The pellet was re-extracted two more times with 20 vol of acetone and centrifuged. All supernatant fractions were combined and reduced to less than 1 ml under N₂; 100 µl of the filtrate was then injected into the HPLC (Zaspel and Csallany, 1983).

Breast conformation was measured as follows: the maximal breast width and length were measured with a callipers, whereas the thickness was evaluated by inserting a metal needle in the fourth anterior of the sternum. Successively, the breast muscles and the thigh and drumstick (bone

and meat) were excised to calculate the breast meat yield, the thigh and drumstick weight and the meat/bone ratio.

Statistical analyses

Data were analysed with a linear model (SAS/STAT, 1990 - procedure GLM) and the significance of differences was evaluated by t-test. The effect of strain only was included in the analysis of the behavioural observations and crop contents, whereas for the productive performance and carcass data, the sex effect and interaction were also included in the model.

Differences in culling and mortality rates were evaluated by X² (Procedure FREQ).

Results and discussion

The chemical composition of the diet and of the grass samples are reported in Table 1. The grass had a high amount of carotenoids (102.10 mg kg d.m.⁻¹) and a-tocopherol (175.25 mg kg d.m.⁻¹). The a-tocopherol content is in agreement with the results of Lopez-Bote *et al.* (1998a) and is relatively higher than the recommendation for broiler diets (NRC, 1994).

Robusta maculata and Kabir chickens showed more active behaviour (Table 2), with more walking, less lying and more interest in the observer ($P<0.05$), and they spent more time outdoors than

Table 3. Comparison between chemical composition of the crop contents in the three strains and in vivo antioxidant capacity at 81d.

Strain		Kabir	Ross	Robusta maculata	SEM
Crude protein	%	10.4a	12.4b	10.0a	2.4
Ether extract	"	3.0	3.5	2.9	1.1
NDF	"	10.0	9.8	10.2	1.8
ADF	"	6.2	5.7	6.3	0.9
Estimated Metabolisable Energy	MJ kg	7.6ab	8.7b	6.7a	2.3
Carotenoids	mg kg ⁻¹	20.2b	19.1a	21.2b	1.6
a-tocopherol	mg kg ⁻¹	38.0b	36.2a	38.5b	2.6
Antioxidant capacity	mmol HClO ml ⁻¹	700B	522A	715B	58

N=20 per strain.

Means within rows bearing different superscript (A..B; a..b) differ significantly at $P<0.01$ and $P<0.05$.

indoors ($P<0.05$). These genotypes showed a quicker reaction ($P<0.05$) in the tonic immobility test confirming the statement of Bryan-Jones (1996), who found that selecting for increased productivity did not result in the elimination of fear and stress behaviour.

In comparing the behaviour of a slow-growing with a fast-growing type, both reared under extensive conditions, Lewis *et al.* (1997) observed that the slow-growing strain was more active. As indicated by Schütz and Jensen (2001), selection for high production rates results in modified behaviour. Behaviour involving high energetic costs is less recurrent in selected strains, allowing

them to save energy that can be reallocated to production traits.

Weeks *et al.* (1994) compared the behaviour of Ross broilers reared under free-range or kept inside and showed that free-range birds made little use of pasture and tended to stay indoors and/or near the house, rather than forage in the pasture. The authors attributed this behaviour mainly to leg weakness, which prevented the birds from pasturing and behaving naturally.

The differences in foraging behaviour agree with the statement of Appleby *et al.* (1992), who reported that free-range conditions allow poultry, mainly from slow growing strains, to express not

Table 4. Performance of broilers at 81d.

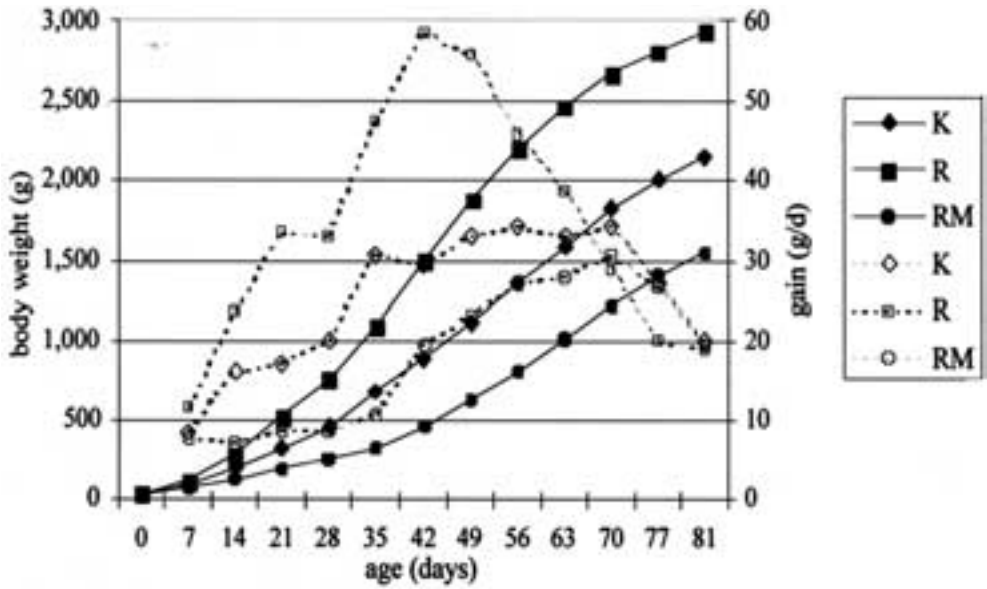
Strain		Kabir		Ross		Robusta maculata		P	SEM	
		F	M	F	M	F	M			
Sex								Sex	Strain	
Live weight (L.W.)	g	2,150	2,372	2,942	3,590	1,540	1,670	**	**	121
Feed intake(1)	g/d	88.6	101.5	112.6	139.1	66.5	73.9	**	**	11.8
Daily gain	"	26.2	28.9	35.8	43.8	18.7	20.2	**	**	5.8
Feed to gain ratio(1)		3.3	3.3	3.1	3.0	3.4	3.5	n.s.	*	0.2
Culled birds	%	0	0	3.0	5.0	0	0	**	*	3.2 ⁽²⁾
Mortality	%	4.0	5.0	9.0	10.0	4.0	4.0	n.s.	**	5.8 ⁽²⁾

N=100 for each strain/sex. (1) 12 replications

** = $P > 0.01$ * = $P > 0.05$.

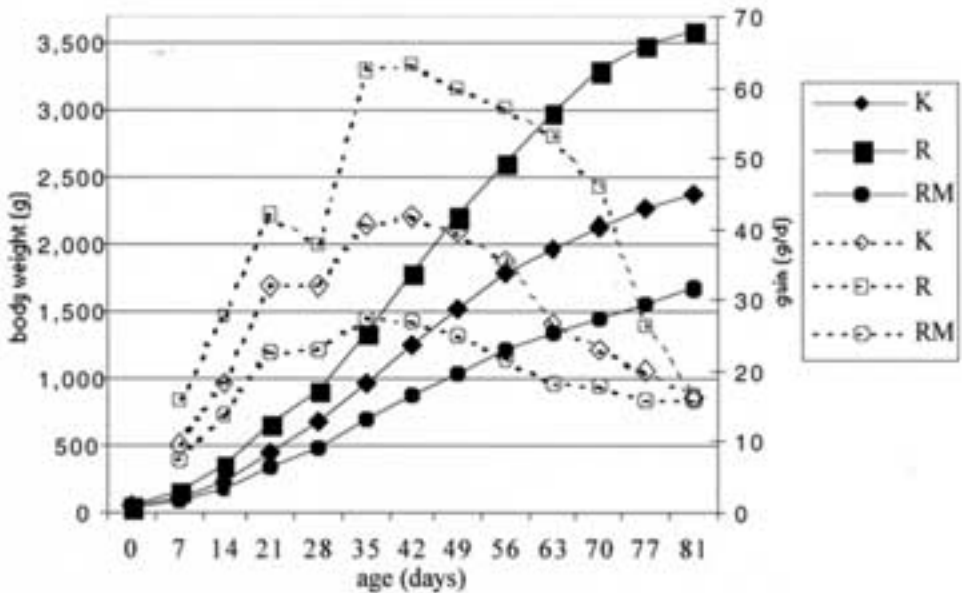
⁽²⁾ C2 value

Figure 1. Trend of body weight and daily weight gain in the three strains (female).



Solid line = body weight; dotted line = weight gain.
 K=Kabir; R = Ross; RM = Robusta maculata.

Figure 2. Trend of body weight and daily weight gain in the three strains (male).



Solid line = body weight; dotted line = weight gain.
 K=Kabir; R = Ross; RM = Robusta maculata.

only species-specific behaviour, but also their innate ability to provide for their own nutritional requirements.

Although it is difficult to estimate chick ingestion, because the more fibrous particles tend to move more slowly toward the proventriculus and gizzard, the comparative analysis of the crop contents showed a different feeding behaviour among strains (Table 3). In particular the crop contents of *Robusta maculata* and Kabir chickens had less protein and energy and higher amounts of α -tocopherol and carotenoids, indicating higher grass ingestion.

The higher antioxidant capacity ($P < 0.01$) of the two slow-growing genotypes, resulted from the higher antioxidant intake (α -tocopherol, carotenoids, etc.), the greater locomotory activity and the slower rate of maturing. It is known that late maturity delays the transformation from oxidative to glycolytic muscle metabolism, and that locomotory activity increases the number of mitochondria in α -W fibres and hence turns them into α -R fibres in all animal species, (Ouhayoun and Dalle Zotte, 1993). Greater oxidative processes increase free-radical production and the animal develops a

more efficient mechanism for controlling them (Alessio, 2000).

Throughout the experiment, the body weights of the three genotypes were markedly different in the two sexes (Figures 1 and 2), and these differences increased with age. All strains showed a reduction in daily weight gain at 4 weeks that coincided with being moved to the outdoor paddock.

As expected, the growth rate of the Ross strain was much higher than that of Kabir and especially of the *Robusta maculata* until 9-10 weeks of age. Thereafter, the daily gains of the Ross genotype dropped and the three genotypes had a similar growth rate.

At 81 days of age, the Ross broilers of both sexes reached their highest body weights (Table 4) with a satisfactory feed/gain ratio, and high culling and mortality rates, confirming previous findings (Castellini *et al.*, 2002a). Mortality was mainly due to ascites (50 % of total: data not shown) and to sudden death syndrome (10%).

All culled birds had leg problems, which prevented normal movement. Arthritis with acute inflammation in several joints was diagnosed

Table 5. Carcass traits of broilers at 81 d.

Strain		Kabir		Ross		Robusta maculata		P	SEM
		F	M	F	M	F	M		
Sex								Sex	Strain
LW/adult LW	%	48.8	47.4	64.1	66.4	41.6	39.7		
Ready-to-cook-carcass	g	1,392	1,541	2,062	2,513	981	1,068	**	**
Ready-to-cook-carcass	% L.W.	64.7	64.8	70.1	70.0	63.9	64.0	n.s.	*
Empty gastrointestinal tract	"	5.9	5.9	5.6	5.5	6.8	6.7	n.s.	*
Gastrointestinal content	"	5.1	5.1	4.7	4.7	5.6	5.6	n.s.	**
Abdominal fat	"	1.1	1.0	1.6	1.1	0.3	0.2	*	**
Breast meat yield	% carcass	20.2	20.8	25.0	25.6	11.8	12.0	n.s.	**
Breast width	cm	11.0	11.0	13.9	14.5	5.9	6.0	n.s.	**
Breast layer thickness	"	2.2	2.2	2.4	2.5	1.7	1.8	n.s.	*
Breast bone length	"	15.8	15.9	14.0	15.8	8.9	9.3	n.s.	**
Thigh	% carcass	17.1	17.1	20.2	21.0	17.6	18.3	n.s.	*
Drumstick	"	16.0	16.1	15.1	15.3	16.5	16.7	n.s.	*
Meat to bone ratio		3.2	3.3	3.4	3.4	2.9	2.9	n.s.	*

N = 10 for each strain/sex.

** = $P > 0.01$ * = $P > 0.05$.

whereas no specific infectious diseases were observed throughout the trial. The reasons for such a high culling rate were probably due to the excessive weight of the birds as already postulated by Jones and Hocking (1999). Weeks *et al.* (1994) showed that about 80% of the Ross birds had gait abnormality at the 7th week of age. With age and increasing live weight, the leg joints of these animals are excessively stressed and lameness, ascites and other related problems increase (Network For Animal Health And Welfare In Organic Agriculture, 2002).

Beside leg weakness, some authors (Qureshi *et al.*, 1998, Rauw *et al.*, 1998; Yunis *et al.*, 2000; Thiele, 2001) have reported that selection for rapid growth reduces the immune-competence and increases the susceptibility to environmental stresses.

The body weight of Robusta maculata broilers was less than 2 kg, which is the minimum marketable weight for organic products (Saveur, 1997), and they had a higher ($P < 0.01$) feed/gain ratio than the Ross. Kabir chick performance was in between that of the other two strains.

According to the objectives reported in the Ross manual (Ross Breeders, 1999), the performance of the free-range reared birds is generally about 25% lower than it would be under intensive conditions. It is evident that fast-growing birds do not perform well under poor environmental conditions, whereas intensive rearing provides them with what is needed to cover all of their physiological needs (Reiter and Bessei, 1996). Besides the poorer environment and the intake of grass it should be pointed out that the dietary requirements of the fast-growing strains from 8 to 12 weeks are unknown and it is possible that they are inadequate to support normal growth and survival at that age.

The carcass traits reported in Table 5 show that the characteristics of the carcass (weight, breast, abdominal fat and meat:bone ratio) were significantly lower ($P < 0.01$) in Robusta maculata broilers than in the Ross broilers. Kabir chickens had intermediate values. The ready-to-cook carcass yield was significantly higher in Ross chickens ($P < 0.05$) presumably due to the higher percentage of digestive tract which in turn was due to the greater grass ingestion.

Male chickens were heavier and leaner than females.

The proportion of drumstick was greater in both Robusta maculata and Kabir chickens when compared to the Ross ($P < 0.05$).

Conclusions

Modern meat-type poultry have been intensively selected for growth rate and feed conversion. As such these strains grow very rapidly and behave very differently with respect to the less intensely selected strains. Such birds may not adapt well to organic growing conditions, as they exhibit leg problems and increased mortality.

Slow-growing genotypes have greater locomotory activity and pasture aptitude and a higher resistance to the poorer conditions of the organic system than the faster-growing hybrids.

The final recommendations of the Network for Animal Health and Welfare in Organic Agriculture (2002) suggest that in order to reduce the likelihood of welfare problems that the use of commercial breeds should be avoided, unless they have been tested and shown to work under organic conditions.

On the contrary chickens with a slower growing rate and, therefore a history of less growth rate selection express more "natural" behavioural patterns, and should probably be used for extensive production systems. However, strains with excessively low growth rates, like the Robusta maculata, require a very long rearing time (until 120 d - Castellini *et al.*, 2002b), resulting in very high production costs. It is clear that such strains would require a special market niche even with an organic label (DOP, tourism etc).

The position of pure breeds as an organic product could be strengthened if future research would show their ability to perform with lower quality feed, and to produce meat with well-differentiated qualitative characteristics. Since the meat obtained from the organic system has a lower oxidative stability (Castellini *et al.*, 2002), the higher intake of antioxidants improves the shelf-life of the products (Lopez-Bote *et al.*, 1988)

The Kabir strain appears to be a genotype that shows suitable adaptation to the organic system.

Research funded by the Regional Agency of Agricultural Development of Umbria (ARUSIA).

The authors wish to thank Giovanni Migni, Dino Parasecoli and Salvatore Denaro for technical assistance.

REFERENCES

- A.S.P.A. - ROMBOLI, I., CAVALCHINI, L., GUALTIERI, M., FRANCHINI, A., NIZZA, A., QUARANTELLI, A., 1996. Metodologia relative alla macellazione del pollame, alla valutazione e dissezione delle carcasse e delle carni avicole. *Zoot. Nutr. Anim.* 22:177-180.
- ALESSIO, H., HAGERMAN, A., FULKERSON, B., 2000. Generation of reactive oxygen species after exhaustive aerobic and isometric exercise. *Med. Sci. Sports Ex.* 32:1576-1581.
- AOAC, 1995. "Official Methods of Analysis" 15th ed. Association of Official Analytical Chemists. Washington, DC. USA.
- APPLEBY, M.C., HUGHES, B.O., ELSON, H.A., 1992. Poultry production systems. Behaviour, management and welfare. C.A.B. Int., Wallingford, UK.
- BENNET, R.M., 1996. Willingness-to-pay measures of public support for farm animal welfare legislation. *Vet. Rec.* 139:320-321.
- BIZERAY, D., LETERRIER, C., CONSTANTIN, P., PICARD, M., FAURE, J.M., 2000. Early locomotor behaviour stocks of chickens with different growth rates. *Appl. Anim. Behav. Sci.* 68:231-242.
- BRYAN-JONES, R., 1996. Fear and adaptability in poultry: insight, implications and imperative. *J. World Poult. Sci.* 52:131-165.
- CARRE, B., ROZO, E., 1990. La prédiction de la valeur énergétique des matières premières destinées à l'aviculture. *Prod. Anim.* 3:163-169.
- CASTELLINI, C., DAL BOSCO, A., MUGNAI C., 2002A. Effect of conventional versus organic method of production on the broiler carcass and meat quality. *Meat Sci.* 60:219-224.
- CASTELLINI, C., MUGNAI, C., DAL BOSCO, A., 2002B. Meat quality of three chicken genotypes reared according to the organic system. *Ital. J. Food Sci.* 14:321-328.
- CESARONE, M.R., BELCARO, G., CARRATELLI, U., CORNELI, U., DE SANCTIS, M.T., INCANDELA, L., BARSOITI, A., TERRANOVA, R., NICOLAIDE, S.A., 1999. A simple test to monitor oxidative stress. *Int. Angiol.* 18:127-130.
- COUNCIL REGULATION (EC) No 1804/99 of July 1999 supplementing Regulation (EEC) No 2092/91 on organic production of agricultural products. *Off. J.*, L 222, 24/08/1999, 1-28.
- FARMER, L.J., PERRY G.C., LEWIS, P.D., NUTE, G.R., PIGGOTT, J.R., PATTERSON R.L.S., 1997. Responses of two genotypes of chicken to the diets and stocking densities of conventional UK and label rouge production systems. II. Sensory attributes. *Meat Sci.* 47:77-93.
- GRASHORN, M.A., 1999. Qualität von hähnchenfleisch aus extensiven produktionsverfahren. Ökologische erzeugung von flügel Fleisch und eiern, Tagun MLU Halle-Wittenberg. 74-78.
- JONES, R.B., HOCKING, P.M., 1999. Genetic selection for poultry behaviour: Big bag wolf or friend in need? *Anim. Welf.* 8:343-359.
- KATZ, Z., 1995. Breeders have to take nature into account. *World Poultry Sci.* 11:124-133.
- LEWIS, P.D., PERRY, G.C., FARMER, R.L., PATTERSON, R.L.S., 1997. Responses of two genotypes of chicken to the diets and stocking densities typical of UK and "Label Rouge" production systems: I. Performance, behaviour and carcass composition. *Meat Sci.* 45:501-516.
- LOPEZ-BOTE, C.J., GRAY J.I., COMAA E.A. FLEGAL C.J., 1998B. Effect of dietary administration of oil extracts from rosemary and sage on lipid oxidation in broiler meat. *Br. Poultry Sci.* 39:235-240.
- LOPEZ-BOTE, C.J., SANZ ARIAS, R., REY, A.I., CASTANO, A., ISABEL, B., THOS, J., 1998A. Effect of free-range feeding on n-3 fatty acid and a-tocopherol content and oxidative stability of eggs. *Anim. Feed Sci. Tech.* 72:33-40.
- NATIONAL RESEARCH COUNCIL, 1994. Nutrient Requirement of Poultry. National Academy Press. Washington DC, USA.
- NETWORK FOR ANIMAL HEALTH AND WELFARE IN ORGANIC AGRICULTURE, 2002 Final recommendation and comments. <http://www.veeru.reading.ac.uk/organic/>
- OUHAYOUN, J., DALLE ZOTTE, A., 1993. Muscular energy metabolism and related traits in rabbit. A review. *World Rabbit Sci.* 1:96-107.
- QURESHI, M.A., HUSSAIN, I., HEGGEN, C.L., 1998. Understanding immunology in disease development and control. *Poultry Sci.* 8:1126-1129
- RAUW, W.M., KANIS, E., NOORDHUIZEN-STASSEN, E.N., GROMMERS, F.J., 1998. Undesirable side effect of selection for high production efficiency in farm animals: a review. *Livest. Prod. Sci.* 56:15-33.
- REITER, K., BESSEI, W., 1996. Effect of the distance between feeder and drinker on behaviour and leg disorders of broilers. Page 131 in Proc. 30th Int. Congr. Applied Ethology, Guelph, Canada.
- ROSS BREEDERS, 1999. Broiler management manual. Ross Breeders Ltd., Newbridge, Midlothian, UK.
- SAS/STAT, 1990. User's guide, Version 6, Cary, NC, USA.
- SAVEUR, B., 1997. Les critères et facteurs de la qualité des poulets Label Rouge. *Prod. Anim.* 10:219-226.
- SCHÜTZ, K.E., JENSEN, P., 2001. Effects of Resource Allocation on Behavioural Strategies: A Comparison

- of Red Junglefowl (*Gallus gallus*) and Two Domesticated Breeds. *Poultry Ethol.* 107: 753-765.
- SCOTT, G.B., MORAN, P., 1993. Fear levels in laying hens carried by hand and by mechanical conveyors. *Appl. Anim. Behav. Sci.* 36:337-346.
- THIELE, H.H., 2001. Breeding strategies to increase fitness in poultry. *Dtsch Tierarztl Wochenschr* 108:140-148.
- WEEKS, C.A., NICOL, C.J., SHERWIN, C.M, KESTIN, S.C., 1994. Comparison of the behaviour of broiler chicken in indoor and free-range environments. *Anim. Welf.* 3:179-192.
- YUNIS, R., BEN-DAVID A., HELLER, E.D., CAHANER, A., 2000. Immunocompetence and viability under commercial conditions of broiler groups differing in growth rate and antibody response to *Escherichia coli* vaccine. *Poultry Sci.* 79:810-816.
- ZASPEL, B.J., CSALLANY, A.S., 1983. Determination of alpha-tocopherol in tissues and plasma by high-performance liquid chromatography. *Anal. Biochem.* 130:146-150.