

Evaluation of the Physical and Sensory Characteristics of Bread Produced from Three Varieties of Cassava and Wheat Composite Flours

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Abstract This study determines the most suitable cassava variety and an acceptable maximum substitution level of wheat flour with cassava flour for bread production in terms of baking and organoleptic characteristics using three varieties of cassava. High Quality Cassava Flour produced from three cassava varieties (*Afisiayi*, *Bankye hemmaa* and *Doku duade*) was used together with wheat in composite at 10%, 20% and 30% substitution levels. Bread samples were baked from the resulting composites and examined for its specific volume, density and hardness. The products were also subjected to sensory analysis for appearance, taste, texture and overall acceptability by a semi-trained panel of consumers. Increasing proportion of cassava flour in the composite bread reduced bread specific volume and increased density and hardness. Increasing the content of cassava in the composite resulted in bread that was less springy and difficult to chew. Springiness of bread substituted with 10% and 20% cassava flour compared well with the control, while those with 30% cassava were significantly less springy than the control. A substitution level of 10% *Afisiayi* and 20 % *Bankye hemmaa* cassava flour in composite bread on overall acceptable was similar to 100% wheat bread and therefore has the most suitable potential to replace part of wheat flour in bakery products.

Keywords Physical properties, Sensory analysis, Cassava, Wheat, Composite flours, Bread

1. Introduction

Over the past decades, changing food habits has increased demand for wheat-based convenient foods such as bread and pastries in many developing countries [1-3]. These products are processed with wheat flour as the main raw material because of the superior baking properties of its proteins [4]. The soaring wheat prices on the global market [5] and local concern about huge import of cereal grains, there is an interest to promote the utilization of local sources of flour for partial substitution of wheat flour in these applications. This would reduce the dependency on wheat imports and also increase livelihoods of local farmers who produce crops that may be applied in flour composites.

High Quality Cassava Flour has been identified as a local alternative to substitute part of wheat flour in composite flours [1]. In Ghana, cassava is one of the most important crops in terms of production, energy intake, and contribution to Agricultural GDP [6]. *Afisiayi*, *Bankye hemmaa* and *Doku duade* cassava varieties are among the improved varieties

most preferred due to their high quality attributes in food forms, pharmaceutical and industrial uses in Ghana. The possibility of using starchy tubers instead of wheat flour in foods depends on their chemical and physical properties. Amylose / amylopectin ratio for example influences the flour's behavior in food systems; example is the viscosity, gelatinization and setback which affect texture of the end product. The absence of gluten and the acceptability of the end products among consumers in terms of sensory attributes are important issues to be considered in bakery products.

The objective of the study was to determine a maximum inclusion level of cassava flour from different cassava varieties in composite flour of wheat and cassava for baking bread without any significant changes in baking capacity and sensory attributes compared to 100% wheat products. Further, we aimed to determine which of the cassava varieties presents the best option in composite flours of wheat and cassava for bread making.

2. Materials and methods

2.1. Cassava

Three different local cassava varieties, *Afisiayi*, *Bankye*

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hemmaa and *Doku duade*, were purchased from farm gates at Pokuase, north of Accra, Ghana.

2.2. Processing of Cassava into Flour

The cassava roots were processed into flour [7]. *Afisiati*, *Bankye hemmaa* and *Doku duade* cassava varieties were washed in potable water, peeled and secondarily washed and grated with a motorized cassava grater (Cassava Grater, CSIR-FRI, Accra, Ghana). The grated cassava was pressed using a manual screw press (Screw Press, CSIR-FRI, Accra, Ghana). The pressed cassava mash was disintegrated using a cassava grater and dried in a solar dryer of temperature 35 - 48°C until constant weight. The dried cassava grits were milled into flour using a disc-attrition mill (Mill Machine, CSIR-FRI, Accra, Ghana). Fine flour with a uniform particle size was obtained by employing a motorized flour sifter (Flour Sifter, CSIR-FRI, Accra, Ghana) with a 250 µm screen. The cassava flour was vacuum sealed in air-tight polyethylene bags until subsequent use [8, 9].

2.3. Preparation of Composite Flour

The three cassava flours were blended with (hard wheat flour at inclusion levels of 10, 20 and 30% and stored in high density polyethylene bags (HDPE) prior to analysis.

2.4. Baking of bread

Bread was baked with the ingredients composition proportions expressed as the percentage of flour used as 100% flour, 43.6% water, 16.6% margarine, 8.3% Sugar, 2.3% concentrated milk, 0.9 salt, 0.6% dried yeast, 0.4% vanilla flavor and 0.2% nutmeg. The ingredients were purchased from a local market in Accra. Bread baked with 100% wheat flour was used as control. All ten flour samples were baked in duplicate. The dough was kneaded by hand for 20 min, molded into loaves and proofed for 3 hr at room temperature (28°C). The loaves were baked in a gas oven (Ariston, New Zealand) at 180°C for 25 min. Five bread samples per composite flour prepared was allowed to cool to room temperature and stored in HDPE bags for further analysis.

2.5. Specific Volume and Density of Bread

The weight (W) of the loaves was measured. Loaf volume (VL) was determined by a modification of the rapeseed replacement method according to the AACC [10] using millet instead of rapeseeds. Bread was put in a basin of known volume (VB) and the basin filled to the brim with millet. The bread was removed and the volume of the millet (VM) was measured with a measuring cylinder. Loaf volume (VL) was then determined according to the following formula:

$$VL (cm^3) = VB - VM \quad (1)$$

Specific volume (SV) was calculated as follows:

$$SV (cm^3/g) = \frac{VL}{W} \quad (2)$$

And the density (DL):

$$DL (g/cm^3) = \frac{W}{VL} \quad (3)$$

2.6. Texture Analysis of Bread

Eighteen grams (18 g) of dough from each flour sample was weighed into aluminum molds of 30 mm diameter and baked into bread. The bread samples of 30mm thickness were then used for the Texture Profile Analysis (TPA) using a TA-XT2 Texture Analyser (Stable Micro Systems Surrey, UK), with a 75 mm compression platen probe. A double-bite compression cycle was carried out. The probe was set to compress the samples from a height of 45 mm down to 23 mm (corresponding to 50% of the average bread sample height) at a speed of 7.5 mm/s during each bite. The hardness of the bread samples was determined as the peak force required to compress it through half of its weight. Other parameters derived from the TPA were springiness as the degree to which samples return to their original size after compression and chewiness, which measure the energy required to masticate the bread. Determinations were carried out on all five loaves per composite flour.

2.7. Sensory Evaluation

Bread loaves were allowed to cool for 1 h and cut into slices of uniform thickness and transferred onto white coloured plates coded with random 3-digit codes. A sensory panel consisting of 20 semi-trained staff members and graduate students at CSIR-Food Research Institute and familiar with sensory attributes of local bread was employed to evaluate the products. A 9-point Hedonic scale was used to rate the breads for appearance, taste, texture and overall acceptability. A score of 1 represented “dislike extremely” and a score of 9 represented “like extremely” [11]. An atmosphere of complete quietness and privacy was provided for each panelist. The sensory evaluation was conducted between 10:30 am and 11:30 am and a randomized complete block design was used in which the samples were randomly assigned to each panelist [12, 13]. Four bread samples were evaluated at a time and individually to the panelists along with water and neutral cream crackers. The sensory evaluation was performed in a designated sensory analysis facility at CSIR-Food Research Institute with conventional lightning and equipped with individual booths.

2.8. Data Analysis

The data obtained were analyzed by ANOVA using SPSS 16.0. Duncan multiple range test (level of significance of $p = 0.05$) was performed to evaluate the level of differences among means of baking properties and sensory attributes of bread samples baked with increasing substitution of cassava flour from the different cassava varieties in the composite flour.

3. Results and Discussion

3.1. Specific Volume and Density of Composite Wheat/Cassava Bread

Specific volume of bread made from wheat and cassava composite flour decreased significantly ($p < 0.05$) with increasing proportion of cassava flour (Table 1). Highest bread specific volumes were obtained with 10% *Afisiayi* flour and 10% *Doku duade* flour and were similar to the control bread made of 100% hard wheat. Bread made with 20% and 30% *Bankye hemmaa* flour had lower specific volume than the other bread samples with the same substitution level. Breads made with *Afisiayi* flour showed the highest specific volume, which was comparable to that of breads baked with 10% *Bankye hemmaa* and 20% *Doku duade* flour. This confirms the findings of Almazan [14] who observed a significant genotypic effect on cassava/wheat composite bread quality, especially at high cassava flour concentrations.

Table 1. Specific volume and density of bread baked with three cassava varieties-wheat composite flours

Cassava variety	Proportion of cassava flour (%)	Specific volume (cm ³ /g)	Density (g/cm ³)
<i>Afisiayi</i>	10	3.43 ^a	0.29 ^a
	20	3.25 ^b	0.31 ^b
	30	3.18 ^{bc}	0.31 ^{bc}
<i>Bankye hemmaa</i>	10	3.07 ^{cd}	0.33 ^{cd}
	20	2.74 ^e	0.36 ^e
	30	2.41 ^f	0.41 ^f
<i>Doku duade</i>	10	3.41 ^a	0.29 ^a
	20	3.13 ^{bc}	0.32 ^{bc}
	30	2.97 ^d	0.34 ^d
Control 100 % wheat		3.46 ^a	0.29 ^a

Means in column followed by the same letter are not significantly different ($p < 0.05$) from each other.

The same trend was observed for the density. Density of bread samples increased significantly ($p > 0.05$) with increasing proportion of cassava flour (Table 1). There was no significant difference between bread loaf density of the control and the breads made with 10% *Afisiayi* flour and 10% *Doku duade* flour.

The decrease in composite bread loaf specific volume with increasing concentration of cassava flour in the samples was similarly observed by Eggleston [15] and Aboaba and Obakpolor [2]. Studies shows that loaf volume is affected by the quantity and quality of protein in the flour used for baking and also by proofing time, baking time and baking temperature [16]. Cassava flour lacks gluten and is therefore unable upon hydration to form the cohesive visco-elastic dough capable of forming the typical fixed open foam structure of bread [4, 17]. Consequently, an increase in proportion of cassava flour in the composite reduces the gluten content as a percentage of the total flour. Gluten is responsible for dough elasticity, thus, an increased substitution with cassava flour would result in weaker and

less elastic dough and a reduction in the leavening ability, resulting in bread with lower loaf volume and higher density. An inclusion of cassava flour beyond 20% significantly reduced the leavening profile of the dough similar to observations in this present study [2].

Weakening of dough with increasing proportion of cassava flour has also been observed [15, 18]. The authors reported decreased dough development time as the level of cassava flour increased. A shorter development time reflects a lower gluten strength and a faster water uptake by the components present in the flour [15]. This was confirmed by the higher water absorption observed as the level of cassava flour in the dough increased and probably correlated to a higher amount of damaged starch in cassava flour and its higher water-binding capacity compared to wheat flour. The authors also found that dough stability decreased with an increased concentration of cassava flour. Dough stability is a good indicator of dough strength as it corresponds to the time during which the dough can resist mixing before it breaks down [15]. Although, cassava flour is more appropriate than its purified starch for use in some bakery applications [19], others have described cassava starch as showing better stability and baking response in composite flours [18, 20].

Texture evaluation of composite wheat/cassava bread

An increase in bread hardness with increasing amount of cassava flour was observed for all three cassava varieties (Figure 1). Bread prepared from the three cassava-wheat composite flours had a harder texture than the control bread made from 100 % wheat flour. This observation corroborates earlier studies by Abdelghafor *et al.* [3] and Phattanakulkaewmorie *et al.* [21], who reported increased hardness in bread with increasing sorghum content in sorghum-wheat composite flours. Although bread hardness is dependent on moisture content, moisture migration and redistribution of water [22], gluten-starch interactions [23] and retrogradation of starch are very important phenomena responsible for bread hardness [24]. As bread cools after baking, starch retrogrades and gel within the inter-granular spaces, providing rigidity and resulting in bread hardening [25]. Cassava flour, essentially, is starch and therefore an increase in its content in the composite flour assist the occurrence of retrogradation in bread upon cooling and in storage. Furthermore, cassava flour was reported to produce firm and compact bread because it increases dough viscosity [20]. Generally, the three cassava varieties resulted in varying bread texture, from 22.0 N in bread made with 10% *Bankye hemma* to 90.9 N for bread made with 30% *Doku duade* (Figure 1). This reflects different extents of retrogradation of starches in these cassava varieties composite flours.

Springiness refers to the rate at which a deformed product goes back to its un-deformed state, when the deforming force is removed while chewiness is the energy needed to masticate solid food to a state of readiness for swallowing [27] and is directly related to hardness and chewiness. Generally, a variation in substitution level had a

corresponding effect on springiness and chewiness. Increasing the content of cassava in the composite resulted in bread that was less springy and difficult to chew. As shown in figure 5, springiness of bread substituted with 10% and 20% cassava flour compared well with the control, while those with 30% cassava were less springy than the control. The chewiness of bread from 10% *Afisiayi* and 10% *Bankye hemmaa* compared fairly well with that of 100% wheat (Figure 6). Conversely, samples from 10, 20 and 30% *Doku duade* differed markedly from the control as were observed to be the most difficult to chew among the remaining varieties. Springiness, like hardness is greatly affected by moisture content, moisture redistribution and retrogradation of starch [22, 24] therefore an increase in cassava flour proportion is likely to result in more retrogradation when the bread cools.

Sensory evaluation of composite wheat/cassava bread

The mean scores given by the sensory panel for appearance, taste, texture and overall acceptability of the cassava-wheat composite flour bread are presented in Figures 2-4. Mean score for overall acceptability on a 9-point scale ranged from 6.1 to 8.0 for all cassava varieties composite flours. The bread samples that did not differ significantly ($p < 0.05$) from the control in overall acceptability were breads with 10% *Afisiayi* flour, 10% and 20% *Bankye hemmaa* flour, indicating the most preferred samples. Figures 2-4 show a comparison of bread from composite flours from different varieties of cassava and

wheat at varying levels of substitution. At 10% level of substitution, bread baked from composite flour from *Afisiayi* cassava-wheat composite flours was rated highest for all three attributes and overall acceptability, exceeding also bread from the control flour, while breads containing *Bankye hemmaa* received the lowest rating (Figure 2). Beyond 10% substitution, bread from the control flour was rated highest compared to bread from the composites (Figure 3). For 30% substitution, bread containing *Doku duade* cassava-wheat composite had the lowest scores for each attribute.

These results are similar to those obtained by Eddy *et al.*, [28] and Aboaba and Obakpolor [2] who reported that breads baked with 10 and 20 % cassava-wheat composite flour were not significantly different in any sensory attributes, and also not in consumers' readiness to buy compared to the control (100% wheat). The authors found that bread baked from 30% composite flour and above showed low mean scores to all sensory attributes measured. The appearance of the breads in our study was quite uniformly rated since only breads with 30% *Bankye hemmaa* and 30% *Doku duade*, respectively, obtained a lower score compared to the control. For taste, samples baked with 20% *Afisiayi* flour, 30% *Bankye hemmaa* flour and 30% *Doku duade* flour differed from the control, whilst the remaining samples showed a comparable taste to the control. The rating of texture showed a greater variability since four of the samples (20% *Afisiayi*, 30% *Afisiayi*, 30% *Bankye hemmaa* and 30% *Doku duade*) obtained a significantly lower score than the control.

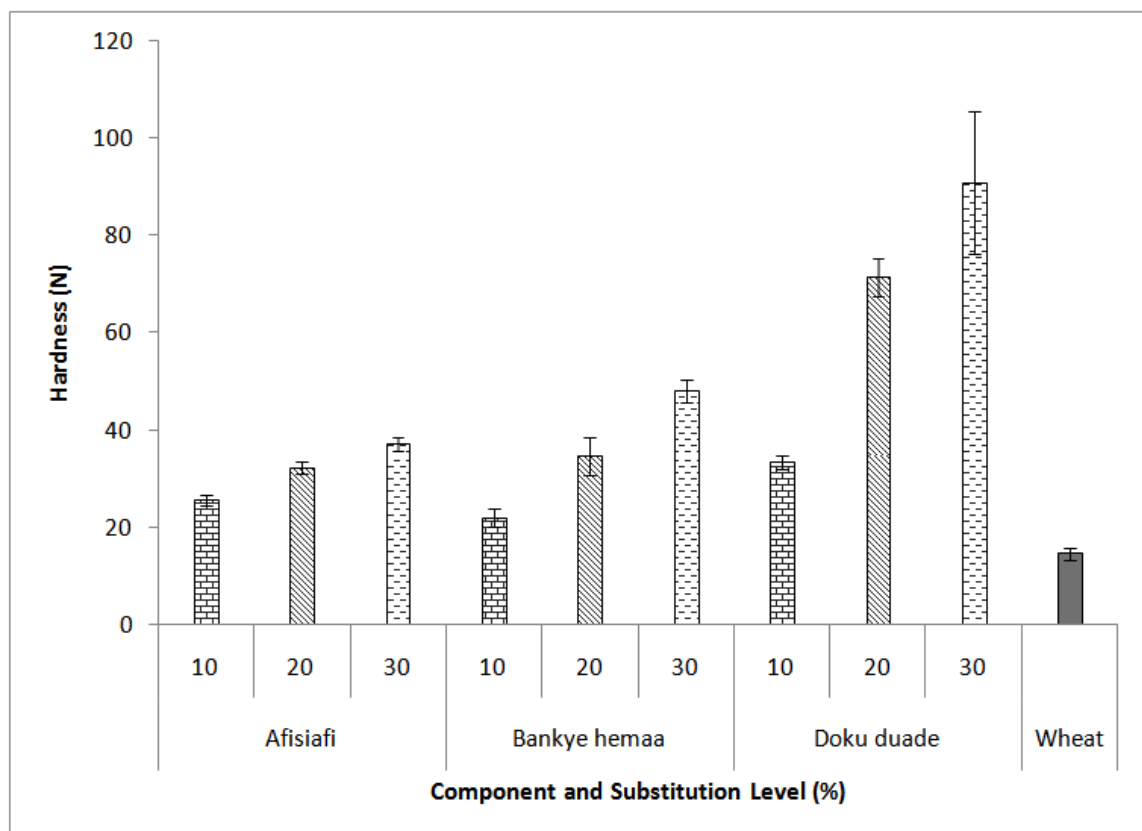


Figure 1. Hardness of wheat/cassava composite flour bread measured using a texture analyzer

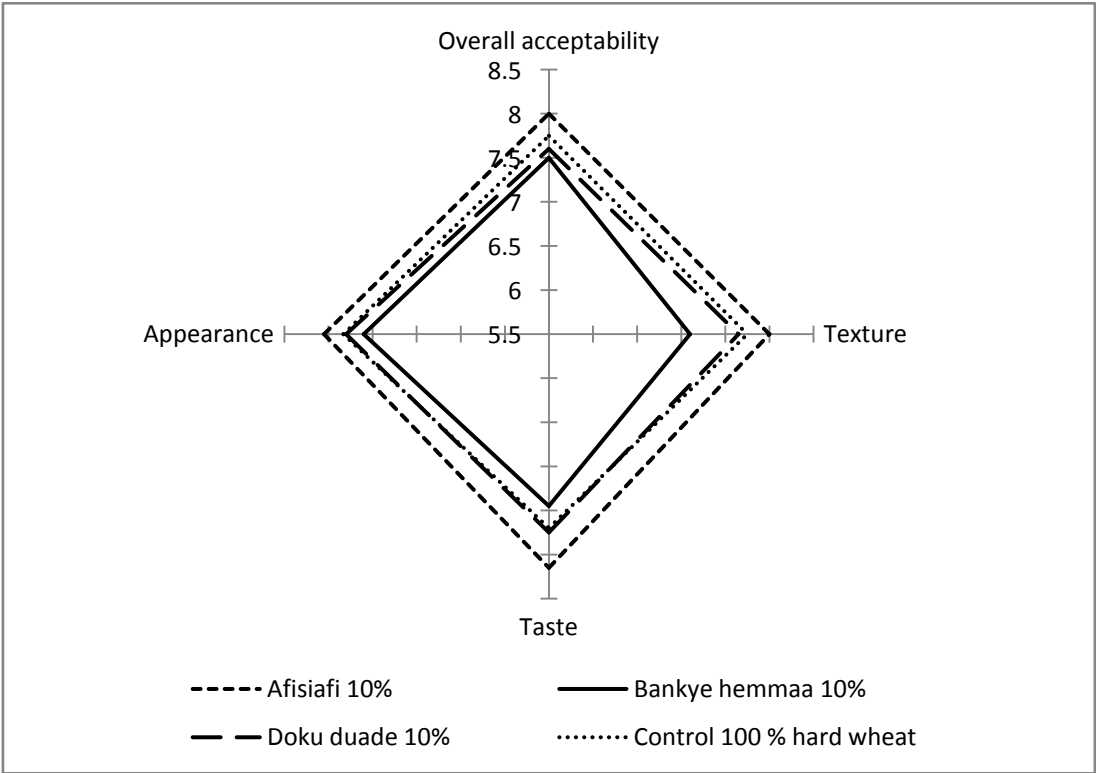


Figure 2. Sensory profile of bread from different varieties of cassava-wheat composite at 10% substitution level

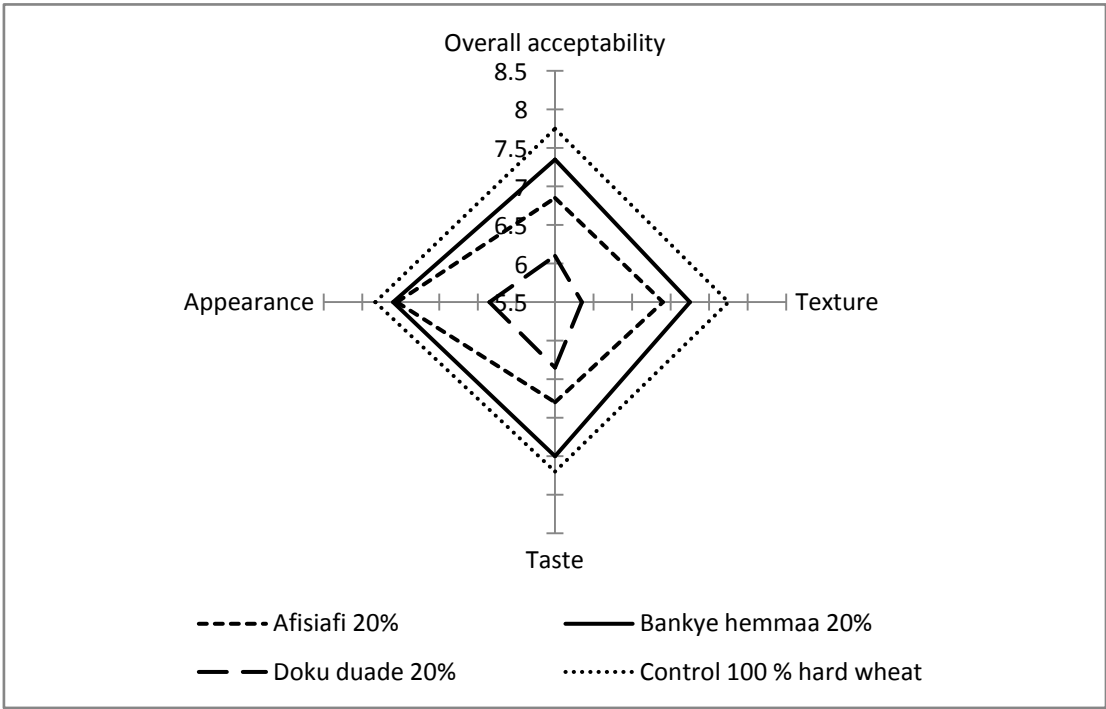


Figure 3. Sensory profile of bread from different varieties of cassava-wheat composite at 20% substitution level

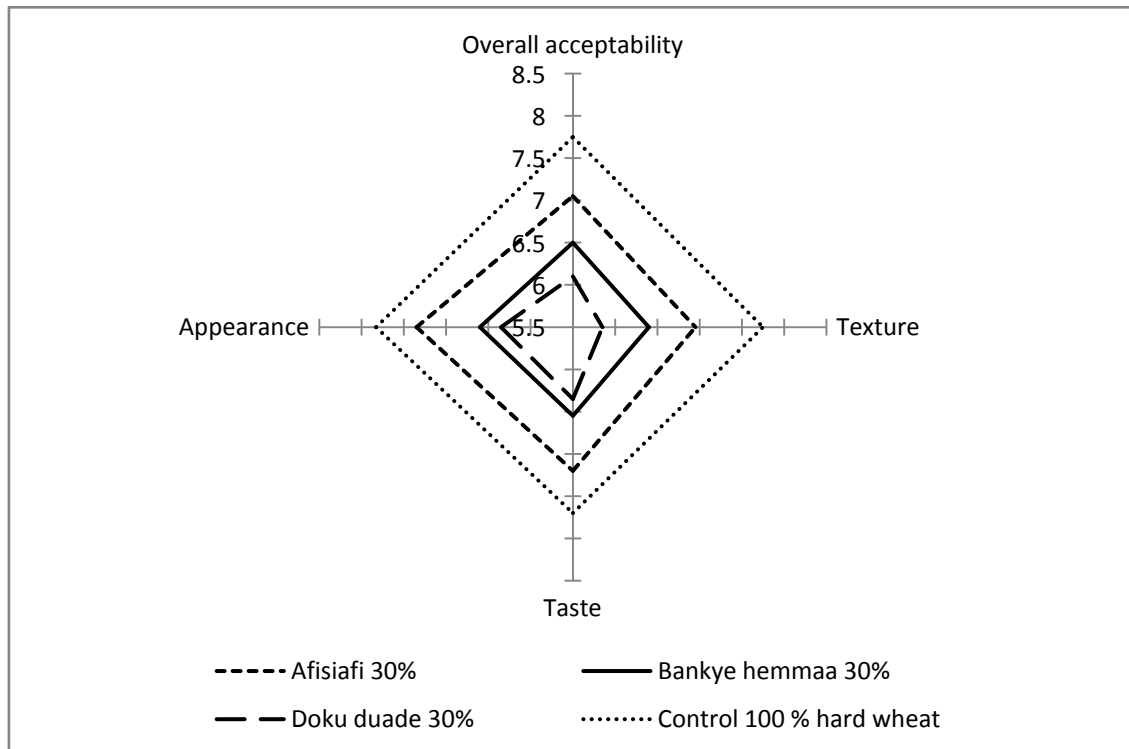


Figure 4. Sensory profile of bread from different varieties of cassava-wheat composite at 30% substitution level

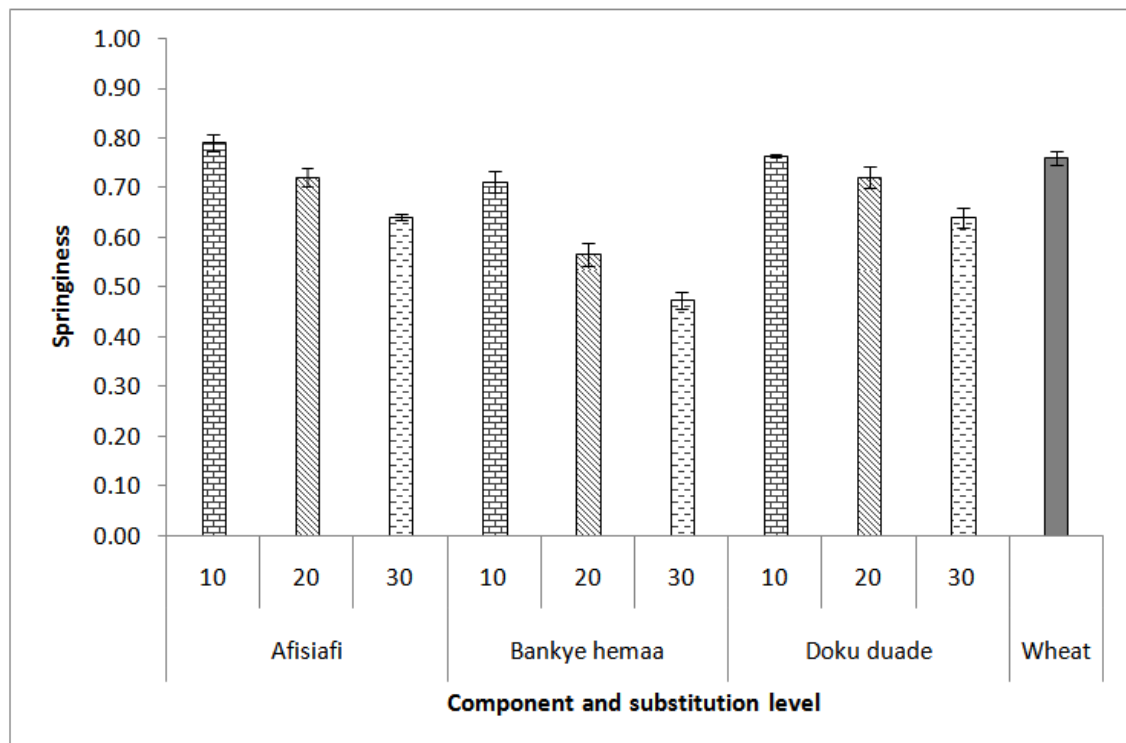


Figure 5. Springiness of wheat/cassava composite flour bread measured using a texture analyzer

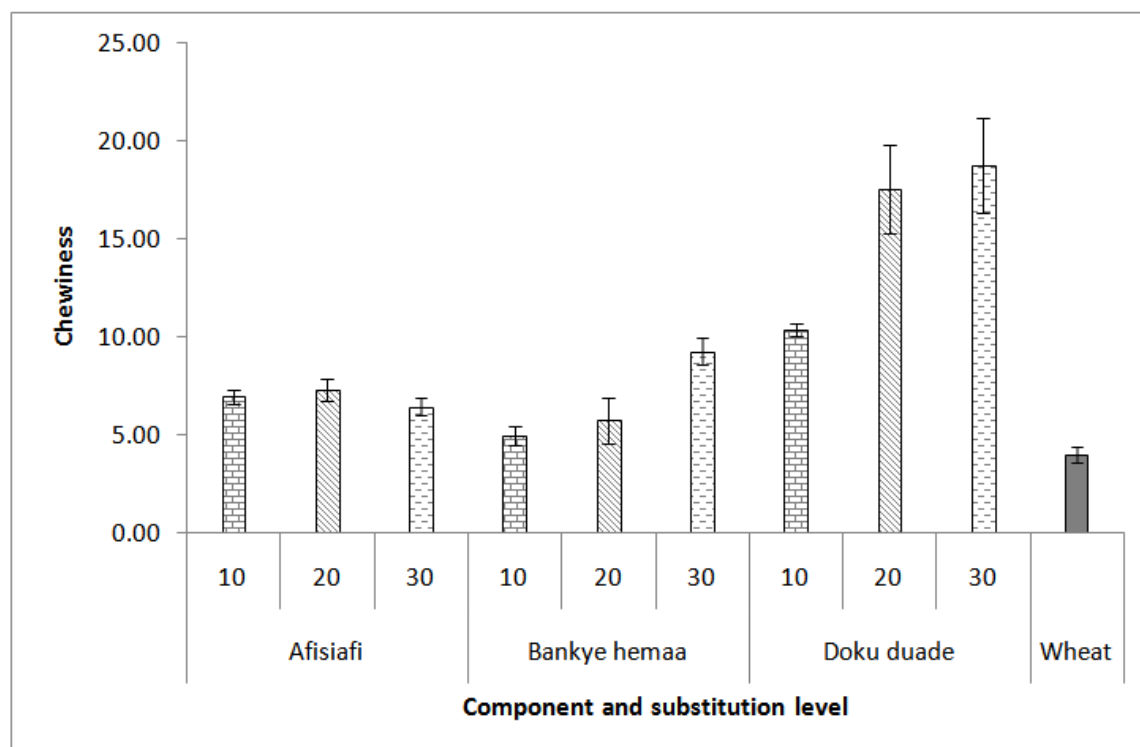


Figure 6. Chewiness of wheat/cassava composite flour bread measured using a texture analyzer

The results showed how an increased concentration of cassava flour within the same variety affected the rating of the sensory attributes. For breads made with *Afisiafi*, 10% inclusion level gave significantly higher scores for all sensory attributes than inclusion levels of 20% and 30%, for which the panel did not observe any significant differences. Bread made with 10% and 20% *Bankye hemmaa* obtained similar scores, which differed significantly ($p < 0.05$) from breads baked with 30% *Bankye hemmaa* with lower scores for all attributes. The same trend was observed for breads made with *Doku duade* cassava flour-wheat composites, where a 30% inclusion level gave lower scores than 10 and 20% for all attributes. The general trend was that an increased amount of cassava flour decreased the score for all sensory attributes. This trend was similar to that observed by Almazan [14] on total score for volume, colour and character of the crust, texture and grain, crumb colour and taste decreased as the concentration of cassava flour increased. Aboaba and Obakpolor [2] showed that an increasing amount of cassava flour affected the appearance of the bread crust and noticed a paler crust colour in samples containing high concentrations of cassava flour (30 and 40%) because of the whiter colour of cassava flour compared to wheat flour. The lower score for texture obtained by the sensory panel for bread samples with 30% cassava flour of all varieties is attributed to the harder texture as was measured by a texture analyzer. This is confirmed by the general comments expressed by the panelists for bread samples containing 30% cassava flour as the texture been “compact”, “sticky”, “heavy” and “brittle” comparable to the high values for hardness, chewiness and lower value springiness. Further,

the panelist described the bread taste as “slight bitterness” comparable to the lower values obtained for 20% *Afisiafi*, 30% *Bankye hemmaa* and 30% *Doku duade*.

The scores obtained for overall acceptability corresponded to a degree of liking from “slightly” to “very much” and indicated that the bread samples were generally appreciated by the panelists. The relatively high amount of shortening and sugar in the bread recipe may have contributed to a pleasant taste. It is also well recognized that addition of fat plasticizes dough and increases bread volume, typically by 10%. It makes bread stay soft and more palatable for a longer period of time [29]. With a relatively high percentage of fat and sugar, it is possible to increase the level of non-wheat flour considerably without significant changes in the bread characteristics [2].

4. Conclusions

An increased proportion of cassava flour in wheat plus cassava composite bread reduced bread specific volume and increased density and hardness due to reduction in wheat proportion and thus of gluten-forming proteins in the composite flours. A substitution level of 10% *Afisiafi* and 20% *Bankye hemmaa* cassava flour in composite bread on overall acceptable was similar to 100% wheat bread and therefore has the most suitable potential to replace part of wheat flour in bakery products. The production of cassava flour from the varieties studied is a huge opportunity for commercial production of bread made from composite flour of cassava and wheat. This is very appropriate for cassava

growing regions as alternative value addition to reduce the high post-harvest losses associated with cassava.

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