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Original scientific paper

Rheological, sensorial, and textural properties of ingredient-mix based dried beef product (*Kilishi*)

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A b s t r a c t: As a ready-to-eat (RTE) meat product, Kilishi is gaining increasing popularity within Africa. Only experienced persons make Kilishi products, and improving the production process using comminuted meat production/technology can enhance the products' quality and uniformity. In line with this, the rheological (elastic modulus, viscosity, and rupture strength), textural (hardness, springiness, cohesiveness, and chewiness), and sensorial (taste, color, texture, aroma, and overall acceptability) properties of ingredient-mix based Kilishi sausage were measured. Traditional Kilishi as a control was compared with seven other comminuted Kilishi products (CK1-7) of different ingredient-mix ratios. Comminuted Kilishi products obtained higher values for textural characteristics compared to the traditional Kilishi. Results indicated that CK7 had the highest elastic modulus (E_o, E_1, and E_2) and rupture strength (18.95 N), while CK2 had the lowest of these values amongst the comminuted Kilishi products. However, TK was more viscous (2.09×10^6 Pas), yet had the lowest rupture strength (6.85 N). Sensorially, the panel rating for overall acceptability showed CK2 achieved the highest score (7.02) which is indicative of its degree of preference. Both rheology and texture strongly correlated ($p<0.05$) with one or more sensorial attributes. The ingredient-mix ratios and degree of exposure to heat treatment significantly influenced the rheological, textural, and sensorial properties of Kilishi. Compared to traditional Kilishi, CK2 appears very promising as it was more preferred by panelists, and among the comminuted Kilishi, CK2 had the most favorable textural and rheological attributes, and had the lowest ingredient-mix ratio, which is indicative of lower production costs than the other comminuted Kilishi products. The comminution technique and use of precise ingredient-mix ratios can provide added value in the Kilishi processing industry.

***Keywords:** beef meat; ingredient-mix; rheology; comminuted meat; sensory; texture*

Introduction

Consumer demand and increasing competition are making meat product manufacturers around the globe embrace new processing methods and ingredient systems (*Weiss et al*., 2010). Across the West Africa sub-region for example, ready-to-eat (RTE) meat products such as roasted and fried beef, or chicken meat, are increasingly popular, largely prepared and sold for consumption either immediately or at a later time, without needing further processing (*Roger et al.,* 2015). A typical example of a RTE meat product is *Kilishi*, which *Olagunju and Taiwo* (2020) considered an increasingly popular street food, with its consumption extending to other parts of Africa. *Seini et al.* (2018) reported that *Kilishi* is not only of artisanal activity and traditionally manufactured, but is typically made from beef meat, dried and grilled into strips, and seasoned with spicy peanut paste. *Seydou et al.* (2019) reported *Kilishi* as either coated or uncoated. The coating involves trimming meat, cut into a parallel pipe shape prior to it being sliced into flat thin sheets, then sun-drying and marinating in complex blended spiced sauce, followed by a second sun-drying, and grilling. The uncoated *Kilishi* is sun-dried meat, slightly seasoned and grilled. Additionally, *Kilishi* is usually prepared and packaged at the point of consumer purchase.

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Specifically, *Kilishi* processing by percentage has slightly less of the meat, but more of the non-meat ingredients (i.e., condiments, spices, etc.). Notwithstanding, the methods of *Kilishi* production (*Badau et al.,* 1997; *Igene et al.,* 1990; *Igene et al.,* 1993; *Yaou et al.*, 1986) and the condiments and spices used (*Nkama et al.,* 1994) appear well established. However, *Kilishi* quality can still vary, even from the same producer (*Igene*, 1988). It was to standardize the non-meat ingredient portion that *Badau et al.* (1997) developed an instant standard ingredient, a groundnut-cake powder, which at that time, improved the overall acceptability/yield and simplified *Kilishi* production. On the other hand, the development of meat processing technology has advanced, particularly over recent years. Through a wide range of methods/procedures, the *Kilishi* processing technology has adopted modifications that help the attainment of desirable properties (*Hidayat et al*., 2017; *Savic*, 1985). Neither the meat or spice formula, however, can serve as a means to classify this type of product. This is because the many formulations can include (similar) combinations of diverse meat and seasoning types. Seasonality in raw material supply, therefore, can bring about periodic differences in the proportions of various meat types and spices employed (*Savic*, 1985). In addition, despite the complex interactions/matrix, comminuted meat systems can provide an environment where the constituent chemical and physical properties would determine the ultimate stability of the product (*Acton et al.*, 1983). Comminution refers to a procedure of reducing a material, to achieve a fine particulate state. The ultimate purpose is to realize a stable comminuted meat matrix (*Acton et al.,* 1983).

Rheological, sensorial, and textural considerations can help establish consumer acceptability of meat products. For example, when a slice of meat or meat product is subjected to heat treatment, the muscle protein obviously denatures. This result is the situation where the myosin converts from its soluble into the gel state. Such (above-mentioned) texture-related contexts (specific to heated-impacted meat muscles) are equated by consumers with cooked meat. Equally, rheological, sensorial, and textural considerations can help in defining the eating quality of meat/comminuted meat (*Hui*, 2012). In the mouth specifically, the texture feel of meat products can be represented by such descriptors as adhesion, mealiness, hardness, rubberiness, etc. (*Hui*, 2012). The hardness, for example, can help to determine not only the commercial value but also consumer acceptance of a meat product (*Caine et al.*, 2003; *Girard et al.*, 2012). Rheological behavior of meat products can be studied through mechanical methods like compression, shear, tension, and torsion. Texture profile analysis (TPA) (compression) and *Warner Bratzler* (shear) tests are two instrumental approaches most commonly used (*Romero de Ávila, et al.*, 2014). The relationship(s) between textural and structural changes in food products, especially those that take place during processing, are unraveled through analyzing the deformation and flow of matter, which has always been underscored by rheological principles (*Gao et al.,* 2003*; Sun,* 2006*; Janmey and Schliwa,* 2008).

Specific to the *Kilishi* product, however, the process of making it still remains rather complicated and time-consuming. Deemed artisanal, experienced persons are necessary to perform the intricacies involved in the making of *Kilishi*, especially when it comes to both the curing and slicing steps. Most likely, improving the production process should help to enhance both the quality and uniformity of the *Kilishi*. The use of ground meat, which resembles those employed in comminuted meat production/technology, could serve as a promising start/pathway. Therefore, the specific objective of the current study was to investigate the rheological, textural, and sensorial properties of ingredient-mix based comminuted *Kilishi* product.

Materials and methods

Schematic overview of study

The schematic overview of the experimental program, showing the major stages from the procurement of meat to laboratory analyses, is presented in Figure 1. Traditional *Kilishi* (TK) served as a control and was compared with seven other comminuted *Kilishi* products (CK1-7) that were composed of different ingredient-mix ratios. Rheological measurements determined the elastic modulus, viscosity, and rupture strength. Textural measurements determined hardness, springiness, cohesiveness, and chewiness. Sensorial measurements determined taste, color, texture, aroma, and overall acceptability. Triplicate measurements were performed for all analyses *via* simple random sampling of the *Kilishi*. All laboratory experiments had institutional approval and followed standard procedures/protocols, which were made up of relevant guidelines and regulations, as found in published references.

Procurement of raw materials

Fresh beef muscles were procured from the central abattoir, Owerri, Imo State, Nigeria. The components used to make the ingredient-mix (spices, groundnut paste, onion, garlic, sugar, salt, and bullion cubes) were procured from the Owerri market, Imo State, Nigeria. These above-mentioned procurements are consistent with those previously described by *Iheagwara and Okonkwo* (2016).

Sample preparation and processing

Meat preparation

The beef meat for the evaluative study had its excess fat, bones, and connective tissue removed and thereafter was washed thoroughly in salted water. The bulk was cut into eight portions, each of which was evenly milled and/or sliced into thin strips of 1 mm thickness. The sliced portion was used for the TK, which served as the control, while the remaining seven portions were used to produce the comminuted *Kilishi* (CK1-7).

Preparation of infused ingredients

The infused ingredients were ginger, alligator/black/red/sweet peppers, onion, garlic, African nutmeg, groundnut paste, Magi seasoning, salt, sugar, and water, as presented in Table 1. These ingredients are well known to be used by the artisans who make *Kilishi* across Nigeria. Preparation of TK followed the exact measurements obtained from an artisanal producer. The purpose of the different ingredient-mix ratios was to reflect the variants practically in use by various *Kilishi* artisans in Nigeria. That is based on the practical assumption that the *Kilishi* of

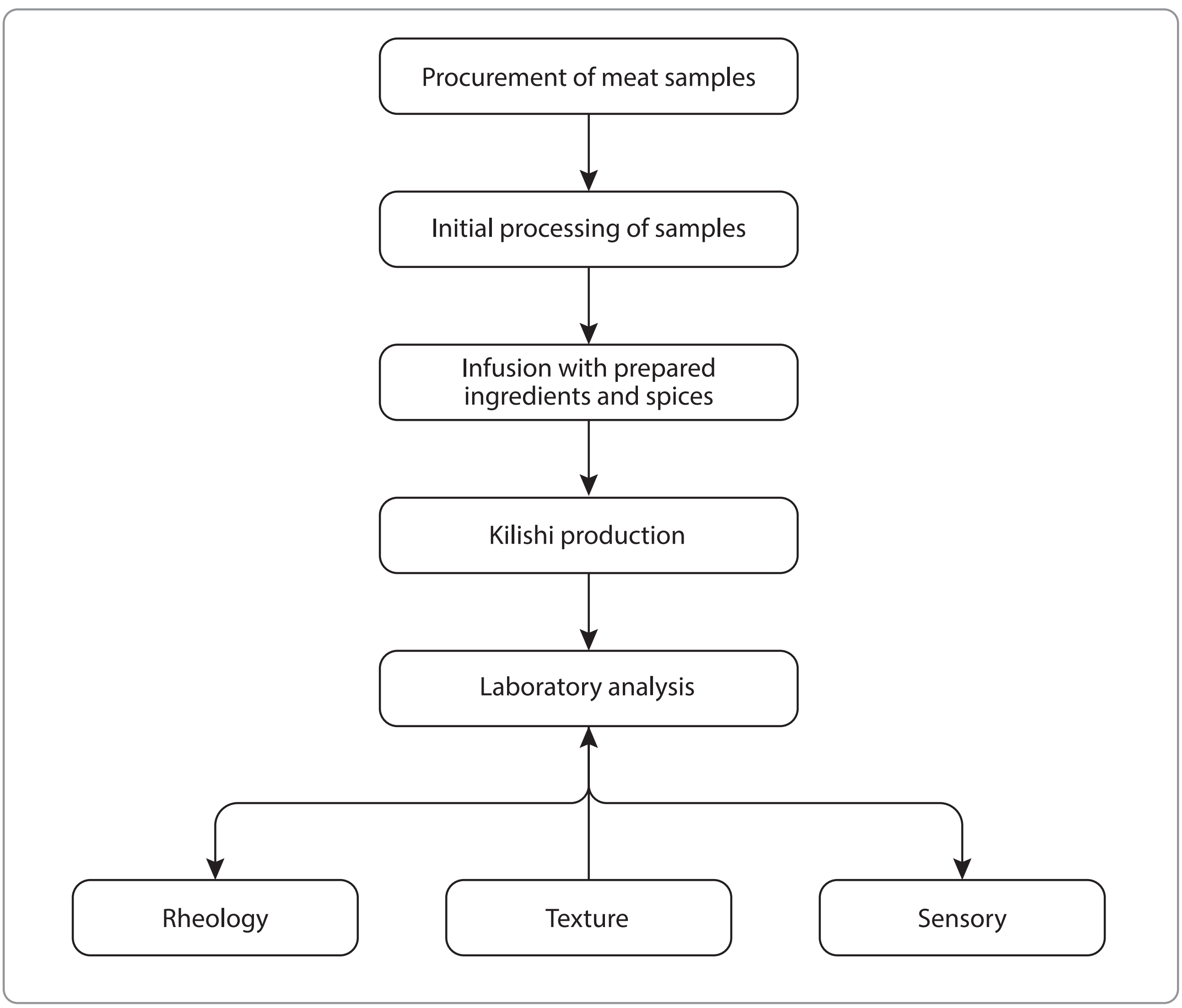

Figure 1. Schematic overview of the experimental program, showing the major stages, from meat procurement to laboratory analyses

an artisan A will not be exactly the same as B, even if they produce side-by-side in the same location.

Preparation of *Kilishi*

TK was prepared by subjecting the thin meat in strips of 1 mm thickness to pre-drying treatment in a hot air oven (Genlab, England, Model M 30 C, S/N 92B060) at 60°C for 3 h. The dried thin meat strips were infused in the ingredient-mix that was previously made to a slurry with water (*Igene*, 1988), as presented in Table 1, and allowed to soak for 30 min. Subsequently, the TK were dried at 60°C for 5 h.

To prepare the comminuted *Kilishi* products, the raw meat was milled together with the infusion ingredient-mixes with different ingredient ratios as presented in Table 1, and molded into flat sheets of 1 mm thickness to generate various comminuted *Kilishi* (CK1-7) (*Iheagwara and Okonkwo*, 2016). Subsequently, the *Kilishi* were dried at 60°C for 5 h.

Following the drying treatment, all *Kilishi* were roasted in a smoking kiln at 100°C for 5 min, to impart aromatic flavor and phenolic compounds with preservative effect. This was then followed by cooling at ambient temperature (28±2°C), and subsequent storage until required for analytical (rheological, textural, and sensorial) measurements.

Determination of rheological, textural, and sensorial properties of Kilishi

The determinations of the studied rheological, textural, and sensorial properties of *Kilishi* were carried out at the Meat Science Laboratory, Department of Animal Science, University of Ibadan, Nigeria. The rheological properties studied were elastic modulus, viscosity, and rupture strength, the textural properties were hardness, springiness, cohesiveness, and chewiness, and the sensorial properties were taste, color, texture, aroma, and overall acceptability.

Determination of rheological properties

Stress relaxation measurement was carried out on the *Kilishi* using a texture analyzer (TMS-PRO Texture Analyzer, Food Technology Corporation, USA) at room temperature. Stress is the deformation force per unit area of the body or material, whereas strain with no dimensions, is expressed as relative change in shape or size of an object due to externally

Table 1. Composition of ingredient-mixes used in *Kilishi* preparation (g/100g)

Ingredients	TK	CK1	CK2	CK3	CK4	CK5	CK6	CK7
Ginger (*Zingiber officinale*)	3.30	3.30	2.81	2.97	3.14	3.47	3.63	3.80
Alligator pepper (*Afromomum meleguata*)	1.20	1.20	1.02	1.08	1.14	1.26	1.32	1.38
Black pepper (*Piper guineense*)	3.00	3.00	2.55	2.70	2.85	3.15	3.30	3.45
Red pepper (*Capsicum frutescens*)	2.00	2.00	1.70	1.80	1.90	2.10	2.20	2.30
Sweet pepper (*Capsicum annum*)	2.00	2.00	1.70	1.80	1.90	2.10	2.20	2.30
Onion (*Allium cepa*)	12.00	12.00	10.20	10.80	11.40	12.60	13.20	13.80
Garlic (*Allium sativum*)	0.50	0.50	0.43	0.45	0.48	0.53	0.55	0.58
African nutmeg (*Monodora myristica*)	1.00	1.00	0.85	0.90	0.95	1.05	1.10	1.15
Groundnut paste (*Arachis hypogea*)	31.50	31.50	26.78	28.35	29.93	33.08	34.65	36.23
Magi seasoning	1.50	1.50	1.28	1.35	1.43	1.56	1.65	1.73
Salt	3.00	3.00	2.55	2.70	2.85	3.15	3.30	3.45
Sugar	3.00	3.00	2.55	2.70	2.85	3.15	3.30	3.45
Water	36.00	36.00	30.60	32.40	34.20	37.80	39.60	41.40

Legend: TK – Traditional *Kilishi* (100% ingredients); CK1 – Comminuted *Kilishi* (100% ingirents); CK2 – Comminuted *Kilishi* (85% ingredients);CK3 – Comminuted *Kilishi* (90% ingredients); CK4 – Comminuted *Kilishi* (95% ingredients); CK5 – Comminuted *Kilishi* (105% ingredients); CK6 – Comminuted *Kilishi* (110% ingredients); CK7 – Comminuted *Kilishi* (115% ingredients) Source: *Iheagwara and Okonkwo* (2016) applied forces (*Hui*, 2012). At a constant strain of 0.02, *Kilishi* samples were compressed using a cylindrical probe (4.0 mm internal diameter) and when compression reached the maximum, the instantaneous modulus (E_0) was calculated from the load. The progressive approximate method described by *Saito et al*. (2002) was used to analyze the stress relaxation curve. The stress-relaxation approximate equation was expressed as follows:

$$\sigma(t) = e_0 \sum_{i=1}^{n} E_i \, exp\left({}^{-T}/_{T_i} \right) \qquad \text{Eq. 1}$$

Where is the stress at relaxation time, is the constant strain, T is the time, is the elastic modulus of the i-th element, and is the stress-relaxation time per *Kilishi* sample of the i-th element shown in Table 2. n_i which is related to the viscosity of the i-th element, n, and E is as shown in equation (2).

$$T_i = {}^{n_i}/_{E_i} \ldots\ldots\ldots\ldots\ldots.(2) \qquad \text{Eq. 2}$$

E_0 is defined as follows:

$$E_0 = E_1 + E_2 + \cdots \ldots + E_n \ldots\ldots\ldots..(3) \qquad \text{Eq. 3}$$

Table 2. Stress-relaxation time (seconds) of different processed *Kilishi*

Kilishi	T_1 (s)	T_2 (s)
TK	15.80	1.96
CK1	38.67	2.43
CK2	36.08	2.84
CK3	37.10	2.88
CK4	38.16	2.93
CK5	42.28	3.26
CK6	43.60	3.49
CK7	45.87	3.65

Legend: T_1 – Stress relaxation time of the first element; T_2 – Stress relaxation time of the second element

The rupture strength of the *Kilishi* was measured by the same texture analyzer at room temperature. *Kilishi* were compressed at the rate of 2.0 mm/s using a cylindrical probe (2 mm internal diameter), and the peak of the force-time curve was regarded as the rupture strength value.

Determination of sensorial properties

The sensorial properties of the *Kilishi* were determined by 30 trained panelists using the appropriate descriptors, consistent with the method previously described by *Carbonell et al., (2002)*. Importantly, informed consent was obtained from all panelists prior to their participation in the sensory analysis. Briefly, the sensory evaluation procedure started with the sensory descriptors of taste, color, texture, and aroma, which were provided to the trained panelists. The sensory descriptors were designated with a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely), which would help the panelists to identify the characteristic changes in the taste, color, texture, and aroma of the studied *Kilishi*. The overall acceptability, computed as the average score of the sum of taste, color, texture, and aroma, was also determined.

Determination of textural properties

The texture profile analysis (TPA) of the *Kilishi* was carried out using the same texture analyzer (above). Specifically, the double compression cycle test was carried out according to the following procedure: a) cylindrical probe = 4 mm internal diameter; b) final strain = 0.05 time interval between the first and second compression at 5 s. The pre-speed, test-speed and post-speed were 0.5 mm/s, 1.0 mm/s and 5.0 mm/s, respectively. The following measurements were elucidated through the TPA parameters: a) Hardness (N) refers to the peak force in the first compression cycle; b) Springiness (dimensionless) refers to the ratio of the length duration of the force input during the second compression to that during the first compression; c) Cohesiveness refers to the ratio of the positive force area during the second compression to that during the first compression; and d) Chewiness (N) refers to the product of hardness, springiness, and cohesiveness (*Caine et al*., 2003; *Duan et al*., 2010).

Statistical analysis

Using boxplots, as well as Levene's, and Shapiro-Wilk tests, the analysis of variance (ANOVA) assumptions considered outliers, homogeneity of variances, and normality (*Ofoedu et al*., 2020). One-way ANOVA was applied to data obtained from triplicate measurements, with results expressed as mean ± standard deviation (SD). Fisher's least significant difference (LSD) was used to resolve mean differences. Whether positive (directly related) or negative (indirectly related), and by a coefficient (r) and probability (p) value (*Okpala and Bono*, 2016), correlation tests aim to establish how strong one variable moves in relation to another (*Mat Roni et al.*, 2020). When correlation was examined, Pearson's test was applied to see how the tested parameters moved with each other, regardless of different ingredient-mix ratios. Probability level of statistical significance was set at $p<0.05$. IBM SPSS software version 20 (IBM Corporation, New York, USA) was used to do the analysis.

Results and discussion

Rheological properties

The rheological properties (i.e., elastic modulus, viscosity, and rupture strength) of the different *Kilishi* are depicted in Table 3. The elastic modulus, viscosity, and rupture strength of TK significantly differed ($p<0.05$) compared to CK1-7. The E_0, E_1, and E_2 values for all *Kilishi* were within the ranges of 2.02–3.86 × 10^5 Pa, 0.96–1.82 × 10^5 Pa, and 1.18–1.69 × 10^5 Pa, respectively. Specifically, the elastic modulus (E_0, E_1, and E_2) values of TK were less than those of CK1-7. However, there was a somewhat increasing trend in the elastic modulus across CK 1-7, although with somewhat decreasing trends across E_0, E_1, and E_2 values. Specifically, the elastic modulus (E_0, E_1, and E_2) was highest in CK7 compared to the other *Kilishi*, while CK2 had the lowest elastic modulus amongst the comminuted *Kilishi*. In this context, the elastic modulus is the amount of resistance to deformation given by the dried meat products to an applied stress. The lower elastic modulus in TK could be as a result of its structural arrangement in fibrous protein strands (*Arfat and Benjakul*, 2012; *Cobos and Di*az, 2014), unlike CK1-7 with their micro-particulate aggregate structural network. The low elastic modulus in TK could indicate stiffening when exposed to small stresses and softening when exposed to larger stresses. In the same vein, the network configuration of the comminuted *Kilishi* could be such that they are soft (compliant) under small stresses but much stiffer under larger stresses (*Hanmey and Schliwa*, 2008).

The viscosities η_1 and η_2 of all the *Kilishi* ranged between 0.56 and 2.09 × 10^6 Pa, and between 0.50 and 0.97 × 10^6 Pa, respectively. Principally (and *vice versa*), the elastic modulus should increase with a decrease in the elastic force (*Matumoto and Yamano*, 1987). As widely understood, an increase in viscosity (η) would occur with decrease in viscous force. This suggests the TK in the current study to be more viscous than the other *Kilishi* (CK1-7). Severe changes in texture are caused by loss of water-holding capacity and shrinkage of meat fiber, which leads to toughening of muscle tissue. The initial pre-drying (heat) treatment during the processing of TK likely caused denaturation and aggregation of proteins which resulted in low viscous flow, and hence, the high viscosity of TK. This corroborates the report of *Fellows* (2017) that solid food becomes more viscous during drying and can pass through series of rubbery and leathery states. The elastic modulus and viscosity

Table 3. Rheological properties of different processed *Kilishi*

Kilishi	E_o(x10^5Pa)	E_1(x10^5Pa)	E_2(x10^5Pa)	η_1(x10^6Pas)	η_2(x10^6Pas)	Rupture strength (N)
TK	2.02±0.01^h	0.96±0.01^f	1.18±0.01^g	2.09±0.01^a	0.67±0.01^a	6.85±0.01^h
CK1	3.63±0.01^d	1.68±0.01^c	1.50±0.01^d	0.83±0.01^c	0.75±0.01^{bc}	14.08±0.01^d
CK2	3.01±0.01^g	1.40±0.01^d	1.38±0.01^f	0.56±0.01^h	0.50±0.01^c	10.32±0.01^g
CK3	3.36±0.01^f	1.51±0.01^e	1.40±0.01^f	0.68±0.01^g	0.53±0.01^e	12.42±0.01^f
CK4	3.48±0.01^c	1.58±0.01^e	1.45±0.01^e	0.75±0.01^f	0.61±0.01^d	13.68±0.01^e
CK5	3.70±0.01^c	1.72±0.01^b	1.60±0.01^c	0.89±0.01^d	0.72±0.01^c	16.27±0.01^c
CK6	3.78±0.01^b	1.79±0.01^{ab}	1.63±0.01^b	0.94±0.01^c	0.79±0.01^b	18.08±0.01^b
CK7	3.86±0.01^a	1.82±0.01^a	1.69±0.01^a	0.98±0.01^b	0.83±0.01^b	18.95±0.01^a
LSD	**0.036**	**0.081**	**0.024**	**0.033**	**0.060**	**0.026**

Legend: $^{a\text{-}h}$ Means with different superscripts in a column differ significantly at $p<0.05$; E_0 – Instantaneous modulus when compression reached maximum; E_1 – Elastic modulus of first element; E_2 – Elastic modulus of second element; η_1 – Viscosity of the first element; η_2 – Viscosity of the second element attributes of *Kilishi* demonstrate elastic component/solid-like behavior and viscous component/fluid-like behavior, respectively. Interestingly, elastic moduli and viscosities are not constants but are functions of force, time, and direction of application of force (*Hanmey and Schl*iwa, 2008). Additionally, both elastic modulus and viscosity, as reported by *Sato et al.* (1995) and *Funami et al.* (1998), could closely associate with the texture.

The rupture strength of all the *Kilishi* ranged between 6.85–18.95 N, with CK7 having the highest (18.95N), and TK having the lowest (6.85N), but CK2 had the lowest rupture strength amongst the comminuted *Kilishi*. The rupture strength of *Kilishi*, specific to the context of this meat product, resembled that of heated sea cucumber meat (Liu et al., 2012). Generally, the higher rupture strength in CK1-7 compared to that of TK demonstrated the impact of the increased elastic component (elastic modulus) of the comminuted products. Possibly, the meat comminution into a matrix of micro-particulate aggregate (*Verdier,* 2003) and heating might have caused strong gel matrices by cross-linking of either protein-protein molecules, protein-lipid-protein molecules or even formation of protein bonds mainly due to hydrophilic interactions and covalent disulfide bonds (*Hashemi and Jafarpour*, 2016). The high rupture strength of CK7 (18.95 N) could suggest the muscle protein had aggregated and denatured, and subsequently dehydrated and shrunk (*Chen et al*., 2011). Besides the degree of cooking/heat application affecting meat toughness, it can markedly vary from muscle to muscle within an animal, as well as from point to point within the same muscle (*Bourne*, 2002). Additionally, the combined action of heating and variations in ingredient-mix ratios, especially in the salt content, could greatly influence the rupture strength of the *Kilishi* products. According to *Barbut and Mittal* (1990), salt reduction and increased heating rates enhances reduction in elastic modulus, resulting in lower rupture strength.

Sensorial properties

The sensory properties (i.e., taste, color, texture, and aroma) of the different processed *Kilishi* are shown in Table 5. The mean taste scores of all the *Kilishi* ranged between 6.82–7.30. CK2 obtained the highest taste score (7.30), whereas CK7 obtained the lowest taste score (6.82). The decrease in the taste mean scores from CK2 to CK7 might be attributed to the differences in the proportions of spices and other ingredients used. The color descriptions and preferences, according to the sensory panel, were significantly different ($p<0.05$) across the *Kilishi*. The color range was considered neither bright nor dark and was liked moderately. Specifically, the (mean) color score was highest for TK (7.00) and lowest for CK7 (6.13). The color differences among the *Kilishi* could be attributed to the milling technology adopted to produce the comminuted *Kilishi*. Color differences could also be attributed to various complex chemical reactions as a result of interactions of the ingredient-mix in the different ratios with the large surface area of comminuted meat (*Ogunsola and Omojola*, 2008). Interestingly, the nature and texture of the meat products significantly influenced *Kilishi* color, as colored compounds were trapped on the surface or enmeshed in the comminuted *Kilishi* of TK and CK1-7, respectively. For TK, with the highest colour score, it is possible that the infusion of thin meat strips in the slurry of ingredient-mix, over time, caused adsorption of colored components onto the meat surfaces. Subsequently, these compounds could be oxidized to produce a brown coloration, in addition to the formation of melanoidin compounds (*Osuji et al*., 2019; *Iwouno et al.*, 2019a; *Osuji et al.*, 2020; *Ofoedu et al.*, 2021) by the action of heat in the presence of sugar and protein. This could thereby impart a desirable brown coloration (*Okafor et al.*, 2018; *Iwouno et al.*, 2019b) compared to that of the comminuted *Kilishi*.

The sensorial texture of *Kilishi* depicts the mouthfeel during mastication, which might corroborate either the tenderness or toughness of the studied meat product. The sensorial texture of all the *Kilishi* differed significantly ($p<0.05$), which can be considered somewhat dependent on the differences in the ingredient-mix used as well as the size of the comminuted/sliced meat. Regarding the aroma score, CK2 had the highest (7.52) whereas CK7 had the lowest (6.53). This suggested that, as adjudged by the panelists, the 85% ingredient-mix utilization for CK2 was moderately liked compared with the less liked hot pungent aroma resulting from the ingredient-mix used for CK7. This aroma result agrees with some previously published data (*Jones et al.*, 2001). Furthermore, the highest overall sensory acceptability was achieved by CK2 (7.02), which was deemed completely acceptable. However, the lowest overall acceptability was given to CK7 (6.02), which indicates this *Kilishi* was the least liked. This could be attributed to its higher percentage of ingredient-mix (115%) which gave rise to higher contents of salt, sugar, seasoning, etc., thus making this *Kilishi* somewhat harsh for the panelists. Somewhat consistent with the argument of *Isah and Okubanjo*

(2012), the sensorial preferences for taste, colour, aroma, and texture of *Kilishi* in the current study would potentially influence consumers' overall acceptability. Based on the sensory evaluation, there is a high chance that both the ingredient-mix variation and the comminution of the beef meat influenced the rheological and textural characteristics of the various comminuted *Kilishi*. Increasing the percentage of ingredient-mix to 115% significantly influenced the rheological and textural characteristics of the comminuted *Kilishi*, which would also affect their sensory properties.

Textural properties

The textural properties (i.e., hardness, springiness, cohesiveness, and chewiness) of different processed *Kilishi* were examined, as shown in Table 4. There were significant differences (p<0.05) in the studied textural properties. Specifically, the

Table 4. Textural property analysis of different processed *Kilishi*

Kilishi	Texture parameters			
	Hardness (N)	Springiness	Cohesiveness	Chewiness (N)
TK	10.97±0.01^{h}	0.38±0.01^{d}	0.37±0.01^{d}	10.50±0.01^{h}
CK1	29.36±0.02^{d}	0.50±0.01^{e}	0.58±0.01^{c}	19.00±0.01^{d}
CK2	25.58±0.02^{g}	0.40±0.01^{d}	0.53±0.01^{c}	15.13±0.01^{g}
CK3	26.40±0.01^{f}	0.42±0.01^{cd}	0.55±0.01^{c}	16.30±0.01^{f}
CK4	28.64±0.02^{e}	0.48±0.01^{ce}	0.57±0.01^{c}	17.97±0.01^{e}
CK5	32.56±0.01^{c}	0.58±0.01^{b}	0.65±0.01^{b}	22.14±0.01^{c}
CK6	33.92±0.01^{b}	0.67±0.01^{a}	0.70±0.01^{b}	23.18±0.01^{b}
CK7	34.94±0.02^{a}	0.72±0.01^{a}	0.78±0.01^{a}	25.04±0.01^{a}
LSD	0.035	0.078	0.053	0.042

Legend: $^{a-h}$ Means with different superscripts in a column differ significantly at p<0.05

Table 5. Mean sensory scores of different processed *Kilishi*

Kilishi	Sensory parameters				
	Taste	Colour	Texture	Aroma	Overall acceptability
TK	6.80±0.41^{f}	6.13±0.30^{e}	6.15±0.40^{b}	6.05±0.42^{f}	6.53±0.37^{f}
CK1	7.05±0.33^{d}	6.58±0.41^{d}	6.13±0.24^{c}	6.15±0.33^{e}	6.67±0.40^{d}
CK2	7.30±0.52^{a}	6.53±0.43^{d}	6.15±0.30^{bc}	6.53 ±0.43^{a}	7.02±0.39^{a}
CK3	7.18±0.43^{b}	6.78±0'31^{c}	6.25±0.42^{a}	6.42±0.35^{b}	6.83±0.32^{b}
CK4	7.10±0.42^{c}	6.84±0.40^{b}	6.12±0.33^{c}	6.31±0.44^{c}	6.78±0.41^{c}
CK5	7.03±0.30^{d}	6.83±0.37^{b}	6.08±0.28^{d}	6.16±0.32^{e}	6.58±0.38^{e}
CK6	7.00±0.33^{e}	6.98±0.46^{a}	6.00±0.26^{e}	6.23±0.38^{d}	6.40±0.28^{g}
CK7	6.82±0.41^{f}	7.00±0.47^{a}	5.58±0.41^{f}	5.82±0.41^{g}	6.02±0.36^{h}
LSD	**0.027**	**0.055**	**0.039**	**0.052**	**0.048**

Legend: $^{a-h}$ Means with different superscripts in a column differ significantly at p<0.05

hardness values of all the *Kilishi* ranged between 10.97 N and 34.94 N. The hardness was highest for CK7 (34.94 N) but lowest for TK (10.97 N). Furthermore, the high hardness of CK7 suggests the occurrence of structural changes as the muscle protein denatured (*Gao et al.,* 2002). However, the lower hardness of TK compared to comminuted *Kilishi* (CK1-7) could be a result of the greater exposure of TK to heat treatment, thereby causing more denaturation in its protein network. During drying (heat treatment) of the *Kilishi*, the myofibrillar proteins tend to coagulate, resulting in different degrees of structure rigidity and denaturation points. This corroborates the report of *Barbut and Mitta*l (1990) that slower or minimal heating produces more rigid myosin gels than does intense heat treatment. This implies that the highest hardness, measured in CK7, could be due to the combined effect of minimal heat treatment and high salt concentration in its ingredient-mix. In addition, the hardness range herein corroborates the hardness data reported by *Liu et al.* (2012), which ranged between 8.86 N and 32.58 N.

The springiness of all the *Kilishi* ranged between 0.38 and 0.72. Specifically, springiness was highest for CK7 (0.72), and lowest for TK (0.38). The springiness range of *Kilishi* herein also corroborates the data of *Liu et al*. (2012), who reported a springiness range of between 0.27 and 1.03 in sea cucumber meat heated at different temperatures. The cohesiveness of the *Kilishi* ranged between 0.37 and 0.78. Clearly, the most cohesive (0.78) was CK7 whereas the least cohesive (0.37) was TK, but CK2 had the least cohesiveness amongst the comminuted *Kilishi*. In addition, the cohesiveness of TK was significantly lower ($p<0.05$) than that of CK1-7. However, no significant differences between cohesiveness of CK5 and CK6 ($p>0.05$) were found, but CK7 was noticeably more cohesive ($p<0.05$) than CK1-6 (Table 4). It could be that the minimal heat treatment and high amount of salt in its ingredient-mix contributed to the more cohesive nature of CK7. Under slower or minimal heat treatment, proteins have enough time to unfold and interact with each other, thus enabling formation of a stronger gel matrix, which would result in higher cohesiveness. Previous studies have also recorded larger cohesiveness at lower treatment temperature or with minimal heat treatment and high salt content in meat batter (*Barbut and Mittal*, 1990).

Chewiness, well known as the net energy required to chew solid food to the point required for swallowing it, significantly differed ($p<0.05$) across all the *Kilishi*, with a range between 10.50 N and 25.04 N (Table 2). Specifically, the chewiness was highest in CK7 (25.04 N) and lowest in TK (10.50 N). The chewiness differences in the *Kilishi* could be attributed to the size of the comminuted/sliced particulates/meat pieces, heat treatment, and protein-water and protein-protein interactions that most likely occurred during drying given the high moisture and protein contents in the meat muscle (*Boggs et al.,* 1998). The comminuted *Kilishi* that were exposed to minimal heat treatment had significantly higher chewiness compared to TK. Similar to hardness, chewiness is also influenced by the mode/nature of heat treatment and salt concentration as reported by *Barbut and Mittal* (1990). Thermal processing should aim to ensure a desirable texture in a given food product. This is because during thermal processing, textural changes in food products do occur, where tissues might soften and render it (the food product) unacceptable to consumers (*Sun*, 2006).

Correlation outcomes

Correlation tests established how the rheological, textural, and sensorial properties of *Kilishi* moved together, regardless of the different ingredient-mix ratios (Table 6). The results showed a wide range of statistically significant ($p<0.05$) correlations, a lot more of which were positive than were negative. Furthermore, the rheological properties (elastic modulus, viscosity, and rupture strength) correlated the most with the textural and sensorial data, and were largely with positive coefficients, except for $\eta_1\times$Hardness, $\eta_2\times$Taste, $\eta_2\times$Texture, $\eta_2\times$Aroma, and $\eta_2\times$Overall acceptability. A closer look at Table 6 shows all the rheological and textural properties correlated with either one or more of the sensorial properties. *Bourne* (2002) asserted that none of the correlations between the (single) instrumental measurement derived from force-deformation curves and sensory data significantly improved on those already reported data. Despite this, and based on the correlation outcomes herein, there is a high chance that both the size of the meat resulting from comminution/slicing and the ingredient-mix variation in the current study might have influenced the rheological, textural, and sensorial characteristics of the *Kilishi*. As heat is applied to the meat product, the muscle protein denatures, and myosin changes from the soluble to the gel state. From this gel state perspective, the rheological parameters could, even at the point of fracture, be associated with the sensory outcomes of the meat products (*Hui*, 2012), which is very much applicable to the *Kilishi* products of the current study.

Table 6. Correlation analysis of rheological properties, textural properties and sensory properties of *Kilishi*

		E_0	E_1	E_2	η_1	η_2	Rupture strength	Hardness	Springiness	Cohesiveness	Chewiness	Taste	Colour	Texture	Aroma	Overall acceptability
Eo	Pearson Correlation	1	.994**	.934**	–.726*	.437	.930**	.985**	.754*	.910**	.918**	.155	.922**	–.443	–.113	–.306
	Sig. (2-tailed)		.000	.001	.042	.279	.001	.000	.031	.002	.001	.714	.001	.271	.790	.461
E1	Pearson Correlation	.994**	1	.963**	–.676	.510	.957**	.990**	.811*	.939**	.950**	.090	.917**	–.506	–.175	–.377
	Sig. (2-tailed)	.000		.000	.065	.197	.000	.000	.015	.001	.000	.832	.001	.201	.678	.358
E2	Pearson Correlation	.934**	.963**	1	–.513	.647	.989**	.959**	.925**	.985**	.997**	–.105	.895**	–.674	–.355	–.565
	Sig. (2-tailed)	.001	.000		.194	.083	.000	.000	.001	.000	.000	.805	.003	.067	.389	.145
η_1	Pearson Correlation	–.726*	–.676	–.513	1	.267	–.466	–.729*	–.177	–.514	–.458	–.769*	–.649	–.028	–.525	–.360
	Sig. (2-tailed)	.042	.065	.194		.523	.244	.040	.676	.192	.254	.026	.081	.948	.181	.381
η_2	Pearson Correlation	.437	.510	.647	.267	1	.673	.433	.830*	.607	.685	–.756*	.362	–.712*	–.847**	–.887**
	Sig. (2-tailed)	.279	.197	.083	.523		.067	.284	.011	.110	.061	.030	.378	.048	.008	.003
Rupture strength	Pearson Correlation	.930**	.957**	.989**	–.466	.673	1	.942**	.939**	.978**	.994**	–.161	.920**	–.669	–.381	–.605
	Sig. (2-tailed)	.001	.000	.000	.244	.067		.000	.001	.000	.000	.704	.001	.070	.352	.112
Hardness	Pearson Correlation	.985**	.990**	.959**	–.729*	.433	.942**	1	.792*	.944**	.941**	.164	.932**	–.505	–.104	–.326
	Sig. (2-tailed)	.000	.000	.000	.040	.284	.000		.019	.000	.000	.698	.001	.201	.806	.431
Springiness	Pearson Correlation	.754*	.811*	.925**	–.177	.830*	.939**	.792*	1	.928**	.946**	–.435	.781*	–.825*	–.603	–.814*
	Sig. (2-tailed)	.031	.015	.001	.676	.011	.001	.019		.001	.000	.282	.022	.012	.114	.014
Cohesiveness	Pearson Correlation	.910**	.939**	.985**	–.514	.607	.978**	.944**	.928**	1	.984**	–.113	.914**	–.743*	–.362	–.598
	Sig. (2-tailed)	.002	.001	.000	.192	.110	.000	.000	.001		.000	.789	.001	.035	.379	.117
Chewiness	Pearson Correlation	.918**	.950**	.997**	–.458	.685	.994**	.941**	.946**	.984**	1	–.169	.893**	–.699	–.406	–.615
	Sig. (2-tailed)	.001	.000	.000	.254	.061	.000	.000	.000	.000		.689	.003	.054	.319	.105
Taste	Pearson Correlation	.155	.090	–.105	–.769*	–.756*	–.161	.164	–.435	–.113	–.169	1	.097	.580	.930**	.852**
	Sig. (2-tailed)	.714	.832	.805	.026	.030	.704	.698	.282	.789	.689		.819	.132	.001	.007
Colour	Pearson Correlation	.922**	.917**	.895**	–.649	.362	.920**	.932**	.781*	.914**	.893**	.097	1	–.507	–.097	–.374
	Sig. (2-tailed)	.001	.001	.003	.081	.378	.001	.001	.022	.001	.003	.819		.200	.820	.361
Texture	Pearson Correlation	–.443	–.506	–.674	–.028	–.712*	–.669	–.505	–.825*	–.743*	–.699	.580	–.507	1	.760*	.871**
	Sig. (2-tailed)	.271	.201	.067	.948	.048	.070	.201	.012	.035	.054	.132	.200		.029	.005
Aroma	Pearson Correlation	–.113	–.175	–.355	–.525	–.847**	–.381	–.104	–.603	–.362	–.406	.930**	–.097	.760*	1	.917**
	Sig. (2-tailed)	.790	.678	.389	.181	.008	.352	.806	.114	.379	.319	.001	.820	.029		.001
Overall acceptability	Pearson Correlation	–.306	–.377	–.565	–.360	–.887**	–.605	–.326	–.814*	–.598	–.615	.852**	–.374	.871**	.917**	1
	Sig. (2-tailed)	.461	.358	.145	.381	.003	.112	.431	.014	.117	.105	.007	.361	.005	.001	

Legend: **. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).

Conclusion

The rheological, sensorial, and textural properties of traditional and comminuted *Kilishi*, formulated using different ingredient-mix ratios were examined. The comminuted *Kilishi* exhibited higher values for those rheological properties evaluated compared to the TK. Texturally, the comminuted *Kilishi* had significantly higher characteristics of hardness, springiness, cohesiveness, and chewiness compared to the TK. Specifically, CK7 obtained the highest textural properties, elastic modulus, and rupture strength, whereas the TK was more viscous, yet with the lowest rupture strength. Moreover, CK2 obtained the lowest rheological and textural values compared to the other comminuted *Kilishi* samples. Furthermore, sensory panel assessment showed that CK2 was the most preferred *Kilishi* product. The ingredient-mix ratios and processing method (degree of exposure to heat treatment) significantly influenced the rheological, textural, and sensorial properties of *Kilishi*. The strong correlation between rheological, textural, and sensorial properties supports this proposition.

Overall, based on the rheological, textural, and sensorial outcomes of this current *Kilishi* study, the CK2 appears very promising compared to the traditional *Kilishi* and the other comminuted ones. The CK2 has greater added-value potential over TK in terms of its rheological and textural characteristics. In terms of sensorial properties, the CK2 appears the more acceptable product than the others. Additionally, the CK2 is formulated with the lowest ingredient-mix ratio, which has a cost saving implication. This study has revealed the integral role the comminuted meat technique and the ingredient-mix ratio can play in the *Kilishi* processing industry. The direction of future studies should focus on optimizing the ingredient-mix used in the production of comminuted *Kilishi* products, especially those ingredients that greatly influenced the rheological, textural, and sensorial properties such as salt, sugar, and seasoning, so as to deduce the best combination that would give optimized output.

Reološka, senzorna i teksturna svojstva sušenog goveđeg proizvoda („Kilishi“) na bazi mešavine sastojaka

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A p s t r a k t: Kao gotov mesni proizvod (RTE- ready-to-eat), „Kilishi“ stiče sve veću popularnost u Africi. Proizvodnjom „Kilishi“ proizvoda bave se samo iskusne osobe, a poboljšanje proizvodnog procesa primenom proizvodnje/tehnologije usitnjenog mesa, može poboljšati kvalitet i uniformnost proizvoda. U skladu s tim, ispitivana su reološka (modul elastičnosti, viskoznost i čvrstoća na pucanje), teksturna (tvrdoća, elastičnost, kohezivnost i žvakaća tekstura) i senzorna (ukus, boja, tekstura, aroma i ukupna prihvatljivost) svojstva mešavine sastojaka kobasice „Kilishi“ . Tradicionalni „Kilishi“ kao kontrola upoređen je sa sedam drugih usitnjenih „Kilishi“ proizvoda (CK1-7) različitih odnosa sastojaka i mešavine. Usitnjeni proizvodi „Kilishi“ postigli su veće vrednosti za svojstva teksture u poređenju sa tradicionalnim „Kilishi“ proizvodom. Rezultati su pokazali da je CK7 imao najveći modul elastičnosti (Eo, E1 i E2) i čvrstoću pucanja (18,95 N), dok je CK2 imao najmanju od ovih vrednosti među usitnjenim „Kilishi“ proizvodima. Međutim, TK je bio viskozniji (2,09 × 106 Pas), ali je imao najmanju jačinu pucanja (6,85 N). Senzorno, ocena panela za opštu prihvatljivost pokazala je da je CK2 postigao najviši rezultat (7,02), što ukazuje na stepen njegove preferencije. I reološka svojstva i tekstura su u snažnoj korelaciji (p <0,05) sa jednim ili više senzornih atributa. Odnosi sastojaka i mešavine i stepen izloženosti toplotnoj obradi značajno su uticali na reološka, teksturna i senzorna svojstva „Kilishi“ proizvoda. U poređenju sa tradicionalnim „Kilishi“ proizvodom, CK2 deluje vrlo obećavajuće jer su ga panelisti preferirali, a među usitnjenim „Kilishi“ proizvodima, CK2 je imao najpovoljnije teksturna i reološka svojstva i imao je najniži odnos mešavine sastojaka, što ukazuje na niže proizvodne troškove od drugi usitnjeni proizvoda „Kilishi“. Tehnika usitnjavanja i upotreba preciznih odnosa mešavine sastojaka mogu pružiti dodatnu vrednost u prerađivačkoj industriji za dobijanje proizvoda „Kilishi“.

***Ključne reči:** goveđe meso; mešavina sastojaka; reologija; usitnjeno meso; senzorna svojstva; tekstura.*

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