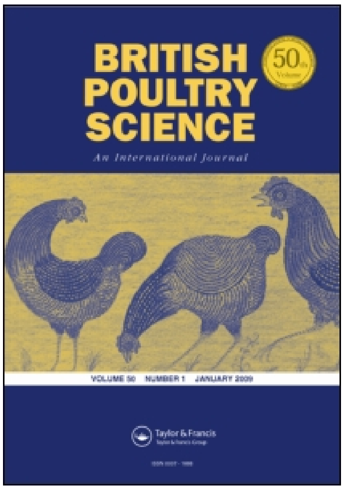

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The effect of breed and feed-type on the sensory profile of breast meat in male broilers reared in an organic free-range system

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Abstract 1. Studies on the sensory profiling of male broiler breast meat were carried out to evaluate the effect of two very different broiler breeds (JA757 and New Hampshire), two different feed types (broiler and grower feed) and age at slaughter (82 and 110 d).

2. The sensory profiling consisted of a pilot study, 4 training sessions, and finally the assessment. During the training session a panel of 9 assessors defined 17 attributes, which were used to describe the smell, texture and flavour of the breast fillets. Each attribute was evaluated on a 15-cm unstructured line scale.

3. The breast meat became significantly less hard, and more juicy and tender in the New Hampshire at 110 d of age, whereas the opposite was found in JA757, which also acquired a more "sourish" flavour with age. The smell of "sweet/maize" and "bouillon" became weaker with age in JA757, but not in New Hampshire.

4. Several significant differences in relation to the main factors of breed and age were found. The traditional broiler hybrid JA757 did best for most smell and flavour attributes, whereas New Hampshire did best for the texture attributes. Age had a negative effect on the flavours and smell attributes "fresh chicken", "neck of pork" and "sweet maize", but a positive effect on the texture attribute "crumbly". In addition meat was more "stringy" at 110 d of age.

5. The flavours "neck of pork" and "umami" were significantly improved when JA757 was fed on the broiler feed and when New Hampshire was given the grower feed. The meat smelt more "sourish" at 82 d of age and less "sourish" at 110 d of age when the grower feed was consumed. Meat was significantly harder and stringier when JA757 was fed on the grower feed. This was not the case for New Hampshire. In general, the meat was significantly less crumbly and stringier with the grower feed.

6. Overall a very distinct difference in sensory profile was found between the two breeds. In addition different slaughter ages and feeding strategies should be taken into consideration in a niche production based on alternative genotypes.

INTRODUCTION

Even though the principles behind organic production include ethical considerations (IFOAM, 2000), organic poultry production is to some degree based on the same rationale as the conventional poultry industry, *i.e.* highly specialised layer and broiler breeds that need to be produced in large flocks to obtain a satisfactory economic output. For organic egg production, one of the consequences is that male chickens are killed just after they have been hatched. This is done since male chickens from layer breeds are considered as having no economic value due to slow growth, low meat production, low feed conversion rate, and different carcase conformation. However, from an organic/ecological perspective this is considered as a huge image

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problem and can lead to less consumer support for organically produced poultry products. As an alternative to the traditional organic egg and broiler production, a niche production based on a combined production of eggs and meat might be considered. This may involve the reintroduction of the so-called dual-purpose breeds that were widespread in the time before industrialisation (Robinson, 1961). In relation to the production of broilers, the slower growing, dual-purpose breeds may even be better suited to a dual role in combination with other branches of production, *e.g.* as pest controllers in fruit production (Clark and Gage, 1996; Pedersen *et al.*, 2004), since slow-growing broilers have proven more active in the outdoor run than fast-growing broilers (Bokkers and Koene, 2003; Nielsen *et al.*, 2003). However, even if the males from a dual-purpose breed are expected to have a higher meat production than males from traditional layer strains, it is still less than traditional organic broiler hybrids (Horsted *et al.*, 2005). Therefore, other quality dimensions must be considered in order to obtain a premium price for slow-growing broilers. Besides the ethical aspect, this could be a superior sensory quality of the meat from dual-purpose breeds. Several studies have identified differences in sensory meat quality in traditional broiler hybrids (Lawlor *et al.*, 2003; Jahan *et al.*, 2005; Brown *et al.*, 2008), but very little has been published in relation to old dual-purpose breeds and to slaughter ages close to sexual maturity (Horsted *et al.*, 2005). Further, the feeding strategy required to obtain good sensory quality in meat from old breeds still needs to be examined.

With this background, the objective of the present study was to test for distinct differences in the sensory profile of breast meat from males from a dual-purpose breed and males from a relatively fast-growing broiler hybrid, and whether this was influenced by feed type and age at slaughter.

MATERIALS AND METHODS

Breeds and rearing of experimental broilers

A New Hampshire dual-purpose breed was selected from the small hatchery "Hellevad" in Denmark where the New Hampshire is used as a female parent to produce a robust layer strain for the organic market. The JA757 from the "Hubbard Breeders" company was chosen to represent a faster growing conventional broiler hybrid. This hybrid was chosen because it had been selected for the organic broiler market after the regulations for organic broiler production in Denmark had been modified (The Danish Plant Directorate, 2008).

The chicks were hatched on the same day and reared for the first 39 d by an organic producer. All broilers were reared together during this period and from one week of age they were given access to an outdoor area with fruit trees for two 1-h periods daily. They were fed on a normal commercial starter diet with 210 g/kg crude protein for the first 3 weeks, and from 3 weeks of age until the introduction to the experiment at 39 d of age they were given a broiler feed (Table 1).

Experimental design and recordings on live broilers

On 15 May 2007 (at 39 d of age), the broilers were allocated to the experiment, which took place in a research orchard with apple trees. The broilers were divided into 12 flocks with 47 broilers in each flock (6 flocks with the New Hampshire breed (3/4 were males) and 6 flocks with the JA757 hybrid (half were males)). Within each breed, three flocks were fed on a commercially produced broiler compound feed, and three flocks received a compound feed for growers. The broiler feed usually has a relatively high crude protein content (190 g/kg) and is based on maize, whereas the grower feed is lower in crude protein (160 g/kg) and is mainly based on wheat with fishmeal as an important protein source. However, analyses suggested a higher content of crude protein in the grower feed than stated by the formula (Table 1). These feed types were chosen for the experiment since the broiler feed and grower feed were the preferred feeds for JA757 and New Hampshire, respectively. Besides, both feed types are on the market and therefore easy to procure in practice.

Average weights at the beginning of the experiment were 1423 and 569 g for JA757 and New Hampshire, respectively. Each pen measured approximately 30×15 m and contained approximately 110 apple trees, *i.e.* each broiler had approximately 9·5 m^2 outdoor area. The broilers had access to a chicken house with perches, but feed and water were allocated in the outdoor area under a rain shield to motivate the broilers to go outside. The feeding silos were filled as required, *i.e.* approximately twice a week. Feed consumption was recorded for each pen by weighing the allocated feed and weighing what was left in the silos on the days of slaughter at 82 and 110 d of age.

Half of the broilers were slaughtered at 82 d and the rest at 110 d of age. Ages of slaughter were chosen according to the French *Label Rouge* concept (Poultrylabelrouge.com, 2008) and the Danish regulation for organic broiler production (The Danish Plant Directorate, 2008). The latter distinguishes between fast and

Table 1. *Ingredient and nutrient contents of the experimental diets*

Ingredient (g/kg):	Broiler feed, pelleted	Grower feed, pelleted
Maize, organic	360·7	0
Wheat, organic	250	500
Barley, organic	0	150
Soya cake toasted, organic	200	92·5
Sunflower cake, organic	120	120
Oat, organic	25	50
Greenmeal, organic	0	30
Fishmeal	0	30
Mono calcium phosphate	12·5	8·2
Calcium carbonate	12·2	13·3
Biotin premix	9·5	0
Rape seed oil	3	0
Rock salt	2·6	2·6
Vitamin premix	2·5	2·5
Sodium bicarbonate	1·5	0·7
Bergazyme (Endo-1·4-beta-xylanase 3·2·1·8. EF no.: E1617)	0·3	0
Betain anhydrate	0·2	0·2

Nutrient content (g/kg):	Formula	Analysis	Formula	Analysis
Crude protein	190	192	160	182
Crude fat	59	58	45	49
Starch	Not stated	383	Not stated	363
Sugar	Not stated	33	Not stated	28
Cellulose	52	Not analysed	69	Not analysed
Crude ash	61	Not analysed	55	Not analysed
Lysine	8·9	8·1	7·5	7·9
Methionine	3·4	3·1	3·0	3·2
Cystine	3·5	3·2	3·0	3·2
Threonine	Not stated	7·1	Not stated	6·8
ME (MJ/kg DM)	Min 12·00	11·79	Min 11·10	10·93

slow-growing broilers, with fast-growing broilers having an age of slaughter of at least 81 d, whereas slow-growing broilers can be slaughtered at 70 d of age unless the brood eggs are organic, when there is no age limit. The definition of a slow-growing broiler is daily weights gain not exceeding 35 g/d.

In the present study all broilers were weighed at 60, 82 and 110 d of age. At 82 d of age samples from the cloacae of 10 randomly chosen broilers from each of the 12 pens were taken and analysed for salmonella. Samples from each pen were pooled, *i.e.* a total of 12 samples were analysed.

Slaughtering of broilers

A sample of 6 male broilers from each plot were randomly selected for sensory assessment, *i.e.* 18 broilers from each treatment. The broilers were caught in the late evening and transported in crates to the slaughterhouse during the night (1 h of transport) and slaughtered in the early morning. After the broilers had been slaughtered and bled, the carcases were scalded in water at temperatures of 58–61°C depending on breed. Feathers were subsequently removed in a plucking machine. The carcases were then placed in a vat with cooling water and subsequently eviscerated and hung up in a cold storage room at a temperature at 4°C decreasing to 1°C. The carcases were kept in cold storage for not less than 24 h and afterwards frozen to −18°C. After a few days, the carcases were transported in a refrigerated van to the Sensory Laboratory at the University of Copenhagen, Department of Food Science.

Sensory assessment

Cooking and serving of samples

Prior to the sensory profiling, the carcases were thawed in a controlled-temperature chamber at 4°C for 30 and 24 h for JA757 and New Hampshire, respectively, due to different carcase weights. Subsequently the breast fillets were cut off and weighed to determine the cooking time, which was arranged so the fillets had a core temperature of 75°C. The fillets (with skin) were cooked in pre-heated hot-air ovens at 185°C. The fillets were subsequently cut into 5 pieces, ensuring that each assessor in the panel received the same part (sample) of the fillet for each assessment (ASTM, 2006).

Sensory method

The sensory profiling, which was made by a sensory panel, consisted of three parts: a pilot study, 4 training sessions, and finally the assessment. The assessment took place over 2 d. In the pilot study, meat from all treatments were used to develop a preliminary set of attributes describing the sensory profile of the meat, as in a previous study by Horsted *et al.* (2005). In relation to the smell attributes, the sample was cut transversely from one end of the sample so a freshly cut surface was used for the assessment. The assessment of the texture was made on the next cut of the sample, whereas the flavour was assessed on a cut from the middle of the sample. Between assessments, the panellists cleared the palate using cucumber, crispbread with a neutral flavour and finally water. Recipes for reference samples were also made during the pilot study.

The panel consisted of 9 assessors, selected according to ISO (1991). A panel leader guided the training sessions. Only the panel leader knew which samples were served during the training sessions. On d 1 of training the panellists were presented with 6 samples in three pairs and, following the training session, the characteristics from the pilot study were discussed and some words changed to give a more precise description of the attributes. The assessors decided on these changes without being influenced by the panel leader. Also the order of assessment of attributes was discussed. On d 2 of training the panellists were presented initially with 4 samples in pairs followed by 4 more samples. The samples were served in a sensory evaluation laboratory accommodated to meet the stipulations of ISO (1988) and ASTM (1986), but this time the panellists were placed in separate booths with no contact with each other. Again after this training session the attributes were discussed. The same procedure was followed on d 3, but this time the panellists received 4 samples in pairs and 5 samples in separate booths. On d 4 of training the panellists were served with 10 samples in the booths and, after this session, no further changes were made after the discussion. The final reference schedule is shown in Table 2. The final assessment was distributed over 2 d and the panellist had 12 samples served each day, *i.e.* 24 samples (8 treatments × 3 replications) during the 2 d. The order of the serving of the samples was chosen randomly by a Latin-square method, but all treatments were served on both days at least once (ISO, 2003; ASTM, 2006). During the training sessions, as well as the final assessments, the FIZZ Network was used for electronic collection of data (Biosystèmes, 2008). Each attribute was evaluated on a 15-cm unstructured line scale, with 15 as the highest score and 0 as the lowest. The anchor points were ‘‘none’’ on the left side and ‘‘extreme’’ on the right for all attributes (ISO, 1993, 2003; Meilgaard *et al.*, 2007).

Table 2. *The final reference schedule used for the sensory assessment*

Attribute and order of assessment		Definitions of sensory attributes derived during vocabulary development
Smell:		
1.	Fresh chicken (positive)	How strong is the smell of fresh chicken meat?
2.	Neck of pork (negative)	How strong is the smell of neck of pork?
3.	Sourish (negative)	How sourish does the sample smell?
4.	Sweet/maize (positive)	How strong is the smell of sweetish maize?
5.	Bouillon (neutral)	How strong is the smell of chicken bouillon?
Texture:		
6.	Hardness (negative)	How hard does the sample feel up to the fourth chewing?
7.	Tenderness (positive)	How tender is the sample up to the fourth chewing?
8.	Juiciness (positive)	How juicy is the sample up to the fourth chewing?
9.	Crumbly (negative)	How crumbly is the sample when ready for swallowing?
10.	Stringy (neutral)	How stringy is the sample when ready for swallowing?
11.	Cohesive (neutral)	How cohesive is the sample when ready for swallowing?
Flavour:		
12.	Fresh chicken (positive)	How strong is the taste of fresh chicken meat?
13.	Neck of pork (negative)	How strong is the taste of neck of pork?
14.	Sourish (negative)	How sourish does the sample taste?
15.	Sweet/maize (positive)	How strong is the taste of sweetish maize?
16.	Umami (positive)	How strong is the taste of umami?
17.	Iron/liver (negative)	How strong is the taste of iron/liver?

Statistical methods

The sensory data were subject to a principal component analysis (PCA) using PanelCheck version 1·2·1 (Matforsk, 2008). Analysis of variance was performed using the MIXED procedure in SAS (SAS, 2008) by the following model:

$$Y_{ijklmn} = \mu + \alpha_i + \beta_j + \gamma_k + \lambda_l + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk} + A_{m(ijk)} + B_{n(ijk)} + \varepsilon_{ijklmn}$$

where Y_{ijklmn} is the sensory attributes; μ is the mean; α_i is the breed *(i = New Hampshire, JA757)*; β_j is the feed type *(j = broiler feed, grower feed)*;

Table 3. *Live weights of broilers (g), least square means (standard error of means)*

	Age (d)		
	60 ($n = 538$)	82 ($n = 538$)	110 ($n = 283$)
Breed × sex: (p)	<0·001	<0·001	=0·001
JA757, male	3073 (19), $n = 133$	4344 (27), $n = 133$	5202 (58), $n = 40$
JA757, female	2492 (20), $n = 135$	3354 (26), $n = 135$	4215 (37), $n = 99$
New Hampshire, male	1184 (16), $n = 196$	1785 (22), $n = 196$	2472 (45), $n = 70$
New Hampshire, female	959 (23), $n = 74$	1368 (36), $n = 74$	1781 (42), $n = 74$
Breed × feed type: (p)	NS	NS	NS
JA757, broiler feed	2770 (20), $n = 133$	3857 (27), $n = 133$	4793 (46), $n = 70$
JA757, grower feed	2794 (19), $n = 135$	3842 (26), $n = 135$	4624 (47), $n = 69$
New Hampshire, broiler feed	1075 (20), $n = 138$	1594 (28), $n = 138$	2155 (42), $n = 78$
New Hampshire, grower feed	1068 (19), $n = 132$	1559 (28), $n = 132$	2098 (45), $n = 66$
Feed type: (p)	NS	NS	=0·01
Broiler feed	1922 (14), $n = 271$	2725 (19), $n = 271$	3474 (31), $n = 148$
Grower feed	1931 (13), $n = 267$	2700 (19), $n = 267$	3361 (33), $n = 135$

γ_k is the age at slaughter ($k = 82$, 110); λ_l is the replication (sample) ($l = 1, 2, 3$); $(\alpha\beta)_{ij}$ is the interaction breed × feed type; $(\alpha\gamma)_{ik}$ *is the* interaction breed × age at slaughter; $(\beta\gamma)_{jk}$ is the interaction feed type × age at slaughter; $(\alpha\beta\gamma)_{ijk}$ is the interaction breed × feed type × age at slaughter; $A_{m(ijk)}$ is the the random effect of panellist; $B_{n(ijk)}$ is the the random effect of serving order; ε_{ijklmn} is error.

In a few cases, some panellists used the scale incorrectly for a given attribute, resulting in incorrect evaluations. In these cases data have been considered as outliers. PanelCheck version 1·2·1 and FIZZ Calculations were used for outlier detection (Biosystèmes, 2008; Matforsk, 2008). We chose to replace outliers by the average for the rest of the panel (Hoo *et al.*, 2002), as the data processing program "PanelCheck" could not handle missing values. The replacement of outliers with the average did not reveal any significant differences compared to excluding the outliers from the dataset when using the SAS program.

The data on body weights were analysed separately for each age group, *i.e.* 60, 82 and 110 d of age, using the above model with only one random effect and where Y_{ijkl} = the body weights at 60, 82 and 110 d of age; μ = mean; α_i = breed *(i = New Hampshire, JA757)*; β_j = feed type *(j = broiler feed, grower feed)*; γ_k = sex (k = *male, female*); $(\alpha\beta)_{ij}$ = interaction breed × feed type; $(\alpha\gamma)_{ik}$ = interaction breed × sex; $(\beta\gamma)_{jk}$ = interaction feed type × sex; $(\alpha\beta\gamma)_{ijk}$ = interaction breed × feed type × sex; $A_{l(ijk)}$ = the random effect of pen × replication; ε_{ijkl} = error.

RESULTS

No *Salmonella* of any species was found in any of the cloaca samples. Mortality was made up to 12 broilers of the New Hampshire and 16 broilers of the JA757. Cause of death was mainly attacks by birds of prey in the first weeks after grouping. However, some of the JA757 were culled because of leg disorders. The number of broilers at 110 d of age was reduced because approximately half the broilers in each flock were slaughtered at 82 d of age. Most of the broilers slaughtered at 82 d of age were males because of a higher growth rate.

The JA757 grew very rapidly compared to the New Hampshire breed with even the females of that breed growing considerably faster than the New Hampshire males, indicated by the significant interaction between breed and sex (Table 3). The main effect of feed type on body weight differed significantly only at the age of 110 d. It was not possible to estimate feed consumption for the New Hampshire due to considerable feed waste. No feed waste was observed in pens with JA757. Thus, the average feed consumption from introduction at 39 d of age to 82 d of age was 202 and 230 g/bird.d for the broiler feed and the grower feed, respectively. From 82 to 110 d of age feed consumptions were 220 and 252 g/bird.d, respectively.

Sensory profile

Principal component analysis (PCA) was performed to visualise relationships (Figure). Terms close together are related and terms far away from each other are different. Principal component 1 is the first axis (horizontal) and is the main source of variance. Principal component 2 is the second axis (vertical) and is the second most important source of variation etc. As indicated by the Figure, there is a huge difference in the sensory profile of the breast meat. It can be seen from the Figure that breeds show an especially large degree of spread on the PCA plots. There is also a tendency for breed × age to be located in pairs, whereas feed type mainly influences the location on the JA757-breed at the age at 110 d. The Figure also gives an indication of

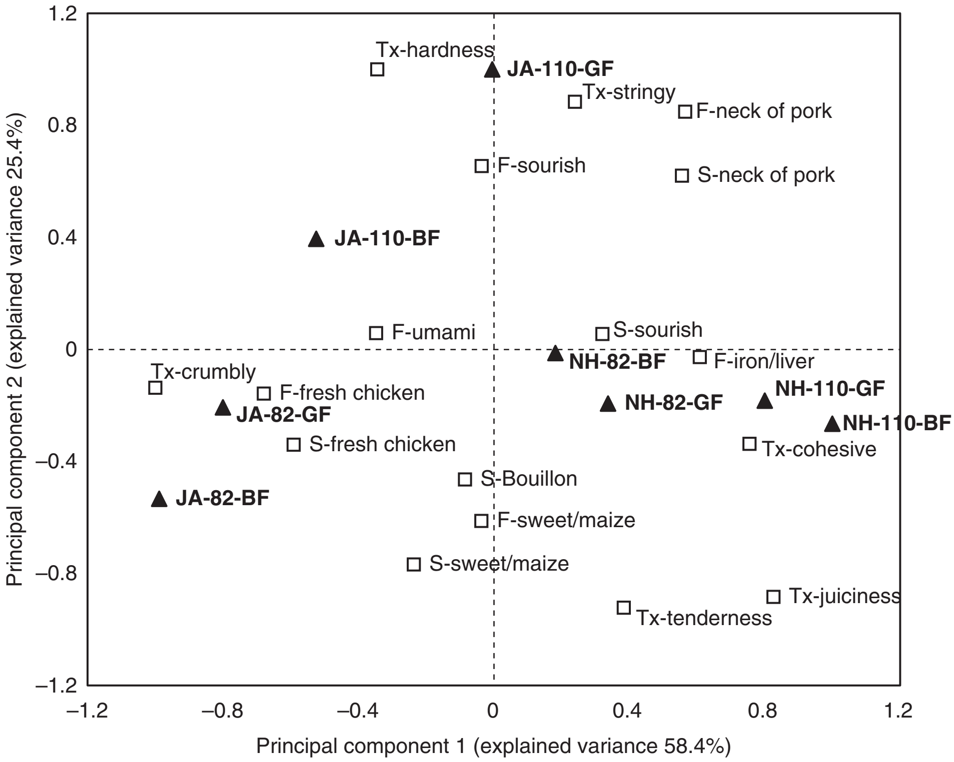

Figure. *PCA correlation loadings plot of principal component 1 versus principal component 2. Treatments (▲): JA = JA757, NH = New Hampshire; 82 and 110 are d of slaughter; BF = broiler feed, GF = grower feed. Attributes (□): Tx = texture, F = flavour and S = smell.*

Table 4. *Scores as least square means (standard error of mean) and significance for smell attributes*

	Fresh chicken (positive)	Neck of pork (negative)	Sourish (negative)	Sweet/maize (positive)	Bouillon (neutral)
Breed × age	NS	NS	NS	$P<0.05$	$P<0.01$
JA757, 82 d	9·4 (0·57)	3·8 (0·55)	4·5 (0·73)	8·0 (0·51)	7·2 (0·45)
JA757, 110 d	7·1 (0·57)	6·5 (0·55)	5·9 (0·73)	5·7 (0·51)	5·7 (0·45)
New Hampshire, 82 d	7·2 (0·57)	5·5 (0·55)	6·3 (0·75)	6·3 (0·51)	5·7 (0·45)
New Hampshire, 110 d	5·6 (0·57)	7·3 (0·55)	6·4 (0·73)	6·1 (0·51)	6·5 (0·45)
Breed × feed type	NS	NS	NS	NS	NS
JA757, Broiler feed	8·3 (0·57)	4·6 (0·55)	5·2 (0·76)	7·1 (0·51)	6·6 (0·45)
JA757, Grower feed	8·2 (0·57)	5·6 (0·55)	5·2 (0·73)	6·6 (0·51)	6·4 (0·45)
New Hampshire, Broiler feed	6·6 (0·57)	6·8 (0·55)	6·0 (0·74)	6·3 (0·51)	6·2 (0·45)
New Hampshire, Grower feed	6·3 (0·57)	6·1 (0·55)	6·7 (0·75)	6·1 (0·51)	5·9 (0·45)
Breed	$P<0.001$	$P<0.05$	$P<0.05$	NS	NS
JA757	8·3 (0·47)	5·1 (0·39)	5·2 (0·66)	6·9 (0·36)	6·5 (0·32)
New Hampshire	6·4 (0·47)	6·4 (0·39)	6·3 (0·66)	6·2 (0·36)	6·1 (0·32)
Age	$P<0.001$	$P<0.001$	NS	$P<0.01$	NS
82 d	8·3 (0·47)	4·7 (0·39)	5·4 (0·66)	7·2 (0·36)	6·4 (0·32)
110 d	6·4 (0·47)	6·9 (0·39)	6·1 (0·66)	5·9 (0·36)	6·1 (0·32)
Feed type	NS	NS	NS	NS	NS
Broiler feed	7·4 (0·47)	5·7 (0·39)	5·6 (0·66)	6·7 (0·36)	6·4 (0·32)
Grower feed	7·2 (0·47)	5·9 (0·39)	5·9 (0·66)	6·4 (0·36)	6·1 (0·32)

correlations between attributes, which correspond very well to groupings in negative and positive attributes (Table 2).

Smell

Significant differences were found for smell attributes in relation to the interactions age × feed type and breed × age, and the main effects of age and breed (Table 4). The meat smelt more "sourish" at 82 d of age and less "sourish" at 110 d of age when the grower feed was consumed (not shown in table). The smell of bouillon was weaker in the meat from JA757, but stronger in the meat from New Hampshire at 110 d of age. The "sweet/maize" attribute

Table 5. *Scores as least square means (standard error of mean) and significance for texture attributes*

	Hardness (negative)	Tenderness (positive)	Juiciness (positive)	Crumbly (negative)	Stringy (neutral)	Cohesive (neutral)
Breed × age	$P<0{\cdot}05$	$P<0{\cdot}01$	$P<0{\cdot}01$	NS	NS	NS
JA757, 82 d	6·6 (0·65)	8.0 (0·79)	6·0 (0·86)	8·2 (0·77)	2·1 (0·74)	5·8 (0·81)
JA757, 110 d	8·0 (0·67)	6·6 (0·80)	4·8 (0·86)	6·6 (0·77)	3·9 (0·76)	6·3 (0·81)
New Hampshire, 82 d	5·6 (0·70)	8·1 (0·82)	7·4 (0·87)	4·9 (0·77)	3·4 (0·78)	7·8 (0·81)
New Hampshire, 110 d	5·0 (0·65)	9·4 (0·79)	8·4 (0·86)	3·7 (0·77)	4·3 (0·74)	8·6 (0·81)
Breed × feed type	$P<0{\cdot}01$	NS	NS	NS	$P<0{\cdot}05$	NS
JA757, Broiler feed	6·2 (0·75)	8·1 (0·86)	5·0 (0·87)	8·6 (0·77)	1·7 (0·82)	5·6 (0·81)
JA757, Grower feed	8·3 (0·65)	6·5 (0·79)	5·5 (0·86)	6·3 (0·77)	4·3 (0·74)	6·5 (0·81)
New Hampshire, Broiler feed	5·9 (0·68)	8·7 (0·82)	8·1 (0·87)	5·0 (0·77)	3·9 (0·77)	7·8 (0·81)
New Hampshire, Grower feed	4·8 (0·70)	8·9 (0·82)	7·7 (0·87)	3·7 (0·77)	4·0 (0·78)	8·6 (0·81)
Breed	$P<0{\cdot}001$	$P<0{\cdot}01$	$P<0{\cdot}001$	$P<0{\cdot}001$	$P=0{\cdot}087$	$P<0{\cdot}001$
JA757	7·3 (0·55)	7·3 (0·71)	5·3 (0·82)	7·4 (0·69)	3·0 (0·67)	6·0 (0·74)
New Hampshire	5·3 (0·55)	8·8 (0·71)	7·9 (0·82)	4·3 (0·69)	3·9 (0·67)	8·2 (0·74)
Age	NS	NS	NS	$P<0{\cdot}001$	$P<0{\cdot}05$	NS
82 d	6·1 (0·55)	8.0 (0·71)	6·5 (0·82)	6·6 (0·69)	2·8 (0·66)	6·8 (0·74)
110 d	6·5 (0·55)	8.0 (0·71)	6·6 (0·82)	5·2 (0·69)	4·1 (0·66)	7·5 (0·74)
Feed type	NS	NS	NS	$P<0{\cdot}001$	$P<0{\cdot}05$	$P=0{\cdot}068$
Broiler feed	6·0 (0·57)	8·4 (0·72)	6·6 (0·83)	6·8 (0·69)	2·8 (0·68)	6·7 (0·74)
Grower feed	6·5 (0·57)	7·7 (0·72)	6·6 (0·83)	5·0 (0·69)	4·1 (0·68)	7·6 (0·74)

was likewise found to be weaker in the meat from JA757 at 110 d of age, whereas no change was found in the meat from New Hampshire. The main effect of breed had a significant influence on 3 out of 5 attributes, since meat from the JA757 hybrid smelt more of ''fresh chicken'', less of ''neck of pork'' and less ''sourish'' compared with meat from the New Hampshire breed. In relation to age of slaughter the meat smelt less of ''fresh chicken'' and ''sweet/maize'', but more of ''neck of pork'' when the broilers were slaughtered at 110 d of age. No significant difference was found in relation to feed type.

Texture

For the texture attributes significant differences were found in relation to the interactions breed × age and breed × feed type, and the main effects of breed, age and feed type. The breast meat from New Hampshire became less hard and more juicy and tender with age, whereas the opposite was found in the JA757 (Table 5). Breed also interacted with feed type, since the meat was harder and stringier when JA757 was fed on the grower feed, whereas the meat was harder from the New Hampshire when they were given the broiler feed. The ''stringy'' attribute in the New Hampshire was not affected by feed type. No interaction between age and feed type was found. In addition to the above interactions breed × age and breed × feed type, the breast meat from New Hampshire was significantly more cohesive and less crumbly in texture than the meat from JA757. The main factors age and feed type had significantly different effects on the ''crumbly'' and ''stringy'' attributes. Thus meat became less crumbly, but more stringy, with the grower feed and at 110 d of age.

Flavour

Significant differences were found for flavour attributes in relation to the interactions breed × age and breed × feed type, and the main effects of breed and age. The ''neck of pork'' flavour was stronger at 110 d of age for both breeds, but for JA757 the score was a little lower at 110 d compared to the score for New Hampshire at 82 d of age, indicated by the significant interaction breed × age (Table 6). Breed further interacted significantly with age in relation to the ''sourish'' flavour attribute, since meat from JA757 became more sourish at 110 d of age, whereas the meat from New Hampshire did not. Breed interacted with feed type in relation to the ''neck of pork'' and ''umami'' flavours. Thus the ''neck of pork'' flavour was stronger in the meat from JA757 when they received the grower feed, and in New Hampshire when fed on the broiler feed. For the ''umami'' flavour the reverse was the case. In addition to these interactions, there were significant main effects of breed on the ''fresh chicken'' flavour, which had a higher score in the meat from JA757. Conversely, the ''iron/liver'' flavour was more pronounced in the meat from New Hampshire. However, the scores given for this attribute were generally low. The main age factor influenced the ''fresh chicken''

Table 6. *Scores as least square means (standard error of mean) and significance for flavour attributes*

	Fresh chicken (positive)	Neck of pork (negative)	Sourish (negative)	Sweet/maize (positive)	Umami (positive)	Iron/liver (negative)
Breed × age	NS	$P<0.05$	$P<0.05$	NS	NS	NS
JA757, 82 d	9·3 (0·72)	2·4 (0·56)	7·1 (0·71)	7·1 (0·85)	6·6 (0·82)	0·9 (0·58)
JA757, 110 d	7·7 (0·72)	5·3 (0·57)	8·9 (0·72)	5·4 (0·85)	5·9 (0·82)	1·5 (0·59)
New Hampshire, 82 d	7·1 (0·72)	5·5 (0·59)	8·0 (0·73)	6·4 (0·85)	5·3 (0·82)	3·0 (0·60)
New Hampshire, 110 d	5·4 (0·72)	6·2 (0·56)	7·8 (0·71)	6·1 (0·85)	5·2 (0·82)	2·9 (0·58)
Breed × feed type	NS	$P<0.05$	NS	NS	$P<0.05$	NS
JA757, Broiler feed	8·7 (0·72)	3·3 (0·62)	7·8 (0·75)	6·8 (0·86)	6·4 (0·82)	1·1 (0·62)
JA757, Grower feed	8·4 (0·72)	4·4 (0·56)	8·3 (0·71)	5·8 (0·85)	5·9 (0·82)	1·2 (0·58)
New Hampshire, Broiler feed	6·2 (0·72)	6·5 (0·58)	7·9 (0·73)	6·3 (0·85)	4·7 (0·82)	3·2 (0·60)
New Hampshire, Grower feed	6·3 (0·72)	5·1 (0·59)	8·0 (0·73)	6·3 (0·85)	5·8 (0·82)	2·7 (0·60)
Breed	$P<0.001$	$P<0.001$	NS	NS	$P<0.05$	$P<0.001$
JA757	8·5 (0·64)	3·9 (0·44)	8·0 (0·63)	6·3 (0·78)	6·2 (0·78)	1·2 (0·53)
New Hampshire	6·2 (0·64)	5·8 (0·44)	7·9 (0·63)	6·3 (0·78)	5·2 (0·78)	3·0 (0·53)
Age	$P<0.001$	$P<0.01$	NS	$P<0.05$	NS	NS
82 d	8·2 (0·64)	3·9 (0·44)	7·6 (0·63)	6·8 (0·78)	5·9 (0·78)	2·0 (0·53)
110 d	6·6 (0·64)	5·8 (0·44)	8·4 (0·63)	5·8 (0·78)	5·5 (0·78)	2·2 (0·53)
Feed type	NS	NS	NS	NS	NS	NS
Broiler feed	7·4 (0·64)	4·9 (0·45)	7·8 (0·64)	6·5 (0·78)	5·6 (0·78)	2·2 (0·54)
Grower feed	7·3 (0·64)	4·8 (0·45)	8·1 (0·64)	6·0 (0·78)	5·9 (0·78)	2·0 (0·54)

and "sweet/maize" flavours, which were both given a significantly lower score at 110 d of age.

DISCUSSION

Even though meat from slow-growing genotypes is reputed to have superior texture (Fanatico *et al.*, 2006), some studies have found the tenderness of broiler meat to decrease with age (Berri, 2000). In the present study we found that meat was less tender and juicy, and harder in the traditional broiler hybrid JA757 when it was slaughtered at 110 d of age. In contrast, the meat from the New Hampshire became more tender and juicy and less hard with age. Similar results have been obtained in another study with two different dual-purpose breeds (Horsted *et al.*, 2005). Meat tenderness may be influenced by various factors (Berri, 2000; Yang and Jiang, 2005), and it can be speculated whether the differences in growth pattern may influence the development in meat texture. However, in the study by Horsted *et al.* (2005), males and females did not have the same growth pattern, but both sexes showed the same development in meat tenderness. Therefore the different development in meat texture is more likely to be related to other genetic differences, such as body composition, *e.g.* reduced abdominal fat (Ricard *et al.*, 1983; Chambers *et al.*, 1989), locomotor activity (Lei and Van Beek, 1997) and pre-slaughter stresses (Debut *et al.*, 2003, 2004), and different breast meat yield and post-mortem metabolism (Berri, 2000). Likewise the muscle structure might be different in terms of more and larger muscle fibres in fast growing breeds (Remignon *et al.*, 1995), just as total amount of collagen and the fatty acid composition in the breast meat vary in relation to breed and age (Nakamura *et al.*, 1975, 2004; Wattanachant *et al.*, 2004).

The traditional broiler hybrid JA757 seems to do best in the present study in terms of smell and flavour, even though interactions with age suggested a negative development with age for the "neck of pork" and "sourish" flavours and the "sweet/maize" smell attribute. Little or no change was found in the meat from New Hampshire for these attributes. Further, age had a negative effect on some attributes across the two breeds. Some studies have found an improvement of some flavour attributes when chickens are slaughtered close to sexual maturity (Touraille *et al.*, 1981*a,b*). However, it was observed that the JA757 began laying eggs before 110 d of age and, since males reach sexual maturity earlier than females (Ricard and Touraille, 1988), this indicates that sexual maturity for the males presumably began around 82 d of age and for that reason the birds received better scores at this age of slaughter. On the other hand, the flavour attributes in the meat from New Hampshire will probably benefit from an even greater age of slaughter, since this breed reaches sexual maturity at a much later age. Thus, in another study it was found that breast meat from two dual-purpose breeds and one slow-growing broiler breed was sweeter and saltier at 120 d of age than at 91 d of age. This development was considered as positive (Horsted *et al.*, 2005).

Other studies have found that the sensory quality of broiler meat depended on diet ingredients (Poste, 1990) and the nutrient content of the feed (Arafa *et al.*, 1985; Ristic *et al.*, 1990; Kennedy *et al.*, 2005). In the present study feed types mainly differed in the ingredients even though a slightly lower content of crude protein and fat was found in the grower feed. However, the lysine, methionine and cystine contents were approximately the same (Table 1). The major carbohydrate source in the broiler feed was maize, whereas in the grower feed it was wheat. Lyon *et al.* (2004) examined the effect of diets with wheat or maize as the major carbohydrate source on commercial broilers with processing ages between 42 and 52 d. It was found that breast meat from wheat-fed broilers was harder, more cohesive, and chewier and had a larger particle size than meat from maize-fed broilers. In addition, ''brothy'' scores were significantly higher in the meat from maize-fed broilers. The significant interactions in our study between breed and feed type regarding ''hardness'' and the ''neck of pork'' and ''umami'' flavours indicate that different ingredients should be considered when very different genotypes are used in the production of high-quality meat. Thus, broiler feed is the preferred feed for the commercial hybrid ''JA757'', and grower feed seems better for New Hampshire. However, it should be noted that the broilers were reared in a very extensive system, where foraging in the open-air run may contribute to the nutrition. Studies on layers in forage-based systems have shown a considerable intake of plant material, earthworms and insects, which contributed to nutrition as well as egg quality (Horsted *et al.*, 2006; Horsted and Hermansen, 2007). In the present study, the New Hampshire was observed to be more active in the open-air run than JA757, which, in contrast, spent a lot of the time resting. This observation accords with the findings of Nielsen *et al.* (2003) that a slow-growing experimental cross was significantly more active in the open-air run compared with a fast-growing broiler hybrid. This indicates that the New Hampshire breed had a higher feed intake from forage than JA757. This might influence the sensory profile of the breast meat.

In conclusion, we found a very distinct difference in the sensory profile between the two breeds and some attributes interacting with age at slaughter and feed type. Thus different slaughter ages and different feeding strategies must be considered when alternative genotypes are chosen in the production of high-quality products. How the consumers will perceive these differences in sensory quality is presumably related to the geographical and cultural origins of the consumer (Berri, 2000). In addition, other quality dimensions may influence consumer perception (Fanatico *et al.*, 2006) and thus the extent to which a premium price is obtainable.

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