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Cassava Pectin and Textural Attributes of Cooked gari (*eba*) and fufu Dough

Wasiu Awoyale, Kazeem K. Olatoye and Busie Maziya-Dixon

Abstract

The textural attributes of cooked gari (*eba*) and fufu dough may be affected by the pectin content of the cassava roots; thus, exploring the interaction between pectin and the texture attributes of processed products such as gari and fufu may assist the processors and consumers of the product. The pectin and starch contents, and the composition of the amylose/amylopectin ratio, influence most of the textural changes in roots and tubers during processing, and subsequent preparation for consumption. The textural characteristics of the cooked gari (*eba*) and fufu dough that may be influenced by the pectin content of the cassava roots include hardness, adhesiveness, gumminess, and moldability/cohesiveness. However, there is presently little or no information on the direct relationship between the pectin content of different cassava varieties and the textural attributes of the cooked gari and fufu dough; therefore, there is a need to evaluate the effect of pectin in different cassava varieties on the textural attributes of cooked gari and fufu dough. This will guide gari and fufu producers on the right varieties to be used for gari and fufu to maintain the textural characteristics of the cooked gari and fufu dough preferred by the consumers.

Keywords: pectin, textural attributes, cassava roots, cooked gari (*eba*), fufu dough

1. Introduction

Cassava is widely grown and used in different agroecological zones across many African countries. Cassava utilization patterns vary considerably in different parts of the world and Nigeria; most of the cassava produced (90%) is used for human food. Cassava can be transformed into different products such as gari and fufu [1]. Gari, a roasted solid-state fermented cassava meal, is the most popular product consumed in West Africa and the most important food product in the diet of millions of Nigerians and Ghanaians [1]. Fufu, a submerged fermented and sieved cassava root, is ranked next to gari as an indigenous fermented food in the southern part of Nigeria [2]. Gari and fufu are prepared into the dough by reconstituting in boiled water and consumed with the preferred soup; thus, their textural attributes are key to consumer acceptability of the products [3].

Texture is the sensory and functional manifestation of the quality attributes of foods detected through the senses of vision, hearing, and touch and from kinesthetic qualities [4]. The texture of cooked root and tuber crops and their products are often cited as a primary determinant of the acceptability of improved and local cassava varieties, which may be influenced by higher polysaccharides such as pectin. This is because pectin has been reported to improve the structural and textural attributes of plant-based products. The fundamental constituent of the pectin molecules is D-galacturonic acid monomers in methyl ester conformation linked by α -(1 $\rightarrow$ 4) glycosidic bonds [5]. The biological function of pectin is to cross-link cellulose and hemicellulose fibers, providing rigidity to the cell wall. Pectin is also a major component of the middle lamella, where it helps to bind cells together. It was observed by Franck et al. [6] that cassava roots have different pectin contents depending on the varieties. This was corroborated by Favaro et al. [7], who reported that uronic acid, which is the main constituent of pectin, was extracted from cassava root cell walls. Also, the abundance of pectin structures in cassava cell walls was confirmed by coloring with Coriphosphine-O, which binds to acidic polysaccharides, including pectin [8].

It has been shown that the action of pectin methyl esterase on pectin affects the food textural quality of plant-based food products, either favorably or deleteriously, depending on the product at hand [9]. However, results obtained by Ampe et al. [10] suggest that cell wall degradation is initiated by endogenous pectin esterase located in the intercellular space and released by pH decrease, followed by the action of microbial polygalacturonase and pectate lyase that depolymerizes pectic chains in the cassava roots. Hence, the effect of pectin on the textural attributes of cooked gari and fufu dough may differ because of their different processing methods. Therefore, this chapter aims to discuss the possible effect of pectin on the textural attributes of cooked gari and fufu dough using studies that have been done on pectin and textural attributes of other starchy foods.

2. Production of gari and fufu

Gari is a dry, crispy, creamy-white/yellow and granular product, which is produced by crushing the cassava root into a mash, fermented (lactic fermentation, optional in some locations), dewatered, and sieved into grits. The grits are then roasted manually or mechanically to make the gari [11]. However, the processing of cassava roots into gari differs from one location to another. Some producers/consumers may prefer sour or bland taste gari, fine or coarse particle size gari, palm oil mixed gari, or even gari enriched/fortified with different legumes or protein sources [11–13].

Peeling of freshly harvested cassava roots manually with a knife is most common, but mechanical peelers are now available in countries such as Nigeria and Ghana [12]. The importance of the peeling process is to remove the brown peel, which might affect the gari color and increase its fiber content. Washing of the peeled roots is done to remove all extraneous materials, which could contaminate the gari. Grating of the washed cassava roots is done using a motorized cassava grater, but hand graters, made by fastening the perforated grating sheets on the wood, are still used in some countries. Grating is done to increase the surface area of the cassava root and free up the moisture so that dewatering of the mash can be done easily. The grated cassava mash is bagged using a polypropylene/polyethylene woven bag or basket (lined with

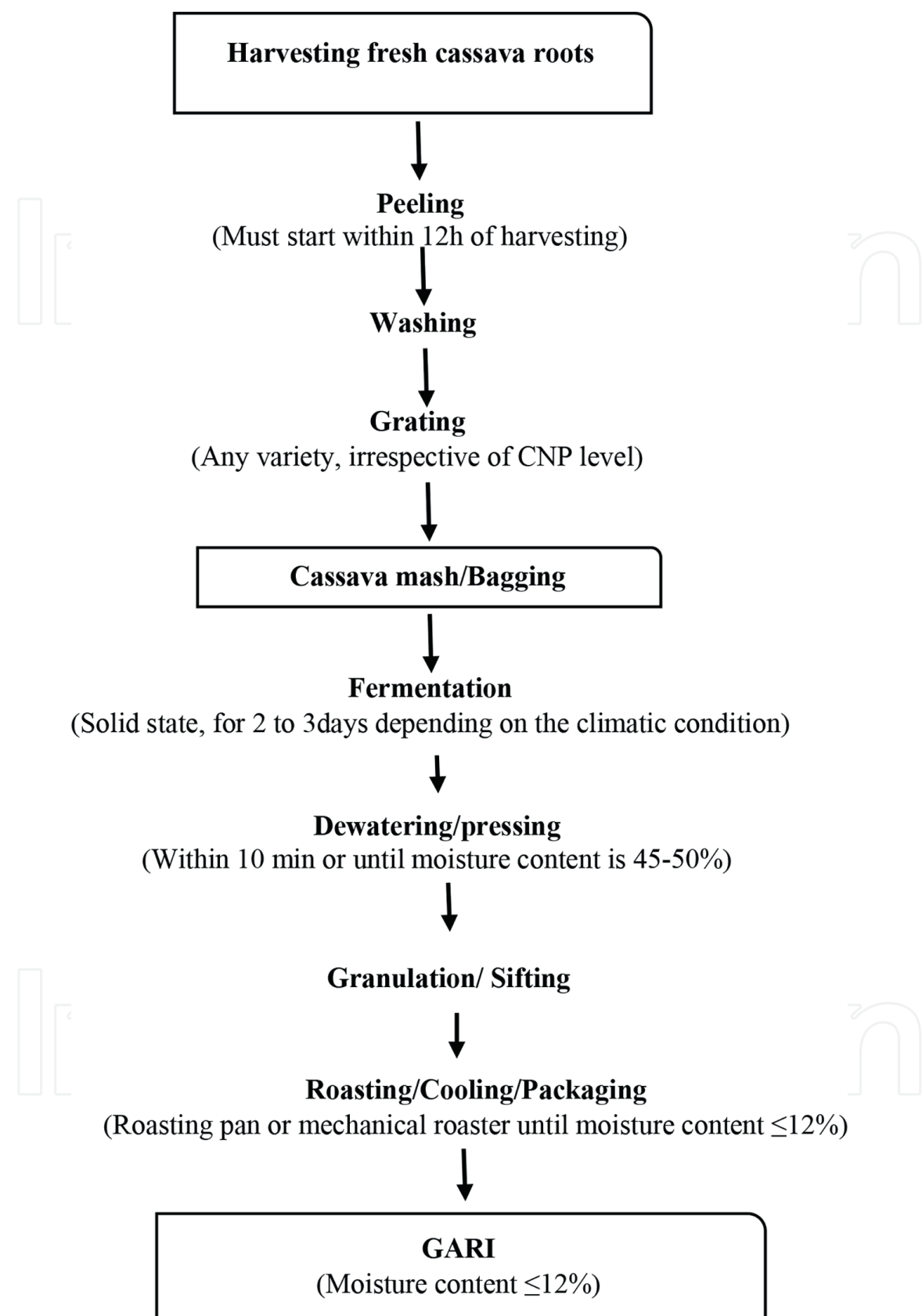


Figure 1.
Production of gari [11].

a polypropylene sack) and left for between 1 and 5 days to ferment, depending on the taste preferred by the consumers. Apart from the taste, fermentation helps to reduce the cyanogenic potential of the product [12].

The fermented mash is then dewatered by pressing with a manual screw or hydraulic press or even wood tied at both ends with a rope, which is still common in most rural communities. Pressing is done to reduce the moisture content of the grated mash before roasting. The cake formed after dewatering is pulverized by a pulverizer/cake breaker or by hand and sieved with a manual woven sieve or rotary sieve, to remove the fiber and lumps. The sieved grit is then roasted, cooled, and packaged (**Figure 1**) [12].

An earthenware stove and a roasting pan made of molded aluminum or stainless steel are used for roasting on a wood fire. In some communities, the roasting pan is smeared with a small amount of palm oil prior to roasting, to produce yellow gari. However, mechanical roasters are now available in Nigeria and Ghana. The roasting

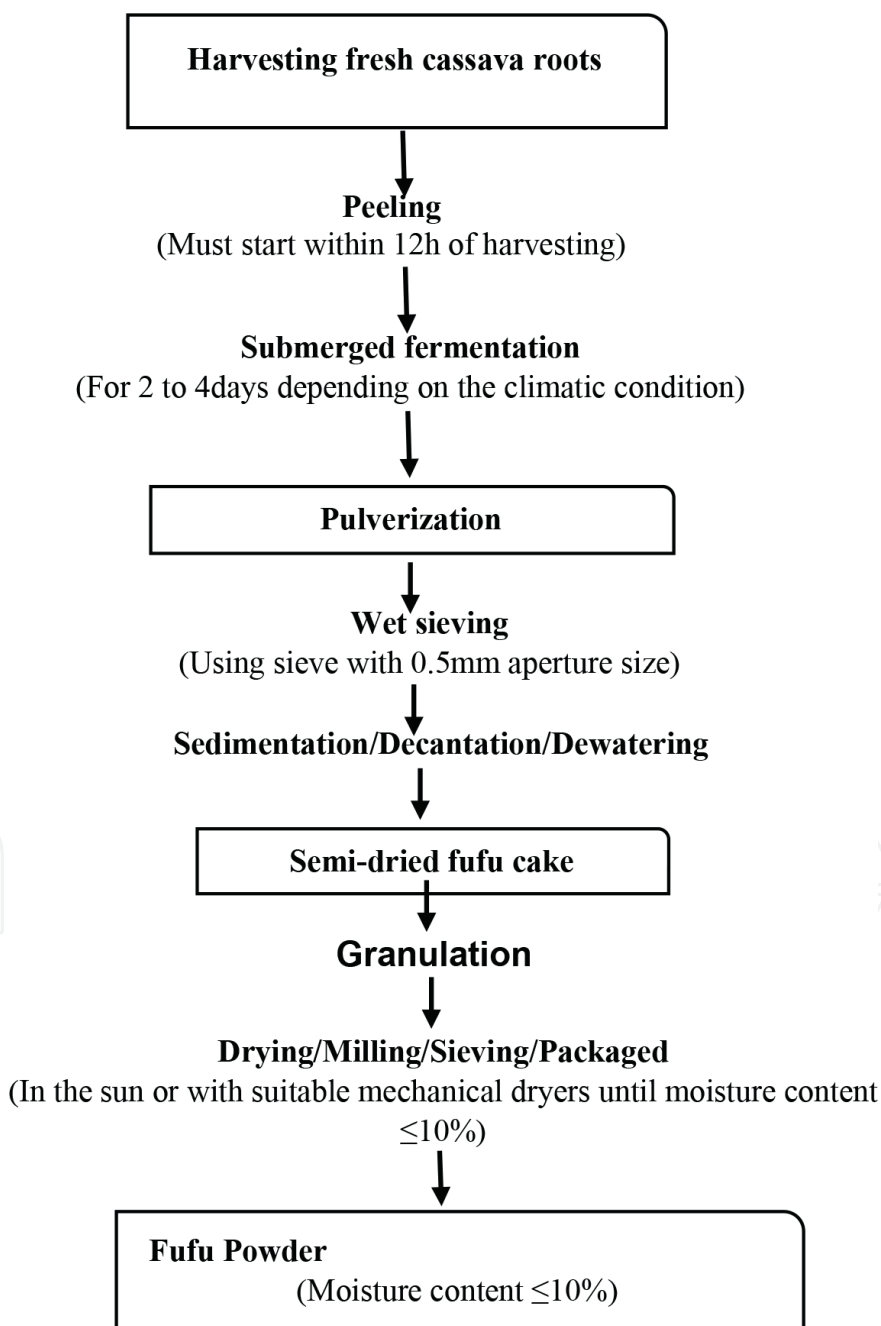


Figure 2.
Production of fufu powder [15].

process develops the gari flavor and improves digestibility, and the extent of drying determines the crispiness and storability of the product. It is important to add that in some communities, the grit is partially toasted and finally dried under the sun, which is not very good as the product will be contaminated. The gari is then cooled for some hours, graded (sieved) depending on the particle sizes preferred by the consumers and packaged depending on the distribution outlet. However, most rural communities package in 50 kg bags for retail. The roasted gari can be consumed in the form of cooked dough (*eba*) with a preferred soup by reconstituting it in boiled water [14]; hence, the textural attributes are very important and may be influenced by the pectin content of the roots.

Fufu is produced by peeling the cassava roots using a stainless-steel knife, washing them with clean water, and soaking them in fermenting drums for four days. The fermented roots are then sieved through a muslin cloth and allowed to form sediment. The sediment is collected and packed in woven polyethylene sacks and dewatered using a manually operated pressing machine. The cake is pulverized and spread on a black polyethylene sheet for drying under the sun. The dried fufu is milled using a hammer mill, cooled, and packaged (**Figure 2**) [15]. Fufu can be sold in a wet form (a semi-solid cake) or in a flour form. Fufu is consumed by reconstituting in boiled water to form a cooked dough, which is consumed with preferred soup [15], thus the need for textural attributes of the fufu that may be affected by the pectin content of the cassava roots.

3. Influence of pectin on the textural attributes of cassava roots

The texture of foods is related to the structure formed by micro- and macromolecular elements forming the cell wall and other regions [16]. Most of the textural changes in roots and tubers during processing are related to pectin and starch contents and the composition of the amylose/amylopectin ratio. Softening of cell walls during the cooking of cassava root was studied for intracellular compounds such as cations (Ca^{2+} and Mg^{2+}), phytic acid, and pectins. It appeared that the cassava variety with the longer cooking time had a lower level of cations and phytic acid and higher levels of chelator-insoluble pectic polysaccharides. It is therefore likely that mealiness is associated with pectins in cassava roots [6]. Maieves et al. [17] reported that cassava varieties whose starch granules are more deeply related to parenchyma tissues, pectin, and cellulose tend to be harder in texture, both in raw and in cooked cassava roots. Infante et al. [18] added that the presence of pectic substances (salts of pectinic and pectic acids, and protopectin) in cassava root may contribute to the texture and hardness of cassava roots, which in turn could be responsible for the mouth feel of cooked or processed foods. A correlation between pectin composition and the cooking quality of boiled cassava roots provided the first evidence that pectins are involved in determining the texture of root and tuber products. In the case of boiled cassava, a soft texture was related to higher levels of methoxylated pectins (i.e., pectins with side groups limiting their ability to form egg-box complexes with Ca^{2+}) and lower levels of nonmethoxylated pectins [19]. This was linked with higher pectin methyl esterase activity, which is associated with increased firmness as the pectin methyl esterase rapidly demethylates pectin in the cell walls and middle lamellae, allowing for hardening through cross-linking with divalent cations [19].

4. Textural attributes of cooked gari (*eba*) and possible influence of pectin

Gari is a roasted, fermented cassava grit, consumed raw, soaked in cold water, or reconstituted in hot water into *eba*, and is common in the diets of millions of people in developing countries [20]. The instrumental texture attributes of *eba* produced from different cassava varieties reported by Awoyale et al. [20] showed that variations exist in their textural attributes. For instance, the hardness of the *eba* was higher in TMS15F1467P0011 gari (54.58 N/m^2) and lower in TMS14F1035P0004 gari (13.71 N/m^2) (**Table 1**). This means that consumers that prefer the firm-textured *eba* can consume the *eba* prepared from the TMS15F1467P0011 gari, while those that prefer the soft-textured *eba* can consume the *eba* prepared from the TMS14F1035P0004 gari. This was in agreement with the hardness of the *eba* prepared from different cassava varieties using the backslopped fermented gari ($21.03\text{--}30.22 \text{ N/m}^2$) [3]. Hardness is defined as an indicator of the most direct response to taste, which has a direct relationship with chewiness, gumminess, and cohesiveness in the texture profile analysis [3]. It was reported by Zhai et al. [22] that the hardness of the blends of waxy rice starch and pectin gels significantly decreased with the increase in pectin inclusion. The authors attributed this observation to the fact that the pectin formed hydrogen bonds with the waxy rice starch molecules, which interfered with the formation of ordered structures during starch retrogradation. This implies that the pectin content in the TMS14F1035P0004 gari may be high and that of the TMS15F1467P0011 gari may be low, hence the lower hardness of the *eba* prepared from TMS14F1035P0004 gari [22]. This observation was also supported by Gafuma et al. [23]. These researchers reported that pectin contributes to a softer texture of bananas during cooking and cooling, which was attributed to the high water retention capacity of pectins. In addition, the high water binding and holding capacity of pectins may keep the cooked banana structural matrix moist, thus maintaining starch in a gelatinized state, hence making pectin-treated bananas relatively soft in a cooled form [23].

The degree to which the *eba* sticks to the hand, mouth surface, or teeth is known as adhesiveness [3]. The adhesiveness of the *eba* ranged from -177.50 N/m^2 to -39.36 N/m^2 , with TMS13F1343P0004 gari having the highest and TMS15F1482P0098 gari the lowest (**Table 1**). This implies that the *eba* prepared from the TMS13F1343P0004 gari may be more adhesive compared to that prepared from the TMS15F1482P0098 gari [3]. Zhai et al. [22] reported that the decrease in adhesiveness in the blends of waxy rice starch and pectin gels with the increase in the pectin content may be associated with the covering of the starch molecules by the pectin, resulting in reduced starch-to-starch hydrophobic interaction. Consequently, the low adhesiveness of the *eba* prepared from TMS15F1482P0098 gari may be attributed to the high pectin content. This is because the lower hydrophobic interaction might have led to inhomogeneity and instability in the network structure of the *eba*, thus reducing the textural characteristics [22].

Usually, the *eba* is squeezed manually, during which the mechanical and geometrical characteristics are assessed, molded into balls with the hand, dipped into the soup, and then swallowed [3]. Hence, moldability is how well the product withstands a second deformation relative to its resistance under the first deformation [3]. The *eba* from TMS13F1053P0010 gari (0.89) had the lowest moldability, and the IITA-TMS-IBA980581 gari (0.98) had the highest moldability (**Table 1**). A similar range of values (0.84–0.98) was reported for the moldability of *eba* prepared from backslopped fermented gari [3]. The high moldability of the *eba* from IITA-TMS-IBA980581 gari may be linked with increased pectin concentration upon cooking and cooling, which may be attributed to the retrogradation of starch [23].

Cassava varieties	Hardness (N/m ²)	Adhesiveness (N/m ²)	Moldability	Stretchability	Gumminess (N/m ²)
TMS13F1343P0004	41.81 ± 0.23hi	39.36 ± 13.60a	0.91 ± 0.00hi	0.96 ± 0.3e–g	38.01 ± 0.20ij
IBA98051	37.64 ± 0.33j	82.31 ± 2.85c–e	0.93 ± 0.00d–h	1.01 ± 0.05a–g	34.96 ± 0.21lm
IBA30572	50.73 ± 1.78bc	83.84 ± 3.54c–e	0.92 ± 0.00f–h	0.97 ± 0.05d–g	46.73 ± 1.54b–d
TMS13F1088P0007	32.00 ± 0.13lm	57.82 ± 1.68ab	0.93 ± 0.02e–h	1.02 ± 0.06a–g	29.66 ± 0.75no
TMS14F1285P0006	31.21 ± 0.76mn	42.67 ± 5.62a	0.93 ± 0.00d–h	0.99 ± 0.01c–g	29.12 ± 0.79o
TMS13F1343P0004	49.58 ± 0.48c	103.22 ± 3.70e–g	0.91 ± 0.04hi	1.04 ± 0.05a–g	45.05 ± 2.64de
TMS13F1160P0004	44.33 ± 1.20ef	98.29 ± 9.11e–g	0.91 ± 0.01hi	1.07 ± 0.09a–f	40.10 ± 0.59gh
TMS13F2110P0008	52.08 ± 0.40b	109.53 ± 25.29f–h	0.91 ± 0.01hi	1.00 ± 0.00b–g	47.05 ± 0.54bc
UYT30106	51.51 ± 2.04b	145.64 ± 12.03ij	0.94 ± 0.01c–h	1.00 ± 0.11c–g	48.07 ± 1.55b
UYT30104	41.19 ± 0.16i	129.69 ± 17.79hi	0.96 ± 0.02a–e	1.07 ± 0.01a–f	39.31 ± 0.54hi
TMS14F1016P0006	30.10 ± 1.24n	68.72 ± 3.94bc	0.95 ± 0.00a–f	1.03 ± 0.04a–g	28.64 ± 1.25op
TMS13F1053P0015	38.29 ± 0.43j	73.97 ± 4.72b–d	0.92 ± 0.02g–i	1.04 ± 0.08a–g	34.94 ± 1.08lm
UYT30111	13.71 ± 0.36p	85.62 ± 2.42c–e	0.95 ± 0.01b–g	1.12 ± 0.04a–c	12.98 ± 0.22q
UYT30112	28.32 ± 0.08o	116.75 ± 4.70gh	0.95 ± 0.00a–f	1.09 ± 0.04a–e	27.00 ± 0.08p
TMS13F1307P0016	41.92 ± 0.06g–i	115.16 ± 0.56gh	0.93 ± 0.01e–h	1.00 ± 0.00b–g	38.60 ± 0.21hi
UYT30109	37.55 ± 0.36j	141.87 ± 1.17ij	0.98 ± 0.00a	1.13 ± 0.07ab	36.81 ± 0.37jk
TMS13F1160P0005	35.61 ± 0.06k	113.29 ± 4.39gh	0.95 ± 0.02b–g	1.07 ± 0.09a–f	33.59 ± 0.71m
TMS13F1153P0001	38.40 ± 0.33j	84.07 ± 10.28c–e	0.93 ± 0.01e–h	1.00 ± 0.04b–g	35.50 ± 0.11kl
TMS13F1049P0001	33.01 ± 0.03l	91.43 ± 13.76d–f	0.92 ± 0.00f–h	1.03 ± 0.00a–g	30.28 ± 0.08no
UYT30108	40.86 ± 1.26i	143.70 ± 3.11ij	0.97 ± 0.02a–c	1.09 ± 0.01a–e	39.35 ± 0.32hi
TMS14F1195P0005	43.43 ± 0.41fg	88.31 ± 7.91c–e	0.92 ± 0.00f–h	1.07 ± 0.01a–f	39.90 ± 0.37gh
TMS14F1285P0017	45.36 ± 0.07e	113.76 ± 2.54gh	0.91 ± 0.00hi	1.06 ± 0.03a–f	41.46 ± 0.09fg
UYT30103	43.41 ± 0.54fg	142.33 ± 0.56ij	0.97 ± 0.01a–c	1.09 ± 0.00a–e	42.04 ± 0.28f
TMEB419 (Control)	37.09 ± 0.01j	118.18 ± 14.42gh	0.95 ± 0.02b–g	1.00 ± 0.00b–g	34.93 ± 0.78lm
UYT30105	47.88 ± 0.62d	158.88 ± 5.35j	0.96 ± 0.00a–d	1.14 ± 0.06a	45.93 ± 0.58cd
TMS14F1035P0004	42.77 ± 0.59f–g	99.40 ± 0.04e–g	0.93 ± 0.00d–h	1.01 ± 0.06a–g	39.83 ± 0.66g–i
UYT30101	54.58 ± 0.08a	145.84 ± 0.47ij	0.96 ± 0.01a–e	1.10 ± 0.01a–d	52.10 ± 0.16a
TMS13F1053P0010	49.56 ± 0.37c	100.50 ± 0.62e–g	0.89 ± 0.01i	0.94 ± 0.04fg	43.92 ± 0.06e
TMS14F1287P0008	34.63 ± 0.01k	83.79 ± 6.15c–e	0.91 ± 0.01hi	0.91 ± 0.10g	31.27 ± 0.12n
UYT30110	45.42 ± 0.40e	177.50 ± 16.45k	0.97 ± 0.00ab	1.06 ± 0.08a–f	43.93 ± 0.51e
Mean	40.46	105.18	0.93	1.04	37.7
p level	*	*	*	**	*

Means with the same letters within the same column are not significantly different ($p < 0.05$);
* $p < 0.05$;
** $p < 0.01$
Values are means of six replicates.
Source: Awoyale et al. [21].

Table 1.
Instrumental texture attributes of eba produced from different cassava genotypes.

Samples	Hardness (N/m ²)	Adhesiveness (N/m ²)	Moldability	Stretchability	Gumminess (N/m ²)
NR14B-218	23.43 ± 0.56e	−54.64 ± 8.89b	0.96 ± 0.00c	0.97 ± 0.04ab	22.40 ± 0.61e
TMS13F1153P0001	19.37 ± 1.14f	−37.40 ± 8.24ab	0.99 ± 0.00a	1.02 ± 0.10ab	19.27 ± 1.14f
TMEB419	45.34 ± 1.34a	−43.28 ± 0.90ab	0.93 ± 0.01d	1.06 ± 0.16a	42.38 ± 1.51a
NR1741	26.93 ± 1.16d	−46.44 ± 8.74ab	0.97 ± 0.00b	1.05 ± 0.07a	26.02 ± 1.06d
TMS13F1020P0001	40.10 ± 0.39b	−30.61 ± 11.86a	0.92 ± 0.01e	0.75 ± 0.29b	36.89 ± 0.42b
IITA-TMS-IBA30572	29.45 ± 0.80c	−51.07 ± 13.04b	0.97 ± 0.00b	1.00 ± 0.01ab	28.59 ± 0.84c
Mean	30.77	−43.91	0.96	0.97	29.26
p level	*	NS	*	NS	*

** $p < 0.05$.
NS: not significant.
Means with the same letters within the same column are not significantly different ($p > 0.05$).
Source: Awoyale et al. [25].

Table 2.
Instrumental texture profiling of cooked fufu dough produced from different cassava varieties.

For consumers that chew *eba* before swallowing, the stretchability is the degree to which the *eba* returns to its original shape after compression between the teeth [3]. The stretchability was higher in the *eba* prepared from the TMS15F1466P0195 gari (1.14) and lower in the *eba* prepared from the TMS14F1287P0008 gari (0.91) (**Table 1**). The high stretchability of the *eba* from the TMS15F1466P0195 gari may be due to the gari's high peak and breakdown viscosities [3]. However, the values of the stretchability of the *eba* prepared from backslopped fermented gari (0.88–1.06) fall within the values of the stretchability of the *eba* in this study [3].

Gumminess is also defined as the energy required to disintegrate a semi-solid food until it can be swallowed [3]. The gumminess of the *eba* ranged from 12.98 to 52.10 N/m². *Eba* prepared from TMS14F1035P0004 gari had the lowest gumminess, and the *eba* from TMS15F1467P0011 gari had the highest gumminess (**Table 1**). The gumminess of the *eba* prepared from the backslopped fermented gari (20.54–27.10 N/m²) falls within the values of the gumminess of the *eba* in this study [3]. The low gumminess of the *eba* prepared from TMS14F1035P0004 gari may be due to the low hydrophobic interaction that might have led to inhomogeneity and instability in the network structure of the *eba*, thus reducing the textural characteristics [22].

5. Textural attributes of cooked fufu and possible influence of pectin

Fufu is a traditional fermented food product consumed in the southern, western, and eastern parts of Nigeria and some other West African countries [24]. The variations in processing methods and differences in the biophysical traits of the varieties may change the textural properties of the cooked fufu [25]. For instance, Awoyale et al. [25] reported that the cooked fufu dough prepared from TMEB419 flour (45.34 N/m²) was significantly ($p < 0.05$) harder than that prepared from TMS13F1153P0001 flour (19.37 N/m²) (**Table 2**). The high pectin content in the cooked fufu dough prepared from the TMS13F1153P0001 flour might have contributed to the softer texture during cooking and cooling [22]. In addition, the high water binding and holding capacity of pectin may keep the cooked fufu dough matrix moist, thus maintaining starch in a

gelatinized state, hence making the fufu dough relatively soft in the cooled form [23]. Awoyale et al. [25] added that the hardness of the fufu dough has a positive correlation with most of the functional properties of the flour (except for dispersibility) and a negative correlation with pasting properties (except for breakdown viscosity and pasting temperature). Although this observation was not supported by the findings of Zhai et al. [22] who stated that as pectin content increased in the waxy rice starch and pectin blends, the peak and final viscosity of the products gradually increased. This may be due to differences in their starch and pectin composition.

Adhesiveness is the degree to which the cooked dough sticks to the hand, mouth surface, or teeth [25]. The adhesiveness of the fufu dough ranged from -54.64 to -30.61 N/m², with the product from TMS13F1020P0001 flour having the highest value ($p < 0.05$) and that from NR14B-218 flour having the lowest (**Table 2**). The low adhesiveness of the cooked fufu from NR14B-218 may be attributed to the lower hydrophobic interaction that may have led to inhomogeneity and instability in the network structure of the fufu dough, thus reducing the textural characteristics [22]. The adhesiveness of the cooked fufu dough had a positive correlation with all the functional properties (except for the water absorption capacity and solubility index), pasting properties, and chemical composition (except for sugar and starch, ash content, and pH value) of the flour [25]. Since high water-holding capacity is a characteristic of pectins, the negative correlation that exists between the adhesiveness of the cooked fufu dough and the water absorption capacity of the fufu flour might be a sign that the fufu flour from the NR14B-218 variety may have low pectin content [16].

Cohesiveness and moldability define how well the cooked fufu dough withstands a second deformation relative to its resistance to the first time. It is calculated as the work area during the second compression divided by the work area during the first [26]. Usually, the cooked fufu dough is squeezed manually, during which the mechanical and geometrical characteristics are assessed, molded into balls with the hand, then dipped into the soup, and swallowed [25]. The moldability of the fufu dough ranged from 0.92 in TMS13F1020P0001 flour to 0.99 in TMS13F1153P0001 flour (**Table 2**). The high cohesiveness of the cooked fufu dough from TMS13F1153P0001 flour may be linked with increased pectin concentration upon cooking and cooling, which may be due to the retrogradation of starch [16]. The moldability of the fufu dough was positively correlated with all the functional properties of the flour (except for water-absorption capacity, swelling power, and dispersibility), the pasting properties (except for peak and breakdown viscosities and pasting temperature), and the chemical composition (except for amylose content) [25]. The positive correlation between the cooked fufu dough moldability and the final viscosity may be evidence that the TMS13F1153P0001 fufu flour is high in pectin content [22]. Also, the possible interaction between the starch molecules and pectin during the gelatinization process may have increased the final viscosity of the dough and then responsible for the high moldability of the cooked fufu dough from TMS13F1153P0001 flour [27].

Stretchability or elasticity is the degree to which the cooked fufu dough returns to its original shape after compression between the teeth [25, 26]. The stretchability was lower in the product from TMS13F1020P0001 flour (0.75) and higher in that from TMEB419 flour (1.06) (**Table 2**). The stretchability of the dough also had a positive correlation with all the functional properties of the flour (except for solubility index and dispersibility), pasting properties (except for setback viscosity, peak time, and pasting temperature), and chemical composition (except for starch and amylose contents) [25].

The energy required to disintegrate a semi-solid food until it can be swallowed is known as gumminess. It is calculated as cohesiveness multiplied by hardness [25, 26]. The gumminess of the product from TMEB419 flour (42.38 N/m^2) was significantly ($p < 0.05$) more than that in the product from TMS13F1153P0001 (19.27 N/m^2) (**Table 2**). The low gumminess of the cooked fufu dough prepared from TMEB419 flour may be due to the low hydrophobic interaction that might have led to inhomogeneity and instability in the network structure of the dough, thus reducing the textural characteristics [22]. Awoyale et al. [25] added that the gumminess of the fufu dough has a positive correlation with the functional properties of the flour (except for dispersibility), a negative correlation with the pasting properties (except for breakdown viscosity and pasting temperature), and a negative correlation with the chemical composition (except for amylose content). The positive correlation between the gumminess of the fufu dough and the breakdown viscosity implies that the TMS13F1153P0001 cooked fufu dough with low gumminess may be high pectin content. This is because Luo et al. [27] reported that the addition of pectin gradually decreased the breakdown value of the waxy rice starch and pectin blends. The authors added that the decrease in breakdown values might be due to the pectin being able to cover the starch granules step by step with the increasing concentration of pectin so that the stability of the waxy rice starch and pectin mixture was enhanced. Also, the negative correlation between the gumminess of the fufu dough and the setback viscosity of the fufu flour may be evidence that TMS13F1153P0001 cooked fufu dough with low gumminess may be high in pectin content. This is because Zhai et al. [22] reported that the addition of pectin significantly reduced the setback viscosity of the waxy rice starch and pectin mixture, implying that pectin inhibited the retrogradation of gelatinized starch.

6. Conclusions

The pectin and starch contents, and the composition of the amylose/amylopectin ratio, influence most of the textural changes in roots and tubers during processing and subsequent preparation for consumption. The textural characteristics of the cooked gari (*eba*) and fufu dough that may be influenced by the pectin content of the cassava roots include hardness, adhesiveness, gumminess, and moldability/cohesiveness. However, there is presently little or no information on the direct relationship between the pectin content of different cassava varieties and the textural attributes of the cooked gari and fufu dough; therefore, there is a need to evaluate the effect of pectin in different cassava varieties on the textural attributes of cooked gari and fufu dough. This will guide gari and fufu producers on the right varieties to be used for gari and fufu to maintain the textural characteristics of the cooked gari and fufu dough preferred by the consumers.

Conflict of interest

The authors declare no conflict of interest.

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