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EFFECT OF REPLACING NITRITE WITH GINGER POWDER IN BRINE SOLUTION ON THE QUALITY OF CURED BEEF

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Keywords: *brine, cured beef, ginger powder, nitrite, quality*

Abstract
The purpose of this study was to evaluate the effect of replacing nitrite with ginger powder in brine on the quality of cured beef. Five kilograms of fresh beef from a mature White Fulani bull was purchased and used for this study. The excessive fat and connective tissues were trimmed off the meat, and the meat slab was chilled at 4 °C for 24 hours before further processing. Nitrite, salt, dextrose and ginger powder were purchased, measured out to prepare brine solution of five concentration levels each level constituted a mode of treatment, where T_0 *served as control reference sample with nitrite, which nitrite was replaced with ginger power in the following concentrations:* $T_1 = 10\%$, $T_2 = 15\%$, $T_3 = 20\%$ *and* $T_4 = 25\%$. *The beef was cured with brine injecting and immersing the samples into brine solution for 72 hours, and refrigerated at 4 °C. The cured beef samples were taken out of the brine, rinsed, wrapped into foil paper and baked in the oven at 204 °C for 20 mins and cooled to room temperature (27 °C). Cured beef samples data were analysed with the help of analysis of variance (ANOVA) following the procedures of SAS (2002) with means significance determined at* $p < 0.05$. *There were significant differences* ($p < 0.05$) *in the physical properties, proximate analysis, vitamin and mineral contents, microbial loads and organoleptic characteristics of beef cured with ginger powder in brine, in* T_3 *featuring the best-quality and highest* ($p < 0.05$) *overall acceptability. In conclusion, ginger powder used in this study as replacement of nitrite enhanced the overall quality of cured beef without detrimental consequences for the consumers, especially in* T_3 *which concentration was therefore recommended.*

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Introduction

Meat is the most valuable livestock product it serves as the first-choice source of protein for human population. However, it is an ideal medium for many micro-organisms for its being nutritious for them, as it provides a suitable environment for proliferation of spoilage bacteria and other food-borne pathogens [1]. Processing of meat products was borne out of the need to preserve meat for its later consumption and to make it available over a long period [2]. Meat preservation in brine has been practiced from immemorial time till modern time. The meat industries worldwide use the methods such as immersion into brine and injection of brine to improve the quality, colour. Moreover, the advanced applications like high pressure pulse vacuum and ultrasound treatments are currently being applied in meat brining for the purpose of improving the texture, colour, sensory characteristics and overall quality of meat [3]. Brining is a method of curing meat and the main ingredients or components of brine used in curing meat are water, salt (NaCl) nitrate or nitrite and phosphates in mixture [4]. Nitrate and nitrite play important role on the safety and quality of cured meat products, and sodium or potassium nitrite are the most widely used as curing agents because it inhibits the growth and formation of neurotoxin *Clostridium botulinum*, hinders the development of oxidative rancidity, develops the peculiar flavour of cured meat and reacts with myoglobin to stabilize the red meat colour [5,6]. However, concerns over the safety of consuming nitrate or nitrite have arisen in modern times. The research [7] stated that the inhibitory effect on nutrient absorption in the intestine is caused by the adverse effects of nitrites and nitrates. The work [8] as well as [9] reported that nitrite in the acidic conditions of the stomach causes formation of nitrosamine which is carcinogenic compound. A study by [10] showed that application of nitrite and nitrate to preserve meat products increase the risk of gastric cancer development. This is defined by the activities of the bacteria naturally present in the meat or by addition of bacteria possessing a nitrate reductase activity which include staphylococci, micrococci and lactic acid bacteria [11,12]. There is also the challenge of sodium chloride super doses presence in cured meat. This is because most brine-enhanced meat products contain high salt concentration of 200 mg to 500 mg of sodium per 100 g of meat product [13] and this could be dangerous, as excessive sodium intake has serious implications for human health especially the development of hypertension [14,15]. As a result, public health and regulatory authorities as well as meat processing industries are developing strategies to reduce sodium intake and to research into alternative substitute for salt, nitrate and nitrite for their application in meat products preservation [16]. Such substitutes are available in most of the plants spices such as ginger. It is an edible root rhizome or root part of the plant *Zingiber officinale* that belongs to the family *zingiberaceae* which has spicy and aromatic taste and smell due to phenolic compounds and volatile and non-volatile essential oils such as shogaols and gingerols. Ginger root is calories free and serves as good source of essential vitamins and other nutrients good for human health [17]. Ginger is well reported [18] as a spice used as food seasoning due to its sweet aroma, pungent taste and for having antioxidant activity that prevents oxidation of lipid as well as provides antimicrobial capacity to serve as effective alternative for either nitrate or nitrite in the prevention of meat deterioration and enhancement of meat quality [19].

This study was therefore carried out to investigate the effect of replacing nitrite with ginger powder in brine on the quality of cured meat to fill the gap in the literature.

Materials and methods

This study was carried out in the Meat Science laboratory, Department of Animal Production, Olabisi Onabanjo University, Ayetoro Campus, Ogun State, Nigeria.

Experimental materials

Five kilograms of beef from mature White Fulani bull was purchased from a reputable slaughter at Ayetoro city in Ogun State, Nigeria. The excessive fat and connective tissues were trimmed off the meat and was chilled at 4 °C for 24 hours before its further processing. 1 kg of fresh beef was allotted to each of the 5 treatments, which piece was further cut into 5 replicates of 200 g per one replicate. Ginger power, salt, nitrite and dextrose were purchased from local market within the study area.

Measurement of experimental materials

A digital sensitive scale Model WT-3003N (WANT Balance Instrument Co., Ltd, China) was used to measure out ginger powder, salt (NaCl), nitrite and dextrose for conducting research in the Meat Science, Laboratory in the Department of Animal Production, Olabisi Onabanjo University, Ayetoro Campus, Ogun state, Nigeria.

Experimental brine solution preparation

Brine solution was prepared following the procedures of [4] as shown in Table 1.

Experimental design

Five levels of brine concentrations were prepared and each level constituted a treatment mode where T_0 served as control reference sample with nitrite, which nitrite was replaced with ginger powder in the following concentrations: T_1 = 10%, T_2 = 15%, T_3 = 20% and T_4 = 25% respectively.

Curing of beef

The curing of beef was carried out following the procedures described by [4], when brine solutions (20 mls) were manually injected into 200 g replicate of beef in each treatment, using syringes of 25 ml volume and the needles, one syringe and needle per one treatment. The injected beef samples were immersed into each of the brine concentration for 72 hours in a refrigerator at 4 °C.

Cooking of cured beef

The cured beef samples were taken out from the brine after 72 hours, rinsed, wrapped into foil paper and baked in a laboratory oven Model: LO-201G (Grieve Corporation, USA) at 204 °C for 20 mins with its turning over with periodicity of 5 mins to avoid burning at internal temperature of 73 °C [4]. The cured, cooked beef samples were taken out of the oven and cooled in a washed and cleansed desiccator to room temperature of 27 °C and stored in a refrigerator at 4 °C until conducting of laboratory analysis and measurements.

Analytical measurements of cured, cooked beef

Physical characteristics

Cooking loss

Percentage of cooking loss of the cured beef was determined by recording the initial weight of the cured beef samples in each treatment and recording the final weight

Table 1. Percentage of the ingredients of brine solution

Ingredients (%)	Treatments				
	T_0 (*N*)	T_1 (*GG*) 10%	T_2 (*GG*) 15%	T_3 (*GG*) 20%	T_4 (*GG*) 25%
Distilled water	82.00	77.00	72.00	67.00	62.00
Salt ($NaCl_2$)	10.00	10.00	10.00	10.00	10.00
Sodium nitrite	0.5.00	—	—	—	—
Ginger	—	10.00	15.00	20.00	25.00
Dextrose	03.00	03.00	03.00	03.00	03.00
Total	100.00	100.00	100.00	100.00	100.00

N = Nitrite, *GG* = Ginger.

of the cooked beef samples and calculating the percentage difference between the two measurements divided by initial weight and multiplied by 100. The result was recorded as the cooking loss which is represented mathematically according to [20] as follows:

$$\text{Cooking loss} = \frac{W_tCB_1 - W_tCCB_2}{W_tCB_1} \times 100, \quad (1)$$

where:
W_tCB_1 = initial weight of cured beef;
W_tCCB_2 = final weight of cured cooked beef.

Thermal shrinking

The thermal (heat) shrinking of cooked cured beef was determined following the procedures of [21]. The initial length of the cured beef minus the final length of the cooked cured beef was divided by the initial length and multiplied by 100. The result was recorded as the percentage of thermal shrinking as follows:

$$\text{Thermal shrinking } \% = \frac{CBL_1 - CCBL_2}{CBL_1} \times 100, \quad (2)$$

where:
CBL_1 — initial length of cured beef;
$CCBL_2$ — final length of cured cooked beef.

Cooking yield

The cooking yield of cured beef measurement was carried out following the procedures of [35] and [22], which was calculated as the final weight of cured cooked beef divided by initial weight of cured beef and multiplied by 100. Thus:

$$\text{Cooking yield } \% = \frac{W_tCCB}{W_tCB} \times 100, \quad (3)$$

where:
W_tCCB = final weight of cured cooked beef;
W_tCB = initial weight of cured beef.

Water holding capacity (WHC) of cured cooked beef

Water-holding capacity of the cured and cooked beef was determined following the procedures of [23] and [24]. This was determined by press method. An approximately 2 g of cured cooked beef sample was placed between Whatman filter papers (Caver Inc, Wabash, USA). The cured cooked beef was pressed between two 10.2×10.2 cm^2 plexiglasses at 2 kg/cm^3 absolute pressure for 1 minute with manual vice. It was calculated with the formula:

$$\text{WHC} = \frac{W_{twp} - W_{tdp}}{W_{tccb}} \times 100\,, \quad (4)$$

where:
W_{twp} = weight of wet filter paper (g);
W_{tdp} = weight of dry filter paper (g);
W_{tccb} = weight of cured cooked beef (g).

Chemical analysis of cured cooked beef

The proximate analysis and pH analyses of cured cooked beef product were carried out following the procedure described by [25].

Lipid oxidation

The thiobarbituric acid reactive substance (TBARS) assay was used to determine the lipid oxidation of the cured cooked beef following the procedures of [26] while vitamins and minerals content of cured cooked beef were determined following the procedures described by [27].

Microbiological analysis of cured cooked beef

The microbial loads of cured cooked beef samples were determined following the procedures described by [28–30].

Sensory evaluation of cured cooked beef

The sensorial properties of cured and cooked beef were evaluated following the procedures described by [31]. The 10 panelists were involved from among the students and staff of Animal Production Department, Olabisi Onabanjo University, Ayetoro campus. They were instructed to the extent of content of the forms they would complete about the cured cooked beef, and were provided with unsalted biscuits and water for taste perception refreshing in between the cured cooked beef samples degustation. Samples from each treatment were given sequentially to the taste panelists. Samples were served on clean saucers and were evaluated independently. The panelists rated the cured cooked beef samples for its colour, flavour, tenderness, juiciness, texture and overall acceptability on a 9-point hedonic scale on which 1 = extremely dislike and 9-extremely liked.

Statistical analysis

Data collected from this study were subjected to analysis of variance (ANOVA) using [32], and the significant differences between means were separated with Duncan multiple range test of the same analytical tool at $p < 0.05$.

Results

The results of physical properties of cured cooked beef affected by replacement of nitrite in brine with ginger powder are shown in Table 2.

Table 2. Physical properties of cured cooked beef as affected by nitrite replacement with ginger in brine

Variable (%)	Treatments					
	T_0 (control) (*N*)	T_1 (*GG*) (10%)	T_2 (*GG*) (15%)	T_3 (*GG*) (20%)	T_4 (*GG*) (25%)	SEM
Cooking loss	17.50^a	18.00^a	17.24^a	15.60^b	18.05^a	1.05
Cooking yield	82.50^b	82.00^b	82.76^b	85.40^a	81.95^b	1.12
Thermal shrinking	15.39^a	17.00^a	13.85^c	11.44^d	17.10^a	0.88
WHC	66.50^b	63.80^c	67.07^b	68.75^a	63.26^c	1.08

a, b, c, d — means on the same row with different superscripts are statistically significant ($p < 0.05$);
***N* = nitrite, *GG* = ginger, WHC = water holding capacity, SEM-standard error of the means of proximate analysis, TBARS and pH.**

Cooking loss

There were significant differences ($p < 0.05$) in the values of cooking loss beyond the levels of nitrite replacement with ginger powder in comparison between the control T_0 and other treatments that featured higher cooking loss values than T_3.

Cooking yield

Cooking yield of cured cooked beef values had similar patterns like cooking loss. Treatment 3 with 20% ginger powder featured the higher (85.4%, $p < 0.05$) cooking yield than other treatments which showed less yield of cured cook beef.

Thermal shrinking

Cured cooked beef in treatment 3 exhibited lowest value (11.44%, $p < 0.05$) of thermal shrinking in cured beef during cooking (baking) while shrinking value was higher ($p < 0.05$) in T_1 and T_4, this was more than it was observed in T_0, T_2 and T_3 respectively.

Water-holding capacity

Cured and cooked beef in T_3 had higher ($p < 0.05$) water holding capacity than in other treatments with 68.75% value, while treatments 1 and 4 had the least ($p < 0.05$) values of 63.26 and 63.80 respectively. Table 3 shows the results of proximate TBARS and pH analysis.

Moisture content

The value of moisture content of cured cooked beef was lower ($p < 0.05$) in T_0 (59.23%) compared with other treatments, while the value of moisture was higher ($p < 0.05$) in T_1 (67.13%) and decreased down from T_2 to T_4 as the level of ginger powder inclusion in the brine solution increased.

Crude protein

The crude protein value was lower ($p < 0.05$) (16.73%) in T_0 compared with treatments T_1 and T_2, while T_3 and T_4 had higher ($p < 0.03$) protein values, as the values of moisture decreased

Fat content

The value of fat was higher ($p < 0.03$) in T_0, and was lower in T_1, T_2 and T_3, while it was high in T_4 with value similar to the values obtained in other treatments, except for T_3.

Ash content

Cured cooked beef in control sample treatment (T_0) had lower ($p < 0.05$) ash content, while this value increased from T_1 to T_4 with the last two treatments featuring the highest ($p < 0.03$) values of 3.85 and 3.90% respectively.

Nitrogen free extract (NFE)

The control sample (T_0) treatment had highest ($p < 0.03$) nitrogen free extract (NFE) value of 26.26% followed by T_1 and T_3, while T_2 and T_4 had the lowest ($p < 0.05$) values.

Thiobarbituric acid reactive substance (TBARS)

The TBARS value was higher ($p < 0.05$) values in control sample (T_0) and T_1 with 0.05 mg/100g, and decreased down to 0.04 mg/100g in T_2, and further decreased to 0.03 mg/100g in T_3 and T_4 as the level of ginger powder increased in the brine solution. The pH was higher ($p < 0.05$) in T_1 to T_4, and lower ($p < 0.05$) in T0 with the value of 5.20 though the values still fell within same scale of alkalinity.

Mineral and vitamins

The results of some minerals and vitamins composition of cured, cooked beef are presented in Table 4. The results on minerals showed that the values of the elements increased as the percentage of ginger inclusion in the brine solution increased, and was lowest ($p < 0.03$) in T_0 (*N* control) except for sodium, which content was highest ($p < 0.05$) in T_0.

The results of all vitamins content observed in the cured cooked beef processed with ginger in brine solution instead of nitrite showed that the values of vitamins were lower ($p < 0.05$) in T_0 than in other treatments, and it increased across the treatments from T_1 to T_4 as the percentage of ginger inclusion in the brine solution increased.

Microbial load

Table 5 presents the results of the microbial loads of cured and cooked beef processed with ginger in brine instead of nitrite solution.

All the microbial counts of thermophilic organisms and others were higher ($p < 0.05$) in T_0 than in treatments T_1 to T_4 and the organisms load also decreased as the percentage of ginger in the brine increased.

Table 3. Proximate composition TBARS and pH of cured cooked beef as affected by nitrite replacement with ginger in brine

	Variable Treatments					
	T_0 (control) (*N*)	T_1 (*GG*) (10%)	T_2 (*GG*) (15%)	T_3 (*GG*) (20%)	T_4 (*GG*) (25%)	SEM
Moisture (%)	59.23^e	67.13^a	65.3^b	64.26$^{c`}$	62.24^d	0.86
Crude protein (%)	17.73^c	18.02^c	20.22^b	22.86^a	23.46^a	0.22
Ether Extract (fat)	5.47^a	5.45^a	5.32^a	4.20^b	4.10^b	0.12
Ash (%)	1.21^c	2.40^b	2.67^b	3.85^a	3..90^a	0.08
NFE (%)	26.26^a	7.00^b	5.45^c	6.03^b	4.98^c	0.13
TBARS (mg/100g)	0.05^a	0.05^a	0.04^b	0.03^c	0.03c	0.05
pH	5.20b	6.20^a	6.25^a	6.30^a	6.35^a	0.04

a, b, c, d, e — means on the same row with different superscripts are statistically significant ($p < 0.05$);
N = nitrite, *GG* = ginger, NFE = nitrogen free extract, TBARS = thiobarbituric acid reactive substances, SEM = standard error of the means with different superscripts are statistically significant ($p < 0.05$).

Table 4. Content of particular minerals and vitamins in cured beef as effected by replacing nitrite with ginger in brine

	Variable Treatments					
	T_0 (control) (*N*)	T_1 (*GG*) (10%)	T_2 (*GG*) (15%)	T_3 (*GG*) (20%)	T_4 (*GG*) (25%)	SEM
Minerals						
Calcium (mg/100 g)	8.20^d	10.26^c	12.05^b	13.67^a	13.84^a	0.28
Magnesium (mg/100 g)	0.25^c	0.28^b	0.30^b	0.43_a	0.45^a	0.07
Sodium (mg/100 g)	104.30^a	93.34^b	90.78^c	87.90^d	85.44^e	0.88
Phosphorus (mg/100 g)	106.00^d	123.66^c	126.05^b	133.08^d	132.60^a	1.04
Iron (mg/100 g)	1.52^d	2.87^c	4.67^b	6.55^d	6.52^a	0.26
Zinc (mg/100 g)	2.34^d	4.59^c	5.70^b	6.98^a	6.75^a	0.16
Vitamins						
Vit. C (mg/100 g)	15.20^d	22.43^c	25.55^b	31.67^a	32.50^a	0.55
B-carotene (ug/100 g)	0.10^d	0.81^c	0.95^b	3.10^a	3.15^a	0.21
Niacin (mg/100g)	10.70^d	13.13^c	16.25^b	19.37^a	19.60^a	0.52
Riboflavin (mg/100 g)	0.08^e	0.13^d	0.15^c	0.18^b	0.20^a	0.01
Thiamine (mg/100 g)	0.15^e	0.17^d	0.19^c	0.21^b	0.22^a	0.02

a, b, c, d, e — means on the same row.

Table 5. Microbial load of cured beef as affected by replacing nitrite with ginger in brine

	Variable Treatments					
	T_0 (control) (*N*)	T_1 (*GG*) (10%)	T_2 (*GG*) (15%)	T_3 (*GG*) (20%)	T_4 (*GG*) (25%)	SEM
TVC (CFU/ml)	4.50^a	3.90^b	3.60^b	2.80^c	2.50^c	0.01
TCC (CFU/ml)	5.70^a	4.50^b	3.30^c	3.00^c	2.40^d	0.02
TFC (CFU/ml)	4.60^a	3.20^b	3.00^b	2.00^c	1.10^c	0.06
TSC (CFU/ml)	3.40^a	3.05^a	2.10^b	2.07^b	1.05^c	0.02
TECC (CFU/m)	3.10^a	2.40^b	2.21^b	1.80^c	1.60^c	0.04

a, b, c, d — means on the same row with different superscripts are statistically significant ($p < 0.05$);
N = nitrite, *GG* = ginger, TVC = Total viable counts, TCC = Total Coliform Counts, TFC = Total Fungal Counts, TSC = Total Salmonella Counts, TECC = Total E. Coli Counts.

Sensory properties

The results of sensorial properties of cured, cooked beef prepared with ginger in brine instead of nitrite are shown in Table 6.

Colour

The results of assessment of the colour of cured cooked beef showed that T_0 had the lowest ($p < 0.05$) score while T_3 and T_4 had the highest one, while similar colour values were recorded for T_1 and T_2. Colour of the product was observed to have increased in intensity as the level of ginger in brine increased against nitrite.

Flavour

The scores of flavour for T_0, T_1 and T_4 were similar and lower ($p < 0.05$) than the scores of the product in T_2 and T_3. Increase in flavour score was observed in cured cooked beef in correlation with increasing the level of ginger in brine solution.

Tenderness

The cured, cooked beef in treatment 4 had highest ($p < 0.05$) tenderness score followed by that in T_3, while T_0 featured the lowest ($p < 0.05$) score for tenderness. The trend in tenderness of the product showed that it increased as the percentage level of ginger increased in the brine solution.

Juiciness

The scores for juiciness of cured, cooked beef product for T0, T_1 and T_2 were similar, but lower ($p < 0.05$) than the scores for T_3 and T_4. However, the score for juiciness was higher in T_3 compared with T_4.

Texture

The results for the texture of cured, cooked beef indicated that the score was lower ($p < 0.05$) in T_0 than in other treatments while the score was higher in T_3 than in T_4. Also, the product texture scores were similar for T_1, T_2 and T_4, but lower than the textural score for the product of T_3.

Table 6. Organoleptic profile of cured beef as affected by replacing nitrite with ginger

	Variable Treatments					
	T_0 (control) (*N*)	T_1 (*GG*) (10%)	T_2 (*GG*) (15%)	T_3 (*GG*) (20%)	T_4 (*GG*) (25%)	SEM
Colour	4.00^c	5.00^b	5.00^b	6.00^a	6.00^a	0.05
Flavour	5.50^c	5.70^c	6.70^b	7.75^a	5.60^c	0.04
Tenderness	4.30^d	5.45^c	5.57^c	6.70^b	7.79^a	0.03
Juiciness	5.00^c	5.30^c	5.43^c	7.50^a	6.35^b	0.03
Texture	4.30^c	5.43^b	5.55^b	6.90^a	5.80^b	0.04
OA	5.20^c	6.50^b	6.55^b	7.65^a	5.50^c	0.02

a, b, c, d — means on the same row with different superscripts are statistically significant ($p<0.05$);
N = nitrite, *GG* = ginger, OA = Overall Acceptability, SEM = Standard errors of the means.

Overall acceptability

The score for overall acceptability of cured, cooked beef was higher ($p < 0.05$) in T_3 followed by scores in T_1 and T_2, and the least score was recorded ($p < 0.03$) in T_0 and T_4.

Discussion

Meat curing with plain salt has been used to preserve meat and meat from the immemorial time [33]. There are four methods of meat curing, which include dry curing, wet curing which is also called brine curing, combination of dry curing and sausage curing, and predominantly salt and nitrate/nitrite are used for the curing process. Meat curing could lead to change in the physical properties of the meat sample during cooking [34]. These include cooking loss, yield, thermal shrinking and water holding capacity.

The previous researchers opined that lower cooking loss and thermal shrinking contributed to higher cooking yield due to greater water-holding capacity and moisture [20–24,35]. Crude protein in cured, cooked beef was lower in T_0 compared with other treatments with ginger inclusion. A inverse linear correlation was observed between moisture content and protein content in the cured, cooked beef such that as moisture content decreased protein content increased, which was high but similar in T_3 and T_4. This could be due to addition of protein in ginger to the cured, cooked meat [36]. These results were in agreement with the findings of [4] who reported that crude protein increased in opposite to decrease in moisture content of cured turkey drumsticks. Inclusion of ginger as replacement of nitrite in the brine could be responsible for decrease in fat content of cured, cooked beef at higher levels of T_3 and T_4. Also, the ash or mineral contents of cured, cooked beef increased, while the thiobarbituric acid reactive substances assay (TBARS) results revealed that lipid oxidation values decreased as the level of ginger inclusion in the curing solution increased, thus showing that ginger is potent enough to hinder lipolysis in the cured, cooked beef, especially in T_3 and T_4 respectively. These results were similar to the report of [37] on protein and lipid oxidation in meat, and [36] on the effect of ginger rhizome powder addition and storage time on the quality of pork. The pH of cured, cooked beef probably due to ginger inclusion in the curing solution was acidic in T0 showing the characteristic of nitrite, while the pH increased from T_1 to T_4 depicting the alkaline nature of ginger in the curing solution. This pH value in T_1 to T_4 could predispose the cured, cooked beef to microbial attack due to high water content as it was demonstrated with the value of moisture content of the product as reported by [38].

Vitamins and minerals are very important in human diets for their playing various roles in human metabolism, growth and maintenance [39]. The results of mineral and vitamins composition of cured, cooked beef revealed that those beef samples cured with ginger contained more minerals and vitamins. This could be explained by the fact that ginger is very rich in minerals and vitamins, and these might have been added to the inherent mineral and vitamin elements in beef thereby more enriching the product. The microbial load profile of cured, cooked beef indicated that the value of the microbes decreased as the level of ginger inclusion in the brine solution increased across the treatments, with the lowest record of total *Escherichia coli* and *Salmonella enteritidis* and the figures for total viable microbes count, coliform and fungal counts did not exceed the permissible and recommended levels in any meat products [12] which made the cured, cooked beef safe and wholesome for consumption. The organoleptic profile of cured, cooked beef processed with ginger in brine instead of nitrite showed that ginger improved the colour of cured, cooked beef as the score of colour assessment got increased as the level of ginger in the cured, cooked beef increased, and got to the peak at both treatments T_3 and T_4. The cured, cooked beef tenderness had similar scores as the colour which increased as the level of ginger inclusion in the brine solution increased, with T_4 reaching the highest score. However, treatment 3 had the highest scores for flavor, juiciness, texture and overall acceptability which made cured, cooked beef in T_3 the best sort assessed by the sensory panelists in this study. The acceptability of any meat product greatly depends on colour, flavour, juiciness and texture which are influenced by water holding capacity of the meat product [4,40,41]. Therefore, as the above characteristics were very high in the cured, cooked beef processed with ginger in brine solution hence ensuring panelists' high acceptability of the product especially T_3.

Conclusion

The application of ginger as replacement of sodium nitrite in brine solution to cure beef proved to be significantly effective, the cooking yield and water holding capacity were higher, while cooking loss and thermal shrinking of the product were relatively low; proximate analysis, TBARS and pH of the product were appropriate, the vitamins and minerals were not abysmally lost in the products, while the microbial load values were not above the recommended values; the organoleptic profile of cured, cooked beef featured high consuming qualities in the treatment 3 demonstrating the highest characteristics. Therefor it was recommended that ginger at 20% could be used to replace sodium nitrite in brine solution for curing beef without any detrimental effect on the consumers' health.

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