International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Meat Quality of Broiler Chicken as affected by Strain, Age at Slaughter and Immobilization Methods

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Abstract: ***The study was carried out to evaluate the effect of six different strains of broilers on age and immobilization methods of slaughter as it affect meat quality. Two hundred and eighty eight (288) day old chicks (40 each for Abor-acre, Mashall, Cobbs, Anark, Ross and Hubbard) were raised for 6 and 8weeks. They were randomly divided into 12 birds per replicate to have 4 replicates per treatment. Eight birds per strain were immobilized (4 for each lateral and cone methods of immobilization), slaughtered, dressed, weighed and cut into primal cuts at 6 and 8 weeks respectively. Physico-chemical properties of meat and organoleptic properties were carried out. The results revealed that Abor-acre strains had the highest ($P<0.01$) live weight (2.31kg), dressing percentage (70.82%) and breast meat (23.21%). The birds slaughtered after 8 weeks showed better ($P<0.001$) live weight (2.22kg), Dressing % (71.81%), back (14.25%) and breast muscle (20.14%). The immobilization methods have no influence ($P>0.05$) on the carcass yield and the various cuts. Live weight, dressing %, back and breast were all significant ($P>0.05$) due to the interaction of strain, age and immobilization methods of slaughter. The least ($P<0.01$) values were reported in Arbor-acre for cooking loss (15.65%) while Ross strain had 4.67% for chilling loss. Higher losses ($P<0.001$) were noted during cooking and chilling of samples but improved ($P<0.001$) crude protein and ether extract were found with the increase in age of slaughter. Killing cone positively influenced ($P<0.01$) the physical parameters (pH, WHC, Cooking and chilling losses) but no significant differences were observed for the chemical composition. Significance ($P<0.05$) was also observed only in the physical properties for interaction between strains and immobilization methods and age at slaughter and immobilization methods. Immobilization of birds with cone and 6 weeks birds enhanced ($P<0.01$) the various sensory parameters examined while the panelists rated meat from Anark strains highest ($P<0.05$) for flavour, Tenderness, Juiciness and the Overall acceptability. The interaction due to all the factors were reported significant ($P<0.05$) for the sensory evaluation. In conclusion, strain, age and immobilization methods of slaughter are critical tools to be considered in assessing the quality of meat.***

Keywords: Strains, age at slaughter, immobilization, meat quality, organoleptic properties

1. Introduction

Presently, one of the global challenges is food security and consists of food production with best quality for the population which increases annually (1). Poultry meat production represents one of the ways to increase production of animal proteins and now occupies the second place in the world just after pork (2). Chicken meat is a low fat protein source and provides essential vitamins and minerals such as Niacin, Vitamin A, Vitamin E and magnesium. It also has a favourable ratio of polyunsaturated fatty acids to saturated fatty acids (PUFA: SFA) making it beneficial to consumers by lowering cholesterol, consequently helping to reduce the risk of cardiovascular diseases (3), (4). Consumers frequently observed chicken meat as a “healthier” option when compared to other meat or protein products at the market (3). They also acknowledge the convenience of portioned retail cuts at relatively low prices in contrast to beef or pork meat (5). Marketing of poultry has been greatly diversified and as a consequence, selection for edible meat yield, mainly breast yield, has been intensified since the consumers are yearning for quality and safe meat.

Several complex factors can affect poultry meat quality properties (5). These factors can be either intrinsic (species, race, type of muscle, sex, genetic origin and slaughtering age) or extrinsic (conditions of breeding and slaughtering, feed, technological treatments and *post mortem* biochemical changes) (5). Meat quality concept is defined as the overall meat characteristics including its physical, chemical, morphological, biochemical, microbial, sensory, technological, hygienic, nutritional and culinary properties (6). In general, the consumers judge meat quality from its appearance, texture, juiciness, water holding capacity, firmness, tenderness, odor and flavour (7). Moreover, the processors involved in the manufacturing of value-added meat products considered quantifiable properties of meat such as water holding capacity, pH, shelf life, collagen contents, protein solubility, cohesiveness, and fat binding capacity as indispensable (7), (8).

Knowles and Broom (9) reported that the handling component was the most potent stressor for broiler chickens. Handling, inversion, the act of shackling and tight shackles may induce stress, pain and flapping, which may lead to dislocations (particularly of the wings), fractures and muscle haemorrhages. Struggling may adversely affect meat quality by producing a build-up of lactic acid in the muscle, resulting in a low muscle pH, which reduces the water-holding capacity of the meat. So, in addition to its welfare importance, there is a financial incentive in encouraging birds to limit their activity as much as possible.

Genetic selection based on important economic traits such as growth rate, body size, edible meat yield and feed conversion ratio has resulted in changes in commercial poultry meat industry (10), (11). As a result, the age to reach market weight, the amount of feed necessary to produce a kilogram of meat and the age at which slaughter occurs have been reduced (12). Today, arguments exist on what age to slaughter broiler birds to achieve optimum quality and returns on investment. Also shackling of birds has been reported to have negative impact on meat quality. The present study is therefore aimed at examining the effect of slaughter age and different methods of immobilization on carcass yield, quality and sensory attributes of six different strains of broiler chickens

2. Materials and Methods

Experimental Site

The study was carried out at the Poultry Unit of Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso. A total of 240 day old broiler chicks, 48 chicks each of Arbor Acres, Marshall, Cobbs, Anark and Ross were purchased from local hatcheries and raised on deep litter in separate for 42 days (6 weeks) and 56 days (8weeks). Each treatment (strain) consisting of 48 birds was divided into 12 birds per replicate to have 4 replicate per treatment. Conventional broiler starter (CP – 23%, ME 3000kcal/kg) and broiler finisher (CP – 20%, ME 2900kcal/kg) diets were given and water supplied *ad-libitum*. Feed intake and body weight of each replicate were determined weekly and all necessary vaccinations and medications carried out as at when due and litter was well managed.

Four birds per treatment were slaughtered using two different methods of immobilization or restrain. The first method was the normal procedure described by (13). This was tagged as lateral immobilization or restrain. The wing and the legs were mechanically restrained on a flat bed (14). The second method is through the use of killing funnel or cone (14), (15). Killing cone (average length 20-25 cm, entry diameter 25-30 cm, exist diameter 4-6 cm) was used to bleed animal. The procedure is to suspend the bird head down in the funnel. This holds the body and allows the neck and head to protrude. The underside of the neck is turned towards the operator who, holding back the bird's head in one hand, severs the junjular vein by cutting on the left side of the neck. The head is not cut off. The funnel prevents the wings from flapping and the birds bleed freely (15). Birds were fasted 8 hours prior to slaughter, then they were weighed to record their fasted live weight, and killed by bleeding for 90seconds from a single cut that severed the carotid artery and jugular vein. After bleeding, birds were scalded, defeathered and eviscerated as described by Abdullah *et al.* (12). Carcasses were then weighed, dressing percentage and cuts (primal cuts) percentages were measured and recorded at each slaughter ages (6 and 8 weeks respectively).

The Major Pectoralis muscle of the breast meat was however subjected to physico-chemical and sensory analysis. The pH values of the meat were determined in duplicates samples using a pH meter. Chilling loss was calculated as the difference in percentage terms between pre - and post-freezing weight (16). Samples were weighed, placed in plastic bags and cooked at 85^{0}C for 25 minutes, and then the meat was dried, allowed to cool at room temperature, and re-weighed to determine cooking loss (16),(17).

Water holding capacity (WHC) of the samples was determined by the filter press method developed by Grau and Hamm (18) as modified by Suzuki *et al.,* (19). Intact meat samples from the primal cuts were weighed, placed between equal sized filter papers (10.1x10.1cm^2) and pressed between two plexi- glasses using a vice for one minute. The meat samples were removed and oven dried at 105^{o}C for 24 hours to determine the moisture content. The amount of water released from the sample was measured as the area of the filter paper wetted by pressing, relative to the area of pressed sample using a compensatory plani-meter is calculated as the water holding capacity.

Proximate analysis was used to determine the chemical attributes of the meat according to A.O.A.C (20). Samples were analyzed for dry matter (100^{0}C in air-forced oven for 24 hours), crude protein (Kjeldahl procedure), ether extract (Soxhlet procedure) and ash (550^{0}C in furnace for 24 hours). The organoleptic properties was conducted using a 10 member trained panelists according to the procedures of AMSA (21). Meat preparation was done using a wet cooking method. The samples were wrapped in impervious polythene pouches which could not be destroyed by cooking process. In the process, the meat samples were cooked in boiling water for 20 minutes using water bath with no spices added to the meat. The meat was then served to 10 member taste panels drawn from students and staff in the Department of Animal Production and Health, Ladoke Akintola University of Technology, Ogbomoso. The trained panelists evaluated the samples for colour, flavour, juiciness, tenderness and general acceptability. The assessment was based on a 9 point hedonic scale. The score was arranged in a descending order, the maximum score 9 was given to extremely like condition while the lowest score 1 was for the poorest condition.

Data Analysis

Data obtained were subjected to analysis of variance (ANOVA) using the General Linear Model for factorial within a completely randomized design of SAS (22) and SPSS (23). Means were separated by Duncan's range option of the same statistical softwares.

3. Results

Carcass yield and Primal cuts

Carcass yield and primal cuts as affected by strain, age at slaughter and immobilization methods is as presented in Table 1. The results revealed that the live weight, dressing percentage and the breast muscle were significantly highest (P<0.01) for Arbor-acre strain. Superior (P<0.05) weight for back and wing part were noted in Cobb broiler strain. Marshall Strain gave the lowest values for all the parameters. The abdominal fat and back were also influenced (P<0.05) by the different strains of broiler chicken. The birds slaughtered after 8 weeks showed better (P<0.001) live weight, Dressing %, back and breast muscle (Table1). The immobilization methods have no influence (P>0.05) on the carcass yield and the various cuts.

There were significant (P<0.01) differences in the live weight, dressing %, back and breast cuts due to strain and age at slaughter interaction with values in Arbor-acre strain at different ages. Significance (P<0.5) was however noted in live weight and dressing % due to strain and immobilization methods interaction while similar trend was observed for interaction between age and immobilization methods of slaughter with the back cuts being included. Only wing, drumstick, thigh and abdominal fat were not significant (P>0.05) due to the interaction of strain, age and immobilization methods of slaughter, moreover all other parameters were significant (P<0.05).

Physico-chemical Properties

Both the physical (WHC, Cooking loss and Chilling loss) and chemical (crude protein and ether extract) properties were significantly (P<0.01) influenced by the different strains of broiler chicken except the pH values (Table 2). The least (P<0.01) values were reported in Arbor-acre for cooking loss (15.65%) while Ross strain had 4.67% for chilling loss. The age at slaughter strongly (P<0.001) influenced nutritional quality of the broiler meat samples as higher (P<0.001) crude protein and ether extract were recorded at birds slaughtered at 8 weeks. Higher losses (P<0.001) (cooking and chilling) were found with the increase in age of slaughter. Killing funnel positively influenced (P<0.01) the physical parameters (pH, WHC, Cooking and chilling losses) but no significant differences were observed for the chemical composition.

Interaction due to strain and age at slaughter showed significance (P>0.05) in all the physic-chemical parameters examined except for the pH values. Significance (P<0.05) was also observed only in the physical properties for interaction between strains and immobilization methods and age at slaughter and immobilization methods.

Sensory

The taste panelists score of broiler chickens as influenced by strain, age at slaughter and immobilization methods is shown in Table 3. No significance (P>0.05) was noted in the ratings of the panelists for meat colour. They however rated meat from Anark strains highest (P<0.05) for flavour, Tenderness, Juiciness and the Overall acceptability. Birds slaughtered at 6weeks of age have better (P<0.01) sensory properties than those at 8 weeks. Similarly, immobilization of birds with funnel enhanced (P<0.01) the various sensory parameters examined. The interaction due to all the factors were reported significant (P<0.05) for the sensory evaluation.

4. Discussion

Literature is replete with information regarding breed or strain effect on carcass characteristics and primal cuts. It was reported that breed significantly affected live weight (5), carcass weight (24), breast and leg muscle weight (25), abdominal fat and edible giblets weight (24),(25), (26) and back and drumstick weights (24) of broiler chickens. All these corroborated the present study. Market demand towards cut-up portions has increased and birds were selected according to main carcass part yield such as breast and thigh meat (27). During the last two decades, the increasing demand for further-processed products, coupled with a preference for breast meat in the Western countries, has shifted selection towards birds with high breast development since it is the most valuable portion of the chicken in the market with a significant economic impart (28), (29),(30). Genetic selection has resulted in considerably heavier commercial broilers that are marketed at younger ages (31). There are also differences among the selected strains depending on their genetic background, and this has been observed in this study.

Dressing percentage is a better index of total edible meat after the visceral organs; blood and feathers have been removed (32). With the significantly higher dressing % in the birds slaughtered at 8 weeks, more edible meat will be available for sales and eventual consumption. This was corroborated by earlier work by Mehaffey *et al.,* (33) and Abdullah *et al.* (12) that live weight, carcass weight and dressing percentage increased with age with different strains of broiler. Moreover high carcass weight command high price. The composition of chicken muscle and technological quality of its meat change as the animal gets older.

The variations that exist among the values for each parameter supported earlier works (5) that meat quality is a function of its genotype and it environmental factors. The results from Abdullah *et al.* (12) revealed a significant (P<0.05) variation in the chemical parameters but no significance (P>0.05) was observed in the physical properties of the meat from different strains of broiler chickens. Crude protein and ether extract reported in this present study were in agreement with van Marle-koster and Webb (34) and Abdullah *et al.* (12). They reported that both strain and age at slaughter had significant effect on body composition for carcass crude protein and ether extract.

The result here is similar to those of Hector (35) and Abdullah *et al.* (30) who have earlier studied the effect of strains on performance and meat quality characteristics of broiler pectoralis muscles and indicated no significance among strains in the muscle pH at any postmortem time period. But this was contrary to the report of Mehaffey *et al.* (33) and Musa *et al.* (25) who showed that strain had significant effect on postmortem pH. Values of pH recorded in this study are comparable with pH values reported in the literature on several chicken strains (17),(33). Since the values obtained for the pH in the current study are within the normal range of the ultimate pH, other physical parameters measured were not negatively influenced above acceptable reported values in the literature (17),(33). However, significant differences were noted in all the physical parameters as affected by strains. Abor-acre birds showed the lowest losses with a superior WHC.

Improved meat qualities are shown in birds slaughtered with killing cone than the lateral methods. The cone prevents struggling, wings flapping and the birds bleed freely. Studies of struggling on the shackling line have revealed that it hastened the initial rate of pH drop and increased the redness of breast meat. Behavioural response to shackling however varied between chicken types, the slow-growing line being more reactive than the fast-growing line. In chicken, normal pH values at 15 min postmortem are around 6.2 to 6.5 (36), (37), whereas normal ultimate ph values are around 5.8 (38). If the Ph after 15mins is low (below 6.0) when the muscle is still warm, the proteins are subjected to denaturation (39), which leads to a decreased water-holding capacity, a decoloration of the meat and increased cooking loss (40),(41),(42). Such defects have been amply described in pigs, but also in turkeys (38) and chickens (39). These meats are often described as pale, soft and exudative by analogy with those described in pigs. They show exudative water loss (43) and a decreased technological yield (39) 44). Although raw pale, soft, and exudative meats show a rather soft texture, they tend to be less tender after cooking because of excessive exudation (43).

Sensory analysis is one of the oldest mean of meat quality control which allows producers to identify, understand and respond to consumer preferences more effectively (45). The sensory results in this work was supported by the report of Fletcher (41) and Gigaud *et al.,* (46) that when slaughter age decreases the flavor of meat decreases whereas the tenderness and the juiciness increase although the flavor in the present study also decreased with age. The decrease of tenderness in chicken meat during muscle growth can thus be due to the structural changes of collagen (47) older birds are more mature at the time of harvest and have more cross-linking of collagen (41). The colour changes could also be justified as poultry breast meat tends to become darker and redder as bird age increases because of highest contents of myoglobin in the muscles (41). Tenderness, together with juiciness and flavour are the most factors with respect to consumer satisfaction (48). Better organoleptic properties were found in the cone immobilized chicken than the lateral one. This was because of a better pH reported in the study which corroborated Shi and Ho (49) report that the organoleptic quality of meat is govern by pH. Consumers are prepared to pay a premium price for improved tenderness. However, variability in meat colour and tenderness is a major economic loss to meat industry throughout the world (48).

5. Conclusion

Abor-acre strain gave the best carcass yield, meat quality. Birds slaughtered at 8 weeks showed better carcass yield and crude protein while physical and sensorial properties favoured those slaughtered at 6 weeks. Killing cone improved the quality and sensory of meat over the lateral method on immobilization. The interactions of any two and all greatly improve the quality of the broiler chicken. Strain, age and immobilization methods of slaughter are important tools to be considered in assessing the quality of meat.

Table 1: Carcass yield and primal cuts of broiler chicken as affected by strain, age at slaughter and methods of immobilization

Strains	LW (kg)	Dressing %	Back	Wing	Drumstick	Breast	Thigh	Abdominal fat
Cobb	2.00^{c}	70.70^{a}	14.19^{a}	8.24^{a}	9.19	22.24^{a}	12.08	0.84^{ab}
Abor Acre	2.31^{a}	70.82^{a}	12.98^{b}	7.90^{ab}	9.24	23.21^{a}	12.00	0.67^{b}
Marshall	1.78^{d}	62.28^{c}	13.27^{ab}	6.86^{c}	8.77	18.21^{b}	11.54	0.97^{a}
Anark	2.16^{ab}	64.91^{bc}	13.69^{ab}	7.10^{c}	9.12	18.38^{b}	12.44	1.06^{a}
Ross	2.06^{bc}	67.25^{ab}	13.29^{ab}	7.67^{ab}	8.92	22.39^{a}	11.82	0.91^{a}
Hubbard	2.06^{bc}	69.84^{a}	12.68^{b}	8.11^{a}	8.46	22.19^{a}	11.78	0.83^{ab}
SEM	0.05	0.23	0.34	0.17	0.19	0.48	0.24	0.11
p-value	**	**	*	*	NS	**	NS	*
Age at slaughter								
6 weeks	1.64^{b}	62.57^{b}	12.73^{b}	7.32^{b}	8.81	17.94^{b}	9.86	0.79
8 weeks	2.22^{a}	71.81^{a}	14.25^{a}	8.65^{a}	9.29	20.14^{a}	10.09	0.99
SEM	0.04	0.84	0.19	0.34	0.11	0.28	0.14	0.07
p-value	***	***	**	*	NS	***	NS	NS
Immobilization methods								
Lateral	2.30	60.80	15.17	7.32	9.00	17.79	10.3	1.04
Cone	2.27	60.30	14.08	7.56	9.00	18.80	9.81	1.05
SEM	0.02	0.82	0.19	0.21	0.12	0.26	0.12	0.09
P-value	NS	NS	NS	NS	NS	NS	NS	NS
Interactions								
Strain*Age at slaughter	**	**	***	NS	NS	**	NS	*
Strain * Immobilization methods	*	**	NS	NS	NS	NS	NS	NS
Age at slaughter* Immobilization methods	*	*	*	NS	NS	NS	NS	NS
Strain* Age at slaughter* Immobilization methods	*	**	**	NS	NS	*	NS	NS

a,b,c: Means along the same column with different superscripts differ according to the level of significance within each main effect.
NS: Non Significant; *P<0.05; **P<0.01; ***P<0.001

Table 2: Physico-chemical of broiler chicken as affected by strains, age at slaughter and methods of immobilization

Strains	*pH*	*WHC*	*Cooking loss*	*Chilling loss*	*Crude protein*	*Ether Extract*
Cobb	6.12	78.99^{b}	19.01^{b}	6.32^{c}	17.53^{c}	10.83^{b}
Abor Acre	6.17	82.38^{a}	15.65^{c}	8.87^{b}	19.00^{a}	8.67^{d}
Marshall	6.15	79.37^{b}	19.42^{b}	9.55^{a}	15.90^{d}	13.33^{a}
Anark	5.99	77.72^{c}	20.23^{b}	9.60^{a}	18.06^{b}	10.00^{c}
Ross	6.15	78.54^{b}	20.90^{a}	4.67^{d}	18.47^{ab}	10.67^{b}
Hubbard	6.00	77.32^{c}	20.22^{b}	9.59^{a}	17.92^{b}	10.63^{b}
SEM	1.12	1.72	1.93	2.35	1.31	1.45
p-value	NS	**	**	**	**	**
Age at slaughter						
6 weeks	6.21	84.37^{a}	14.43^{b}	5.89^{b}	16.17^{b}	9.32^{b}
8 weeks	6.11	77.48^{b}	20.12^{a}	9.24^{a}	19.21^{a}	10.21^{a}
SEM	0.02	2.15	1.02	1.07	1.21	1.14
p-value	NS	***	***	***	***	***
Immobilization methods						
Lateral	6.10^{b}	74.21^{b}	26.01	5.40	16.84^{b}	10.23
Cone	6.30^{a}	79.21^{a}	19.25	2.50	17.14^{a}	9.45
SEM	0.06	2.23	1.66	1.07	1.32	1.34
P-value	**	**	**	**	NS	NS
Interaction						
Strain*Age at slaughter	NS	**	**	**	**	**
Strain * Immobilization methods	NS	*	*	*	NS	NS
Age at slaughter* Immobilization methods	***	*	*	NS	NS	NS
Strain*Age at slaughter* Immobilization methods	NS	*	*	NS	NS	NS

a,b,c,d: Means along the same column with different superscripts differ according to the level of significance within each main effect.
NS: Non Significant; *P<0.05; **P<0.01; ***P<0.001

Table 3: Sensory attributes of broiler chicken as affected by strains, age at slaughter and methods of immobilization

Strains	*Colour*	*Flavour*	*Tenderness*	*Juiciness*	*Overall acceptability*
Cobb	6.46	6.09^{b}	6.91^{b}	6.79^{a}	6.00^{b}
Abor Acre	6.55	5.91^{b}	6.35^{c}	6.45^{b}	5.91^{b}
Marshall	6.18	6.27^{ab}	6.36^{c}	5.60^{c}	5.27^{c}
Anark	6.46	6.95^{a}	7.73^{a}	6.80^{a}	7.30^{a}
Ross	6.45	5.73^{b}	6.09^{c}	5.73^{c}	6.00^{b}
Hubbard	6.43	5.74^{b}	6.08^{c}	5.79^{c}	5.28^{c}
SEM	0.24	0.17	0.31	0.20	0.31
p-value	NS	*	*	*	*
Age at slaughter					
6 weeks	6.23^{a}	6.21^{a}	6.83^{a}	6.76^{a}	6.98^{a}
8 weeks	5.31^{b}	5.00^{b}	5.21^{b}	5.05^{b}	6.23^{b}
SEM	0.25	0.21	0.17	0.14	0.11
p-value	**	**	**	**	**
Immobilization methods					
Lateral	5.21^{b}	6.30^{b}	5.89^{b}	6.31^{b}	6.54^{b}
Cone	6.72^{a}	7.21^{a}	6.76^{a}	7.21^{a}	7.21^{a}
SEM	0.32	0.21	0.12	0.22	0.21
P-value	**	**	**	**	**
Interaction					
Strain*Age at slaughter	*	*	*	*	*
Strain * Immobilization methods	*	*	*	*	*
Age at slaughter* Immobilization methods	**	**	**	**	**
Strain*Age at slaughter* Immobilization methods	*	*	*	*	*

a,b,c: Means along the same column with different superscripts differ according to the level of significance within each main effect.
NS: Non Significant; *P<0.05; **P<0.01; ***P<0.001

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