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PHYSICO-CHEMICAL, TECHNOLOGICAL AND SENSORIAL QUALITIES OF MEAT AND SAUSAGE FROM BROILER CHICKENS FED DIETARY WHITE AND CAYENNE PEPPER POWDERS

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ABSTRACT

Repeated purchase of edible products by customers can be attributed to quality and taste – a target for producers and processors. The technological, physico-chemical and sensorial qualities of meat and sausage of broiler chickens fed dietary white pepper (WP) and cayenne pepper (CP) powders was investigated. Fifty-six broiler chickens with average weight ranging between 2.0 – 2.2 kg were selected. Prior to the experiment, broiler birds were selected from seven experimental groups supplied seven experimental diets. Post - evisceration, meat technological and physico-chemical indices were taken while sensory scores were awarded by semi-trained panelists. Analysis was carried out using One-Way ANOVA and Linear Mixed Model of SPSS with significant means ($p<0.05$) separated using Duncan Multiple Range Test. Results reveal overall minimization of loss and improved instrumental colour values of meat from B+200CP group was better but B+200WP group had better technological indices. Sausage from meat of birds fed B+200CP and B+125WP+125CP diets had preferred ($p<0.05$) loss and instrumental colour values. Panelists adjudged that meat from birds fed B+125WP+125CP diet had higher ($p<0.05$) overall flavour and acceptability sensorial scores though similar ($p<0.05$) as B+100WP+100CP and B+250CP groups; but identical in juiciness score as sole WP groups. Sausage from groups fed the Basal and B+125WP+125CP diets had better overall sensory scores, as panelists choice for or against pungency was the distinguishing index. B+200WP, B+200CP and B+125WP+125CP diets can be fed to broiler chickens to enhance meat technological, physico-chemical and sensorial characteristics respectively but meat from the latter and Basal groups are suggested for sausage.

1.Introduction

There are evidences suggesting a relationship exists among product quality, product cost and product safety (Cruz, 2015). Consumers are the target of every production chain and every production line is flawed without careful pre-consideration of the needs of consumer, knowing fully well that satisfying consumer expectations affect shopping behaviour. Satisfaction derived from the quality of a product strongly influence the intention to repeatedly purchase a product while quality cues or attributes of meat affect choice of purchase. Font-I-Furnols and Guerrero (2014) explained that the intrinsic (colour, amount of fat and layering) and extrinsic (price, origin, quality labels) properties of a product and their interactions impact the eventual sensations experienced by consumers. Consumer perception of meat and preference for certain meat qualities encourage consumer to purchase meat products. Sensations experienced from meat are based on attributes such as tenderness, juiciness and taste which correlate highly with the intent to buy at the point of purchase (Banović *et al*., 2009; Garmyn, 2020).

Poultry meat contain essential desirable nutritional profile such as low lipid content and relatively high proportion of unsaturated fatty acids essential for healthy growth and development. Nutriment profile of poultry meat reveals chicken meat is comparable to other meats in cholesterol profile but offers superior nutrients when the protein, total fat and calorie content is juxtaposed with meat from other sources (Babic *et al*. 2014; Marangoni *et al*., 2015). Nowadays, investigations of meat qualities of broiler chickens subjected to nutritional modification raises curiosity among consumers, and notable studies have been embarked on to connect causal factors affecting consumer attitudes with meat attributes. Since product quality is retained as best as possible under cold storage, the physical and nutritional qualities of perishable products is judged when stored meat is bought; largely affecting the quality of product and appeal to purchasers. Also, the technological properties of meat such as its water holding and absorptive properties influence its interaction with other ingredients (flour) and food additives or marinades for the production of chicken meat sausage (Lees *et al*., 2019; Mudgil and Barak, 2019; Szendrő *et al*., 2020). Hence, producers and processors see it expedient to modify meat properties to satisfy consumer expectations.

Additives have been incorporated into broiler diets to improve the sensory characteristics of food. (Kralik *et al*., 2017; Sanwo *et al*., 2019). Exploration of these substances influence decision to purchase since properties of meat and meat products are critical to purchase. Hot red pepper and cayenne pepper contain capsaicin, vitamins, potassium, manganese and flavonoids that contribute to performance and quality (Younis and Abdel-Latif, 2017; Adegoke *et al*., 2018). On the other hand, Akinoso *et al*. (2013) reported that *Piper nigrum* contribute piquant taste and flavour to cuisines as a result of its piperine (the principal functional compound) content alongside minerals such as calcium, manganese, iron, zinc, potassium, magnesium, carotene, zeaxanthin, lycopene (excellent sources of vitamin B complex groups such as pyridoxine, riboflavin, thiamine and niacin) and rotundone – an aromatic compound (Drew *et al*., 2016).

Studies on performance among birds fed dietary pepper powders suggests sensorial and eating qualities of meat are likely sacrificed at higher levels of inclusion. Notably, a study conducted by Sanwo *et al*. (2019) showed that cayenne pepper inclusion at minimal dosage exhibited improved meat quality profile. Since consumer satisfaction and product quality are intrinsically connected to repeated purchase and limited information currently exists on the impact dietary pepper powders exert on quality of meat and sausage from meat-type chickens; an experiment was therefore conducted to investigate the physico-chemical, technological and sensorial qualities of meat and sausage from broiler chickens fed dietary white and cayenne pepper powders.

2.Materials and methods

Meat of broiler birds fed diets containing pepper powders were sourced. Diet layout birds were subjected to comprise:

Treatment (T) 1 - Basal diet (B) (No additive added)

T2 - Basal diet + 200 g White Pepper (WP) (B+200WP)

T3 – Basal diet + 250 g White Pepper (B+250WP)

T4 - Basal diet + 200 g Cayenne Pepper (CP) (B+200CP)

T5 – Basal diet + 250 g Cayenne Pepper (B+250CP)

T6 - Basal diet + 200 g WP and CP (B+100WP+100CP)

T7 - Basal diet + 250 g WP and CP (B+125WP+125CP)

Proximate composition of the Basal diet was determined following AOAC (2005) method with 22.90% crude protein, 12.05% metabolizable energy, 3.80% crude fibre, 3.98% ether extract, 1.36% calcium; 0.58% Phosphorus, 1.61% lysine and 0.54% methionine present.

2.1.1. Experimental layout

Twenty-eight broiler chickens with weight range between 2.2 and 2.5 kg were selected for meat quality analysis, while another twenty-eight birds with weight range between 1.8 and 2.2 were sacrificed for sausage. One bird was selected from each of the seven (7) treatment groups that comprise of four (4) replicates. The same procedure was followed for sausage, totaling 56 birds for both meat and sausage quality evaluations. Selected birds were conventionally dressed following ethical guidelines detailed by the Animal Welfare Board of the College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta (FUNAAB, 2016).

2.1.2. Procedure for sausage preparation

Chicken meat sausage was formulated up to 500 grams. Composition of chicken sausage is presented in Table 1. Fresh meat from the breast muscles were obtained, weighed and run through a 5 mm plate in a grinder unit of Kenwood (Hampshire U. K) food processor and placed in cellulose casing at 10 - 15 mm length distance. Seven (7) batches of sausage, each corresponding to a treatment was constituted. Each batch was further subdivided into rolls as replicates, comprising four (4) rolls for sensory and technological properties respectively.

Table 1. Ingredient composition of chicken sausage

Ingredients	**Composition (%)**
Breast Muscles	48
Wheat Flour	25
Vegetable Oil	10
Additives	2
Ice/Cold Water	13
Salt	2
Total	100

* Additives – White pepper 0.3 g, Cayenne pepper 0.3 g, Ginger 0.25 g, Turmeric 0.90 g, Coriander 0.23g, Seasoning 0.02 g

2.2. Data Collection

2.2.1. Physico-chemical indices of chicken meat and sausage

2.2.1.1. pH and temperature evaluation

Meat pH was taken by placing the electrode of the pH meter (model pH – 108A) deeply into the breast region after standardization (Kim *et al*., 2009), while a simple insertion was performed for raw sausage. Thorough rinsing was done after each dipping.

2.2.1.2. Colour evaluation

Two wings from each dressed bird per replicate was neatly separated and meat colour was examined using a colorimeter (CHROMA METER CR – 410, JAPAN). Lightness (L*), redness (a*) and yellowness (b*) colorimetric coordinates were evaluated using details published by Kralik *et al*. (2017) while colour intensity/saturation index (chroma value and hue angle) were calculated according to Melahat Özbek *et al*. (2020) from the a* and b* values for chicken meat and sausage.

2.2.1.3. Cooking loss determination

Left thigh of each carcass was apportioned for loss evaluation. Selected samples were weighed, wrapped in separate air-tight

polythene bags and cooked in a water bath at 70 °C for 30 minutes (Sanwo *et al*., 2019). Sausages were labelled and placed in microwave oven (Samsung GE109MST) at 600 Watt power level for 15 min. Subsequently, the internal temperature of each sausage was measured using a digital thermometer probe.
Cooking loss for both meat and sausage were obtained using the formula below.

$$\text{Cooking loss (g)} = \text{Weight before cooking} - \text{Weight after cooking} \quad \textbf{(1)}$$

$$\text{Cooking loss (\%)} = \frac{weight\ before\ cooking - weight\ after\ cooking}{weight\ before\ cooking} X\ 100 \quad \textbf{(2)}$$

2.2.1.3. Determination of meat and sausage refrigeration loss

Left drumstick from each carcass was selected per replicate. The samples were weighed and labelled prior to refrigeration, re-weighed after 24 hours of refrigeration for refrigeration loss analysis as follows:

$$\text{Refrigeration loss (g))} = \text{weight before refrigeration} - \text{weight after refrigeration} \quad \textbf{(3)}$$

$$\text{Refrigeration loss (\%)} = \frac{weight\ before\ refrigeration - weight\ after\ refrigeration}{weight\ before\ refrigeration} X\ 100 \quad \textbf{(4)}$$

2.2.1.4. Assessment of meat water holding capacity

Fifteen grams of meat from the breast region of each carcass was cut out to determine meat water holding capacity. Samples were blended using conventional blender prior to centrifugation using 22.5 ml of 0.6 M saline solution. Afterwards, contents were stirred with a glass rod for 1 minute as described by Hamm (1975). Next, samples were placed in the refrigerator for 15 min as slurry formed was stirred for 1 min before placement into centrifuge **(**MERLIN 503, Spectra scientific Ltd, Great Britain**)** for 15 mins. Supernatant layer gotten was decanted and the solution obtained was documented. Liquid retained in meat was reported as water holding capacity (ml) per 15 g of meat.

$$\text{WHC} = \frac{Before\ centrifuge - After\ centrifuge}{Before\ centriguge} \text{ x } 100 \quad \textbf{(5)}$$

2.2.1.5 Determination of meat water absorptive capacity

Thirty grams of meat from the breast muscles was cut out and blended with 20 ml of distilled water for 2 minutes to obtain water absorption capacity (WAC) of meat samples. Homogenized mixture was poured and rinsed with 20 ml of distilled water into a pre-weighed centrifuge tube, then centrifuged using the procedure detailed by Arganosa *et al*. (1991) (MERLIN 503, Spectra scientific Ltd, Great Britain) at 2000 rpm for 25 min. Unabsorbed residual water decanted post-centrifugation and water absorbed by meat was calculated as:

$$\text{WAC (\%)} = \frac{gram\ of\ water\ absorbed}{gram\ of\ meat} \text{ x } 100. \quad \textbf{(6)}$$

2.2.2. Analysis of sensory profile of chicken meat and sausage

Cooked chicken meat and microwaved sausage samples were dissected into pieces, according to the number of panellists (20). Panellists were separately presented with coded samples to evaluate sensorial attributes ranging from appearance to pungency. Ordinary water was provided for gaggling to prevent or minimize any carry over effect. Panellists scored samples using slightly modified hedonic scale (Sanwo *et al*., 2013) by responses on a 9-point hedonic scale intensity (1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike moderately, 4 = Dislike slightly, 5 = Intermediate, 6 = Like slightly, 7 = Like moderately, 8 = Like very much, 9 = Like extremely). Colour, juiciness, meat flavour, tenderness, saltiness, saltiness, pungency, overall flavour and overall acceptability were attributes judged by panellists.

2.3. Statistical analysis

Data obtained were subjected to a one-way analysis of variance using the generalized linear model procedure of Statistical Package for Social Sciences version 21 (SPSS, 2012). Covariate analysis was carried out on the initial weight of drumstick prior to the determination of cooking and cooking loss percentage. Data obtained from sensory experiments (Chicken meat and Sausage) were subjected to Linear Mixed Model with panellists' effect weighted following GLM procedure of the same statistical package. Significantly different means (p<0.05) were separated using Duncan Multiple Range Test of the same Statistical Package.

3.Result and Discussion

3.1. Evaluation of physico-chemical and technological indices of meat from chickens fed experimental additives.

pH, refrigeration and cooking losses; refrigeration and cooking loss percentages; absorptive power; holding capacity and colour of meat from chickens fed dietary peppers is documented in Table 2. Meat final weight, refrigeration loss and loss percentage; cooking and cooking loss percentages; meat water absorptive power; lightness, yellowness and redness were affected (p<0.05). Final weight of meat was reduced (p<0.05) post-refrigeration among meat from birds given B+200WP diet than B+250WP and B+250CP diets. Meat refrigeration loss and refrigeration loss (%) values were statistically identical with more loss from meat of birds fed B+200WP diet compared to other groups. Percentage cooking loss of meat of birds fed the Basal and B+125WP+125CP diets increased than meat of birds given B+200CP diet but other groups had comparable loss percentages. Meat water absorptive power was least (p<0.05) among chickens offered B+250WP diet, but higher among meat of birds supplied B+200WP diet, though comparable as values obtained from B+200CP, B+250CP and B+125WP+125CP groups. Meat lightness was highest among groups supplied cayenne pepper powder additive solely at 200 and 250 g 100 kg^{-1} of feed than lightness value of meat of birds offered 200 g 100 kg^{-1} white pepper diet. Meat redness was pronounced (p<0.05) among birds in B+100WP+100CP group than all other groups, but the Basal, B+200WP and B+200CP groups were lower, while B+250CP was least. Yellowness was intensified (p<0.05) in meat of birds given the Basal diet than B+200CP and B+125WP+125CP, but least among B+250WP group.

Table 2. Physico-chemical and technological indices of meat from broiler chickens fed dietary white and cayenne pepper powders

Parameters	Basal (B)	B+200WP	B+250WP	B+200CP	B+250CP	B+100WP +100CP	B+125WP +125CP	SEM
pH	6.41	6.44	6.18	6.55	6.55	6.36	6.42	0.05
Refrigeration loss in Meat								
Final wt (g)	114.36^{ab}	110.38^{b}	114.72^{a}	113.46^{ab}	114.46^{a}	114.25^{ab}	114.45^{ab}	0.82
Ref. loss (g)	1.45^{b}	5.05^{a}	1.00^{b}	1.40^{b}	1.00^{b}	2.00^{b}	1.50^{b}	0.38
Ref. loss %	1.30^{b}	4.39^{a}	0.88^{b}	1.08^{b}	0.81^{b}	1.92^{b}	1.36^{b}	0.34
Cooking loss in Meat								
Initial wt (g)	106.25	117.25	116.50	117.50	117.50	113.50	112.75	2.49
Final wt (g)	97.13	107.53	108.63	112.30	109.30	105.40	102.70	2.41
Cooking loss (g)	9.13	9.73	7.88	5.20	8.20	8.10	10.05	0.58
Cooking loss %	8.66^{a}	8.38^{ab}	6.80^{ab}	4.26^{b}	6.90^{ab}	7.00^{ab}	8.91^{a}	0.51
Meat water absorptive power and holding capacity (%)								
WAP	53.70^{bc}	88.30^{a}	39.20^{c}	69.00^{ab}	71.70^{ab}	60.30^{bc}	76.70^{ab}	4.06
WHC	58.47	55.12	53.72	61.37	54.04	54.17	62.87	1.61
Colour indices								

L*	51.42^{c}	48.54^{d}	52.82^{b}	54.16^{a}	54.08^{a}	51.76^{c}	53.06^{b}	0.50
a*	10.72^{d}	10.59^{d}	12.17^{b}	10.60^{d}	9.90^{e}	14.98^{a}	11.17^{c}	0.44
b*	12.43^{a}	7.53^{d}	3.37^{f}	10.17^{b}	8.36^{c}	4.17^{e}	10.91^{b}	0.87
Chroma	16.41	12.99	12.63	14.69	12.96	15.54	15.61	1.96
Hue	1.16	0.71	0.28	0.96	0.84	0.28	0.98	0.12

$^{a, b, c, d, e, f}$ - means on the same row with different superscripts differ significantly (p <0.05).
CP – Cayenne pepper powder WP- white pepper powder WAP – water absorptive power
WHC – water holding capacity wt – weight L* - Lightness a* - Redness b* - yellowness

High moisture loss in meat result in low-weight product caused by increased water or moisture escape from muscle cells. Meat quality is affected as water soluble sarcoplasmic proteins, vitamins and enzymes are released. High refrigeration loss and loss percentage was recorded for meat from chickens given B+200WP diet than other groups. According to Anne *et al*. (2016) light muscle and dark muscle vary in processing attributes owing from their respective preponderances in red and white fibre contents with different functionalities within meat muscle proteins matrix, resulting in the immobilization of extraneous water into meat. The variation between gastrocnemius and pectoralis major myofibril in chicken meat (Ismail and Joo, 2017), determine the extent of enlargement that occurs, causing pull of extraneous water. With B+200WP diet fed effecting high loss, but not B+250WP; an inference posited is that the consumption of white pepper powder by broiler chickens at 250 g was not optimal to increase the amount of pectoralis major myofibril in meat. High cooking loss indicates moisture was lost during thermal treatment of meat. Meat from chickens supplied B+200CP diet had the lowest cooking loss percentage. According to Olsson *et al*. (2003), the effect of production system on cooking loss resulted in lower loss (%) in meat from animals raised on organic substances compared with that fed conventional diet. Hocquette *et al*. (2010) likewise declared that chemical composition of muscles is fairly constant but contains variable lipid composition between species, within species as well as between muscles and cuts. Such modifications brought about by peppers incorporated alter the properties of meat. The outcome of feeding B+200CP diet contradicted the report of Sanwo *et al*. (2019) possibly due to strain (Abor acres vs Cobb broiler chickens) variation. Tougan *et al*. (2013) identified the contributory role genetics and environmental factors play on muscle composition and meat quality. Notably, consumers pay premium for meat and meat products, especially those characterized by not only high flavour scores, better nutritive value and low-fat content; but rich in vitamins and minerals concentration.

Meat with the highest affinity for pull of exterior water was obtained from birds offered B+200WP diet but lowered in meat of groups supplied B+250WP diet. Protein structure and composition affect the absorptive capacity of fresh meat. Sarcoplasmic proteins bathe the myofibrillar proteins that provides needed biochemical functions such as energy, to synthesize protein and remove soluble metabolic by-products (Sanwo *et al*., 2019). Dietary white pepper powder possibly at its lowest inclusion percentage facilitated increased sarcoplasmic protein production within muscle cells that results in modified structural tissues. Marino *et al*. (2014) posited that optimum moisture absorption may occur owing to the water binding capacity of meat, as the sarcoplasmic proteins show higher affinity. Such meat will likely yield higher tenderness score – a delight to consumers who focus on marination brining as it becomes juicier (FSIS, 2013). Wang *et al*. (2006) likewise buttressed that high water absorptive power values are important to transfer dissolved ingredients from external sources into meat. On the other hand, contradictory and opposing values between refrigeration loss (%) and water absorptive power values could be attributed to the different proteins responsible for water pull and binding (Xiong, 2005).

Instrumental colour analysis of meat of birds offered additives reveal impact of diet on lightness, redness and yellowness parameters. Haem pigment directly correlates with paleness of breast meat and pale meat in turn is negatively correlated with lightness (L^*) values (Boulianne and King, 1998; Karunanayaka *et al*., 2016). On the contrary, Anadon, (2002) explained that light dissipation affects meat L^* value with an inverse correlation observed against heme pigment concentration with minimal impact on meat redness (a^*) and yellowness (b^*) values, while Jankowiak et al. (2021) clarified that lower pH corresponds with higher L^* value. The report of the latter authors contradicts findings from this study. Feeding birds 200 and 250 g cayenne pepper per 100 kg of the Basal diet yielded numerically higher pH. Meat L* values of meat of chickens supplied cayenne pepper at 200 and 250 g 100 kg^{-1} of Basal diet is in partial agreement with the findings of Tashla *et al*. (2020), whose study showed that lightness value was pronounced in meat of birds from the Control group that were fed dietary garlic, black pepper and hot red pepper as supplement. Alteration in meat lightness is dominantly caused by elevated meat colour opacity. This occurs due to the potency of dietary pepper powders to inhibit the extent of fat deposition, thus improving the lipid metabolism.

Possible dissipation of meat myoglobin result in increased lightness values but not the formation of PSE meat since canthaxanthin is the dominating red carotenoid in pigmented broilers (Hamelin and Catherine, 2012). Kim *et al*. (2010) stated that pigment content and redox state account for much of the variation in a* values since meat myoglobin presence is significantly correlated with redness (a*). All redness values for all treatment groups exceeds documented values by Akiba *et al*. (2001) and Wattanachant *et al*. (2004) for commercial broiler chickens. Though Tasla *et al*. (2020) established stronger redness intensity in thigh meat of broilers fed 1% hot red pepper; blood heamoglobin – myocytes and heme pigments transfer to the muscles were facilitated by biomolecules in peppers.

This study had birds on the Basal diet with the highest meat yellowness score. On observing high variability in meat yellowness despite homogeneous xanthophyl fed, Sirri *et al*. (2010) inferred that other factor influence meat yellowness along with pigment concentrations and this study supports the posit. All additives impacted negatively on yellow skin pigmentation of the birds with B+250WP and B+100WP+100CP diets most notable. In broilers, zeaxanthin influences the prominence of yellowness in tissues, more noticeably in the abdominal fat (Hamelin and Catherine, 2012). A likely explanation is that pepper powders suppress zeaxanthin formation and its deposition in the skin at varying rates. Alternatively, peppers may negatively impact the absorption of xanthophyl in the feed or intestine as xanthophyl is directly associated with intestinal integrity (Ortega *et al*., 2012). Our findings agree with the report of Pugliesea *et al*. (2013), that bioavailability of carotenoids is affected by dietary factors such as the nature, type and amount of carotenoid consumed or added to the diet.

3.2. Sensory characteristics of meat from chickens supplied dietary ***Piper nigrum*** **and** ***Capsicum frutescens***. Sensory characteristics of meat from chickens fed dietary additives is documented in Table 2. All sensory indices measured were significant ($p<0.05$) except saltiness and pungency. Meat from birds offered B+250CP, B+100CP+100WP and B+125CP+125WP diets had colour scores that were 'moderately liked' when compared against the Basal, B+200WP and B+200CP groups that were 'slightly liked'. Meat of chickens given B+200WP, B+250WP and B+125WP+125CP diets were 'moderately juicy' with higher juiciness score than B+200CP group that had 'slightly liked' score. 'Intermediate flavour' score was ascribed to meat of birds fed the Basal and B+200CP diets but 'slightly flavourful score' was awarded to B+100WP+100CP and B+125WP+125CP groups which was significantly higher. Meat of chickens supplied B+200WP diet had statistically similar values as meat of chicken offered the Basal, B+250WP and B+125WP+125CP diets ('moderately tender') but was significantly higher than tenderness score of meat of birds fed B+250CP and B+100WP+100CP diets ('slightly tender'). Higher overall flavour score of meat obtained from birds supplied dietary B+125WP+125CP was comparable ($p<0.05$) as score from B+250CP and B+100WP+100CP groups, both labelled 'moderately desirable' by panellists. A similar trend was observed for meat overall acceptability scores as all three treatment groups previously mentioned were adjudged 'moderately liked' for overall acceptability.

Meat of birds supplied dietary cayenne peppers singly at 200 and 250 g 100 kg^{-1} of the Basal feed as well as B+125WP+125CP diet had highly attractive colour score according to panellists. Inclusion of 125g WP: 125 CP powder did not negatively influence perceived score by panellists, indicating a foundation template for meat quality from birds fed dietary cayenne pepper. Xiao *et al*. (2011) associated improved meat colour L* (lightness) with the supplementation of vitamin E. Pepper carotenoids, especially capsanthin and capsorubin exhibited anti-oxidative properties.

Table 3. Sensory characteristics of meat from chickens given *Piper nigrum* and *Capsicum frutescens* as additives

Parameters	Basal (B)	B+200WP	B+250WP	B+200CP	B+250CP	B+100WP +100CP	B+125WP +125CP	SEM
Colour	6.19^{b}	6.45^{b}	6.51^{ab}	6.41^{b}	7.10^{a}	7.09^{a}	7.15^{a}	0.08
Juiciness	6.76^{ab}	7.18^{a}	7.09^{a}	6.32^{b}	6.81^{ab}	6.82^{ab}	7.22^{a}	0.08
Meat flavour	5.73^{b}	5.95^{ab}	5.97^{ab}	5.75^{b}	6.02^{ab}	6.68^{a}	6.68^{a}	0.10
Tenderness	7.08^{ab}	7.21^{a}	7.03^{ab}	6.59^{abc}	6.48^{bc}	6.26^{c}	7.12^{ab}	0.09
Saltiness	5.14	4.99	5.23	5.43	5.29	4.82	5.31	0.08
Pungency	6.56	6.36	6.33	6.52	6.32	6.37	6.44	0.09
Overall flavour	6.60^{bcd}	6.30^{cd}	6.69^{bc}	6.06^{d}	6.81^{abc}	7.17^{ab}	7.34^{a}	0.08
Overall acceptability	6.53^{cd}	6.18^{d}	6.67^{bcd}	6.42^{cd}	6.90^{abc}	7.26^{ab}	7.46^{a}	0.09

$^{a, b, c, d}$ – Means in the same row with different superscripts are significantly (p <0.05) different.
CP – Cayenne pepper powder; WP - white pepper powder

Capsanthin accounts for approximately average of the total carotenoids found in fully ripe fruits (Mohd Hassan *et al*., 2019) while phenolic compounds (flavonoids - mainly quercetin and luteolin); phenolic acids; capsaicinoids; tocopherols; carotenoid, ascorbic acid; nitrates and nitrites (Campos *et al*., 2013) in peppers (fresh peppers and their seeds) contribute to light dispersion, pH and colour properties of meat. Meat juiciness was adjudged better for groups offered white pepper at 200 and 250 g 100 kg^{-1} diets, and meat of birds fed B+125WP+125CP diet, while B+200WP diet offered yielded meat with desirable tenderness score. As Warner (2007) predicted, there is a connection between meat water holding capacity (WHC), texture and juiciness. Meat from birds given white pepper diets of 200 and 250 g 100 kg^{-1} and B+125WP+125CP diet all had higher scores but the latter group had numerically higher WHC. White pepper at low dosage moderately modified muscle fat and water proportions by depositing phytochemical that influenced meat juiciness, alongside other intrinsic and extrinsic factors such as water released from meat during mastication mixed with saliva (Oppen *et al*., 2022). Juárez *et al.* (2012) similarly alluded to the textural (tenderness) properties of meat such as water-holding capacity (WHC) and fat content. These factors contribute to the lubrication, mastication and chewing sensations experienced by panelists offered meat of birds fed B+200WP diet. Such complex sensory attributes are reportedly attached to descriptors such as fibre characteristics, cohesiveness, adhesion, mushiness, softness and amount of residual connective tissue. Flavour score of meat from chickens fed both combinations were adjudged ‘moderately flavorful’, having higher flavour score than meat from birds fed the Basal and B+200CP diets. Meat flavour forms during cooking owing to Maillard reaction and lipid oxidation. Amino acids, peptides and ribose - precursors contribute to meat flavour when exposure to increasing heat which triggers the Maillard reaction in combination with nucleotides and additional amino compounds, such as creatine, carnosine and creatinine (Sun *et al*., 2022). Brenes and Roura (2010) pointed out that the combined effect of additives results in complexity as a result of the quantity and variability of bioactive compounds, and mixture of essential oils present, causing feasible effects that alter the concentrations required to achieve a particular impact. Also, Arimboor, (2015) explained that ground and aqueous pepper (paprika) contributed to colour and flavour alterations in soups, stews and sausage, thus confirming the potency of aromatic constituents in pepper powders. Furthermore, lipid degradation releases compounds that transfer fatty aromas to cooked meat. Polyunsaturated fatty acids (PUFA) are sources of aromatic volatiles in cooked meat, thus contributing to flavour development. Phospholipids sucked out of meat gave meat a biscuit-like aroma that pale in comparison to the flavour sensations perceived from lipid-derived aldehydes and alcohols, accompanied by increased formation of compounds derived from maillard reaction (Mottram and Edwards, 1983; Shahidi and Hossain, 2022). For meat overall flavour, meat of chickens supplied B+125WP+125CP diet was preferred by panellists. Increased the concentration of soluble flavour components triggers a variety of chemical reactions that modify flavour properties, thus influencing the overall flavour of the meat. Also, melted fat spreads across the surface as boiling temperature increases alongside decomposition products contribute to perception of meat overall product, thereby, influencing sensations experienced such as mouth feel and juiciness. With B+125WP+125CP diet adjudged best for colour, juiciness, flavour and overall flavour, it expectedly translates to higher score for acceptability.

3.3. Physico-chemical properties of sausage from meat of chickens fed dietary peppers.

Physico-chemical properties of sausage formulated from meat of chickens fed dietary pepper powders is presented in Table 4. Sausage internal cook temperature and refrigeration loss percentage were significantly ($p<0.05$) different, but pH, cooking and refrigeration losses as well as cook loss percentage were not significant ($p>0.05$). Peak core temperature of sausage was recorded among the Basal, B+200WP and B+250CP groups after cooking in microwave. Low temperature was recorded for sausage from B+250WP group but other groups had intermediate ($p>0.05$) temperature values. Refrigeration loss (%) was significantly higher and lower respectively in sausages formulated from meat of birds fed B+250CP and B+200CP diets respectively, though all other groups had statistically ($p<0.05$) intermediate percentages. Sausage lightness (L*), redness (a*) and yellowness (b*) intensity values were affected but chroma and hue values were not influenced.

Intensity of sausage lightness, redness and yellowness was more vivid among sausage from meat of birds fed B+125WP+125CP diet. Least ($p<0.05$) lightness and yellowness values were observed among B+100WP+100CP group as B+200CP group had the least redness score.

Table 4. Physico-chemical properties of sausage from meat of chickens fed dietary pepper powders

Parameters	Basal (B)	B+200WP	B+250WP	B+200CP	B+250CP	B+100WP +100CP	B+125WP +125CP	SEM
pH	6.71	6.77	6.65	7.00	6.52	6.75	6.14	0.26
T (°C)	68.50[a]	68.75[a]	52.55[b]	56.65[ab]	69.60[a]	63.90[ab]	59.25[ab]	2.09
Loss (%)								
Cooking (g)	4.95	3.75	7.05	4.45	8.70	5.00	5.50	0.63
Cooking (%)	6.52	5.21	9.13	6.54	12.35	7.71	8.03	0.86
Ref (g)	6.40	4.30	5.55	3.80	8.70	5.00	5.50	0.57
Ref (%)	8.87[ab]	6.77[ab]	8.01[ab]	5.06[b]	14.19[a]	8.42[ab]	8.76[ab]	1.00
Colour								
L*	47.61[d]	51.24[ab]	47.69[cd]	50.55[b]	48.58[c]	46.31[e]	51.81[a]	0.54
A*	2.88[bc]	2.78[c]	2.79[c]	1.93[d]	2.74[c]	3.19[b]	3.54[a]	0.49
B*	34.03[c]	37.93[b]	34.03[c]	35.10[c]	37.38[b]	30.02[d]	40.48[a]	0.88
Chroma	34.15	38.03	34.14	35.15	37.48	30.19	40.63	1.98
Hue	11.82	13.64	12.20	18.19	13.64	9.41	11.44	1.09

[a, b, c, d, e] - Means on the same row with different superscripts differ significantly ($p<0.05$).
CP – cayenne pepper powder; WP- white pepper powder T – Internal cook temperature
Ref - refrigeration

Refrigeration loss values of sausage were modified by pepper powders fed and this could be attributed to the carry over effect from the meat. B+200CP diet had the overall lowest refrigeration and cook loss values which could be attributed to the type of protein developed within tissues of birds fed the dietary ingredient. Also, various oxidation-processing steps affect the properties of poultry meat, compromising animal growth, performance, and ultimately the quality of livestock. Protein and lipid oxidation have been recognized as a major threat to the quality of subsequently processed poultry products (Xiao *et al*., 2011). Instrumental analysis of L* and a* can easily be applied to muscle colour, but b* (blue and yellow) are not typical or intuitively related to meat (Mancini and Hunt, 2005) but can be to its products. French *et al*. (2000) observed a correlation between b* and carcass fat score when comparing finishing cattle on grass and concentrate. Carotenoid influence is exhibited by food properties which carotenoids are incorporated into as well as post-harvest handling, processing, storage and cooking practices (Pugliesea *et al*., 2013). In fact, capsaicinoid and colour intensities are considered key interwoven factors. Carotenoids are considered sources of red and yellow pigments that can inpact poultry product. Birds reportedly cannot generate these carotenoids, hence, ingredients such as red pepper, pine and corn meal when offered in the diet can be a source of supply (Marounek and Febriansyah, 2018). Sausages from meat of chickens offered B+125WP+125CP diet yielded brightest colour properties for l*, a* and b*. The interaction of both peppers in the diet and externally in chicken sausage reveal carotenoids were concentrated in the product. The pigments supplied by both peppers facilitated colourful properties that can attract customers to the product. The significance is reflected in the posit that consumer purchasing decision to a large extent depend on product colour.

3.4. Sensory characteristics of sausage from meat of chickens fed dietary peppers as additives. Panellist assessment of sausages obtained from meat of chickens given dietary peppers powders is presented in Table 5. Colour, pungency, overall flavour and overall acceptability of chicken sausage were significantly ($p<0.05$) influenced. Colour score of sausage from birds given B+200WP diet was higher ($p<0.05$) and described as 'slightly liked' by panellists, but B+200CP and B+100WP+100CP groups were awarded lower score values, though other groups excluding B+200WP had similar ($p>0.05$) values. Pungency of sausage of meat of birds offered the Basal diet was labelled 'intermediate' by assessors, though pungent ($p<0.05$) compared to sausage from B+250CP and B+125WP+125CP meat. Sausage overall flavour and acceptability for the Basal and B+125WP+125CP groups was scored higher ($p<0.05$) than B+200CP and B+100WP+100CP groups though similar ($p>0.05$) as awarded for B+200WP, B+250WP and B+250CP groups. Both groups with the highest ($p<0.05$) overall favour and acceptability scores were described as 'slightly desirable' and 'slightly liked' sausages respectively by panellists. Sausage from B+200WP, B+250WP and B+250CP groups were similar ($p>0.05$) as the Basal and B+125WP+125CP groups for both overall flavour and acceptability indices. Colour modifying properties of pepper was reported by Arimboor (2015) with modifications in colour and flavour of soups, stews as well as sausage with the addition of ground and aqueous pepper (paprika) reported. Similarly, documented colour stabilization of nitrite-free dry sausages with the incorporation of paprika and tomato paste by Bázan-Lugo *et al*. (2012) further alluded to this. Peppers possess tremendous variation in colour and oxidative properties (Umoh *et al*., 2020). This study yielded sausage enhanced colour properties that appeal to panellists. For pungency, sausage pungency index decreased as the concentration of dietary pepper powders increased. Anderson *et al*. (2017) explained that while consuming soup containing cayenne pepper, the urge for salty and spicy foods significantly decreased while desire for sweet and fatty foods significantly increased accordingly, implying that altered desire exists when pungent molecules are consumed. Pungency, however is subjective to individual preference. Sausage overall flavour and acceptability were scored higher for formulations compounded from meat of chickens given the Basal and B+125WP+125CP diets. Express approval by panellists may be as a result of different perceptions of sensations and interactive complexities. Flavour of sausage for meat of birds fed B+125WP+125CP diet generated via aromatic interaction within botanicals possibly increased with mixture of peppers which may have influenced the volume of lactic acid and ions in product, contributing to perception expressed (Tikk *et al*., 2006).

Table 5. Sensory characteristics of sausage from meat of chickens fed dietary pepper (White and cayenne) powders

Parameters	Basal (B)	B+200WP	B+250WP	B+200CP	B+250CP	B+100WP +100CP	B+125WP +125CP	SEM
Colour	5.84^{ab}	6.55^{a}	6.07^{ab}	5.15^{b}	5.81^{ab}	5.14^{b}	6.18^{ab}	0.15
Juiciness	4.90	4.90	4.94	3.79	3.76	4.79	5.07	0.17
Sausage flavour	6.41	5.96	5.96	5.30	5.62	5.30	6.33	0.15
Tenderness	4.65	5.22	5.97	5.17	5.18	5.88	4.65	0.18
Saltiness	3.24	2.79	3.22	3.19	2.91	2.86	3.31	0.09
Pungency	5.61^{a}	5.07^{ab}	4.99^{ab}	4.66^{ab}	4.13^{b}	4.35^{ab}	4.07^{b}	0.17
Overall flavour	6.36^{a}	6.05^{abc}	6.16^{ab}	5.05^{c}	5.69^{abc}	5.25^{bc}	6.72^{a}	0.13
Overall acceptability	6.40^{a}	5.68^{abc}	6.25^{abc}	5.07^{c}	5.73^{abc}	5.30^{bc}	6.75^{a}	0.15

$^{a, b, c}$ – Means in the same row with different superscripts differ significantly ($p<0.05$).
CP– Cayenne pepper powder WP- white pepper powder

Overall flavour is important for preference (Wang *et al*., 2021) considering that meat intra muscular fat play important role not just in flavour development but improved dissipation of flavour. Jachimowicz *et al*. (2022) explained that functional compounds in herbs incorporated into chicken diets can enhance sensorial perception of broiler chicken meat by altering the fatty acid content. Such alterations possibly extended to overall flavour perception by panellists for sausage from meat of birds fed B+125WP+125CP diet; supported by Lu *et al*. (2017) who explained that pepper fruit or powder incorporated as additive act as flavouring agent with aroma transmission in product. Shahidi and Hossain (2022) likewise explained that heat treatment at high temperatures released aromatic compounds by complex interaction of lipid oxidation and maillard reaction; reducing sugars and amino acids as well as volatile compounds that consequently translated into high overall acceptability scores for sausages from both the Basal and B+125WP+125CP groups. Overall increased impact from incorporation of peppers contribute significantly to wellbeing and consumer satisfaction since spiciness can be increased without negative consequences on well-being sensations (Byrnes and Hayes, 2013).

4.Conclusions

From this study, supplying B+200CP and B+250WP diets to broiler chickens can be explored to achieve improved physico-chemical and technological qualities of meat respectively while overall sensorial or organoleptic characteristics of meat from birds offered B+125WP+125CP diet is desirable to satisfy consumer sensorial preference. Sausage formulated with meat from the latter group had appealing colour (instrumental) values, while sausage formed from meat of birds fed B+200CP diet enhanced sausage weight post-microwave cooking. If sensorial characteristics of sausage is targeted and pungency is not desired, chicken sausage from meat of the Basal group is suggested, otherwise, sausage from meat of chickens fed B+125WP+125CP diet is recommended.

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Conflict of interest statement

Authors declare no conflict of interest

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