

The Influence of Grating, Fermentation and Variety on the Physio-Chemical Quality of Cassava Starch

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Abstract

The study was conducted to determine the influence of grating and fermentation parameters on the physicochemical quality of starch obtained from two cassava varieties in Sierra Leone (*i.e.*, SLICASS 11 and SLICASS 6). Fresh cassava roots harvested from the Department of Agricultural Engineering were peeled, washed and grated before fermentation and starch extraction. Fermentation was carried out under separate aerobic and anaerobic conditions for a period of Seven days. Physicochemical analyses were conducted at the Post-harvest Food and Bioprocess Engineering Laboratory of the Department of Agricultural and Bio-System Engineering, Njala University to determine the solubility, water absorption capacity and swelling power of starch extracts obtained from various experimental treatments. Fermentation method and duration had significant effects on the solubility, water absorption capacity (WAC) and swelling power (SP) of starch extracts. Maximum solubility and WAC were recorded on the fifth day, for both cassava varieties tested, with apparent significant difference resulting from the two grating bands (*i.e.*, with 1.5-inch nail hole and 4-inch nail hole sizes, respectively). While swelling power increased consistently with temperature for starch obtained from SLICASS-11 variety, an irregular pattern was observed for SLICASS-6 variety. A multiple correlation analysis proposes a significant and weak correlation between temperature, WAC (+0.150) and swelling power (+0.048). Also multiple correlation analyses suggest a significant correlation between fermentation period, the functional properties of starch extracts obtained from both fermentation methods and cassava varieties (*i.e.*, solubility (-0.226), water absorption capacity (+0.301) and swelling power (+0.329)).

Keywords

Fermentation, Grating Band, Cassava Variety, Solubility, Swelling Power

1. Introduction

Cassava (*Manihot* spp.) is one of the indispensable food crops consumed and sustains food security in the tropics, especially Sub-Saharan Africa. Due to indispensability to both human and animal, there have been several investigations on the aspect of nutrition and quality improvement of this crop and its products [1]-[3].

In Africa, cassava can be processed and consumed as food in various forms: boiled, fried or baked and processed as garri, Fufu, fermented flours, fresh tuber, cassava cake, starch, etc., and it is processed before consumption in order to detoxify and prolong shelf life. Also according to the researches by [4] [5], it confirmed that microbial activities during fermentation reduce HCN content of cassava as the fermentation period extends. The processing method may be similar as in all cases, heat is needed, but the end product names vary by country, region, and local dialect, whereas the most common product well known in West Africa and beyond is cassava flour, garri, fufu and cassava starch [6].

Cassava can tolerate poor soil and is subsequently drought-resistant. Maturity varies by varieties but early maturity for fast variety begins 6 months after planting, therefore, its root can be ready for harvest 6 to 12 months and harvesting of root can be delayed until 2 years [7] [8]. A major limitation of cassava production is the rapid postharvest deterioration of its roots, which usually prevents their storage in the fresh state for more than a few days [9].

For more than a decade now, cassava has been accepted as the second staple food crop in Sierra Leone and a potential raw material for a wide range of processed products in many Sub-Saharan nations, especially Sierra Leone. Also, it is recognized as a major agricultural commodity for poverty eradication, ensuring food, and nutritional security. Regardless its importance to Sierra Leonean, it is also among the chief food growth in the developing world of South America, Asia and Sub-Saharan African countries [10].

The level of dependence of cassava in the sub-Saharan region was estimated as 45% according to [10], which is approximately 750 million people as their primary sources of carbohydrate, therefore, demand of cassava is at increase, as the top three major producers in the world include Nigeria, Brazil and Thailand with annual production of 37.5 million tons, 24.5 million tons and 24.5 million tons respectively [11], and the production increases every year.

In Sierra Leone, cassava is used for many purposes and only two parts of cassava plant are used, that is the root (tuber) and leaves for both human and animal. Cassava tuber (root) can be processed in many ways to obtain products that can be directly used for consumption, but most of the processing methods involve fermentation. Fermentation is said to be the oldest method of food preservation

and conservation used by many people in West Africa and different parts of the world, but according to writing history, the origin of fermentation is very difficult to trace [12].

Fermentation is important in processing cassava tuber (root), it helps reduce postharvest loss by prolonging its shelf-life, it also helps detoxify hydrogen cyanide (cyanogenic glucosides) content especially when the fermentation period increases [13]. The fermentation method varies by preference where some farmers use aerobic method by grating the tuber (root) and use the mash to ferment in a sack and this is the most common practice in Sierra Leone. On the other hand, Anaerobic is used but not common in Sierra Leone where the mash or root is sub mass in water for a couple of days.

According to the study by [14]-[16], microorganisms involved in cassava fermentation process were found to be the following: *Bacillus subtilis*, *Klebsiella sp.*, *Candida tropicalis*, *C. krusei*, and a wide spectrum of lactic acid bacteria, major among which are *Lactobacillus plantarum* and *Leuconostoc mesenteroides*.

Generally, product quality prior to fermentation has been a big challenge for cassava producers in Sierra Leone as fermentation processes influence on the quality, therefore, this research could have a significant impact on identifying the influence of fermentation on the quality of cassava products.

2. Materials and Methods

The study was conducted at the Department of Agricultural Engineering, Njala University, Sierra Leone. Laboratory work and data collection were specifically carried out in the Postharvest Food Laboratory, which is within the Departmental facilities.

Cassava varieties used for the study were from the lineage of SLICASS number 6 and 11. SLICASS variety is one of the improved varieties that are currently under experimental observation at the Department of Agricultural Engineering.

2.1. Sample Preparation

Peeling and washing: Peeling was done manually by removing the outer cortex and the wooding part at which the tuber attached to the plant. The peeled roots were transferred into a bowl containing clean water for thorough washing.

Grating: Manual grating was employed due to sample size and the study design. Two grating bands were used of different grating raspier. 4-inch nail size band has a raspier height 0.7 cm and perforate area of 0.32 cm², and 1.5-inch nail size band has a raspier height of approximately 0.5 cm and perforate area of 0.12 cm². Each of the varieties used was gratered using the two bands.

2.2. Fermentation

After grating, the wet mash was collected into a stainless container, homogenized and divided into two portions. A portion was used for Aerobic fermentation and the other for anaerobic fermentation. The process of fermentation lasted for

six (6) days and portion from both (Aerobic and Anaerobic) were taken for determination of moisture content and extraction of starch, this process continues for seven days (Day 0 to Day 6).

Starch extraction

Starch was extracted using the wet method as described by [17] with slight modification. Approximately 100 to 150 grams of cassava mash were crushed further to produce a pulp using electric blender. The pulp was suspended in water, stirred and filtered using muslin cloth. The filtrate was allowed to stand for about 2 hours and the water decanted. The starch was allowed to settle in the sun and the sediment was removed and dried in forced air oven at 45°C for 48 hours with continuous weighing for every 8 hours starting after the first 24 hours, till a constant weight was obtained. The process of starch extraction was done for each day throughout the fermentation period for both aerobic and anaerobic.

3. Analysis of Functional Properties

3.1. Water Absorption Capacity, Swelling Power and Solubility

The water absorption capacity, swelling power and solubility were determined using the modified method of [18] to extract starch from both Aerobic and Anaerobic fermentation from Day 0 to Day 6. Approximately, 1.0 gram of sample was transferred into a weighed graduated centrifuge tube of 20 milliliter. 15 milliliter of distilled water at room temperature was added and stirred gently with hand till a solution was observed. The solution was heated in a water bath (GFL 1083) for 30 minutes with constant shaking. The heating was done at various temperatures of 40°C, 45°C, 50°C, 55°C and 60°C. After the samples were removed from the water bath, it was allowed to cool to room temperature and were centrifuged (EBA 21) for 15 minutes at 3000 rpm. After the supernatant was discarded and the residues were weighed and transferred to a forced air oven to dry to a constant weight. The dried residue was weighed and the volume was noted. The solubility, swelling power and water absorption capacity were calculated using the following formulae:

$$\text{Swelling Power} = \frac{W_{\text{wet residue after centrifuge}}}{W_{\text{sample dry basis}} - W_{\text{dried residue}}} \times 100$$

$$\text{Solubility (\%)} = \frac{W_{\text{dried residue}}}{W_{\text{sample dry basis}}} \times 100$$

$$\text{Water Absorption Capacity (\%)} = \frac{\text{Weight of dry residue}}{\text{Initial Weight of sample}} \times 100$$

$W_{\text{wet residue after centrifuge}}$: is the weight of the sediment paste after centrifugation.

$W_{\text{sample dry basis}}$: is the weight of the initial sample on dry basis.

$W_{\text{dry residue}}$: is the weight of the residue of supernatant after oven dry.

3.2. Data Analysis

Data obtained from the study were analyzed using Microsoft Excel 2013 and SPSS statistical software version 16.0.

3.3. Result and Description

Result for Solubility

Data obtained for solubility for the two varieties were analyzed and the results are presented in **Figure 1**. Solubility curve compares two varieties of cassava (SLICASS 11 and SLICASS 6), the left hand shows graph for SLICASS 11 (aerobic and anaerobic) and the right hand shows SLICASS 6 (aerobic and anaerobic). From the graph of SLICASS 11, the solubility shows an increase from Day 1 and maintains the maximum pick at Day 2 for both aerobic and anaerobic with anaerobic being superior of aerobic, the solubility decreases from Day 2 to Day 7 for anaerobic, but aerobic takes the second increase from Day 6 to Day 7. Generally, the fermentation effect on solubility shows its maximum effect at Day 2 for both fermentation method (aerobic and anaerobic).

For graph on the right hand (SLICASS 6), shows increase for both fermentation methods but not uniform. Aerobic (orange color) shows its maximum pick between Day 2 and Day 3, where anaerobic maintained a pick from Days 5 to 7.

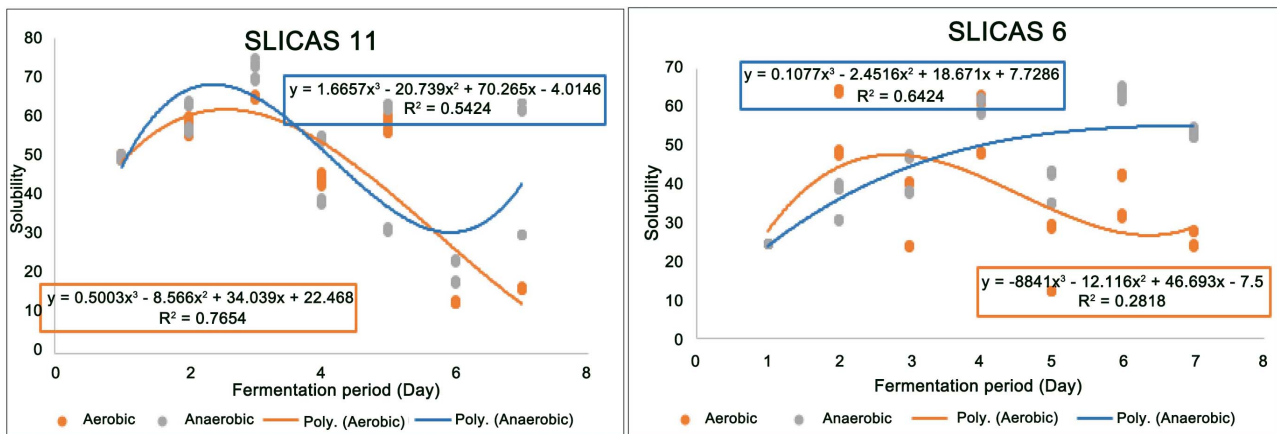


Figure 1. Solubility curve with respect to fermentation period and method, where graph on the left = SLICASS 11 and graph on the right = SLICASS 6 and the blue curve = Anaerobic, where orange curve = Aerobic.

Result for Water Absorption Capacity (WAC)

Results showed below (**Figure 2**) are graphs showing water absorption capacity (WAC) for SLICASS 11 (graph on the left hand) and SLICASS 6 graph on the right hand. The result compares the effect of fermentation period and method on water absorption capacity of cassava starch. The test (SLICASS 11) shows little effect on anaerobic fermentation method where it shows slight or no increase in WAC across the fermentation period, on the other hand, aerobic curve shows a spontaneous increase from Day 2 and maintains constant and pick at Day 6. The effect of fermentation begins at Day 2 for both fermentation method, but intensive for aerobic. A polynomial equation of third order was drawn for the two methods and the results for R^2 were Aerobic = 0.0735 and Anaerobic = 0.0211.

Result of SLICASS 6 (graph on the right hand) shows three curves where aerobic is orange, anaerobic blue and aerobic + anaerobic black. The curves presented

a similar trend, where the maximum picks were maintained between Days 5 and 6 for the three curves. R^2 was obtained from the polynomial equations of third order for the three curves where aerobic $R^2 = 0.2123$, anaerobic $R^2 = 0.3541$ and aerobic + anaerobic $R^2 = 0.2162$. Generally, the WAC for both varieties shows its maximum pick between Days 5 and 6 for the two fermentation methods.

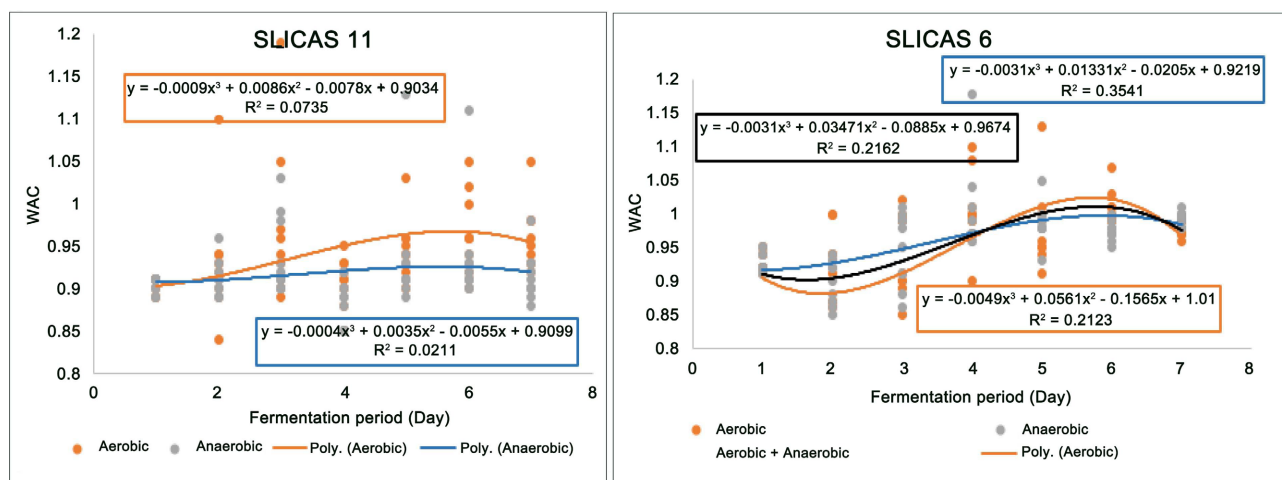


Figure 2. Water absorption capacity (WAC) curve with respect to fermentation period and method, where graph on the left = SLICASS 11 and graph on the right = SLICASS 6 and the blue curve = Anaerobic, orange curve = Aerobic, and black curve = both Aerobic and Anaerobic.

Result for Swelling Power

Figure 3 showed results obtained for swelling power of two varieties (SLACAS 11 and SLACAS 6), where graph on the right hand represented SLICASS 11 and graph on the left hand represented SLICASS 6.

From the result for SLICASS 11 fermentation period shows greater effects on anaerobic than aerobic where the swelling power pick was observed between Day 2 and Day 3 with anaerobic being superior to aerobic, after Day 3 aerobic decreases till the final day of fermentation, where anaerobic curve decreases till Day 6 and takes a second increment as shown in the graph (SLICASS 11). The trend line was determined for the two fermentation method curves using polynomial third order and R^2 was obtained; aerobic $R^2 = 0.5582$ and anaerobic $R^2 = 0.5011$.

Result of SLICASS 6 (graph on the right hand) shows curves of aerobic (orange) and anaerobic (blue). The curves presented an increase of swelling power for anaerobic from Day 1 to Day 6 with a maximum pick observed between Days 5 and 6, whereas the aerobic curve shows an increase from Day 1 to 3 and its maximum pick observed at Day 3. Also a trend line of the curves was determined with polynomial third order and the following R^2 results were obtained; aerobic $R^2 = 0.1917$ and anaerobic $R^2 = 0.5755$.

Figure 4 shows polynomial curve of third order on the effect of fermentation period on solubility for both varieties and the averages of the two. The trend-line shows how the solubility responded to fermentation period, where the blue line =

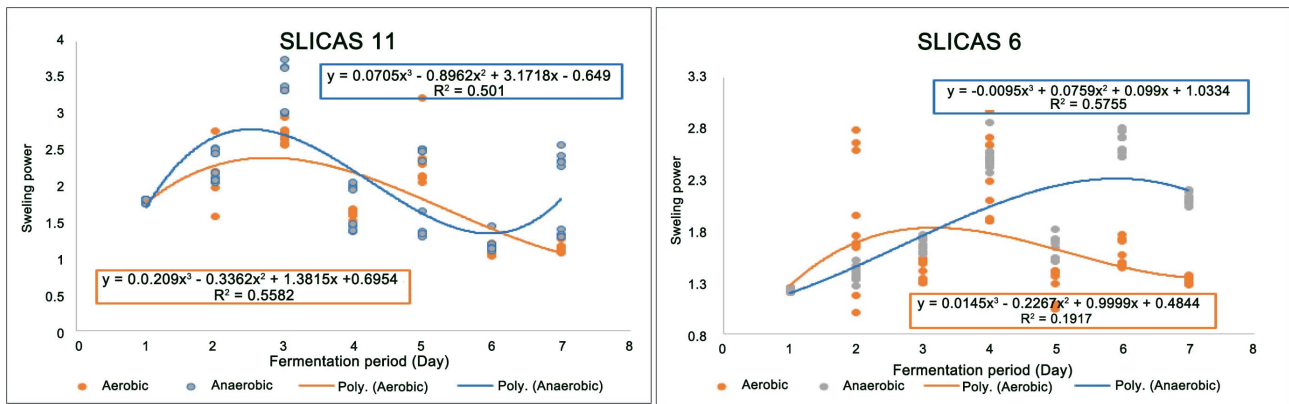


Figure 3. Swelling power curve with respect to fermentation period and method, where graph on the left = SLICASS 11 and graph on the right = SLICASS 6 and the blue curve = Anaerobic, where orange curve = Aerobic.

SLICASS 6, orange line = SLICASS 11 and Black line = average for both varieties. The solubility increases consistently from Day 1 to Day 2 for both varieties and their averages as it attained the highest picks with SLICASS 11 been superior. It later decreases uniformly from Days 3 to 6 and maintained constant till Day 7.

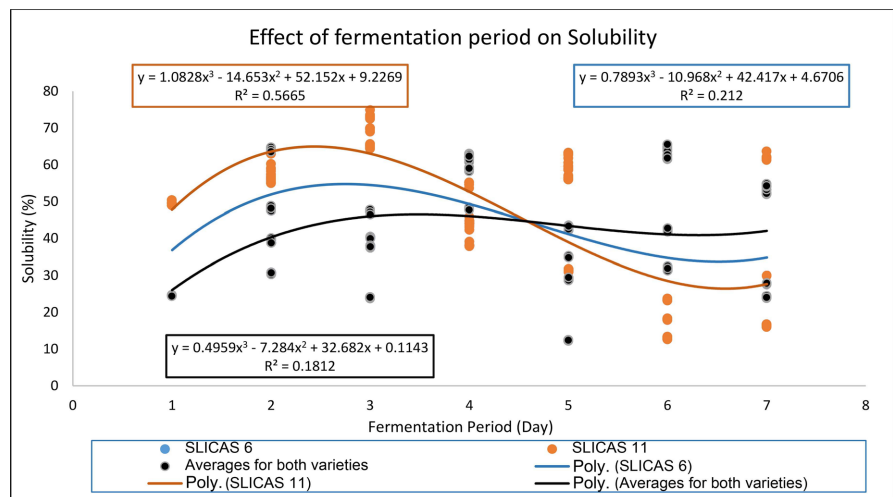


Figure 4. Effect of fermentation period on solubility.

The graph (Figure 5) shows the influence of fermentation period on swelling power of cassava starch. From the graph, the swelling power increases as the fermentation period extends from Day 1 to Day 3 till the swelling power attains its maximum pick for SLICASS 11 variety, while SLICASS 6 maintained a slight increase from Day 1 to Day 4 and later maintained constant till Day 6. The lines were drawn using polynomial equation third order and R² was determined for each line, where SLICASS 11 obtained the higher value of R² = 0.4611, SLICASS 6 R² = 0.2002 and the average of both varieties R² = 0.1657.

The graph (Figure 6) shows a relationship between Solubility and Swelling power. The curve shows that a linear relationship between the two, is at initial; the swelling power decreases slightly as solubility increases to 20%, after which

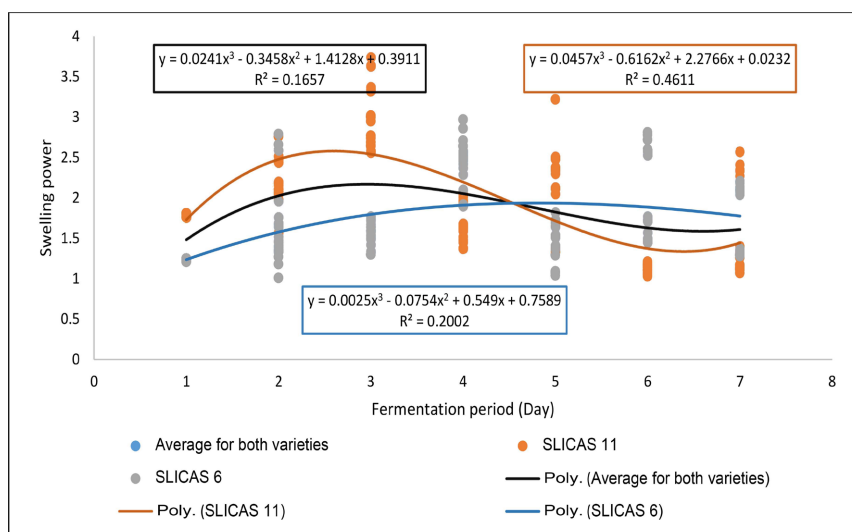


Figure 5. Influence of fermentation period on swelling power.

the swelling power takes linear increase as the Solubility increases. The curve presented an R-square quadratic of +0.937, which indicates a strong interaction between the two.

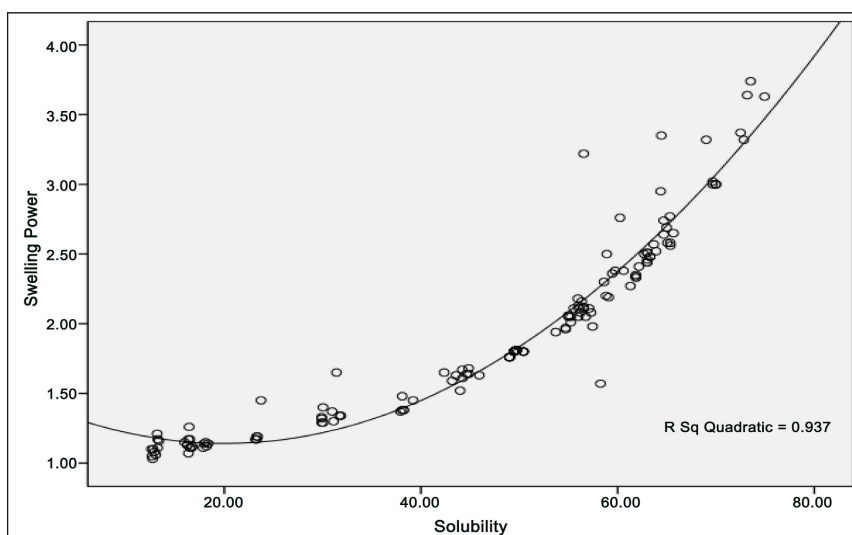


Figure 6. Relationship between solubility and swelling power.

Statistical analysis of functional properties

Table 1 shows correlations interaction relationship between dependent and independent variables, where solubility shows a positive and significant correlation between fermentation method and fermentation period, swelling power and grating bands, but a negative correlation for water absorption capacity, similarly water absorption capacity presented significant and positive correlation for grating band, fermentation period and fermentation method. Likewise swelling power shows significant correlation for fermentation method and period, water absorption capacity and solubility.

Table 1. Correlation significant (2-tailed) between function properties and fermentation period.

		Correlations						
		Variety	Gratering Band	Fermentation method	Fermentation Period	Solubility	Water Absorb Capacity	Swelling Power
Variety	Pearson Correlation	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a
	Sig. (2-tailed)
	N	140	140	140	140	140	140	140
Gratering Band	Pearson Correlation	. ^a	1	0.000	0.000	+0.047	+0.021	+0.005
	Sig. (2-tailed)	.	.	1.000	1.000	0.581	0.806	0.950
	N	140	140	140	140	140	140	140
Fermentation method	Pearson Correlation	. ^a	+0.000	1	+0.000	+0.318**	+0.060	+0.303**
	Sig. (2-tailed)	.	1.000	.	1.000	0.000	0.484	0.000
	N	140	140	140	140	140	140	140
Fermentation Period	Pearson Correlation	. ^a	0.000	0.000	1	+0.226**	+0.402**	+0.329**
	Sig. (2-tailed)	.	1.000	1.000	.	0.007	0.000	0.000
	N	140	140	140	140	140	140	140
Solubility	Pearson Correlation	. ^a	+0.047	+0.318**	+0.226**	1	-0.049	+0.898**
	Sig. (2-tailed)	.	0.581	0.000	0.007	.	0.562	0.000
	N	140	140	140	140	140	140	140
Water Absorb Capacity	Pearson Correlation	. ^a	+0.021	+0.060	+0.402**	-0.049	1	+0.335**
	Sig. (2-tailed)	.	0.806	0.484	0.000	0.562	.	0.000
	N	140	140	140	140	140	140	140
Swelling Power	Pearson Correlation	. ^a	+0.005	+0.303**	+0.329**	+0.898**	+0.335**	1
	Sig. (2-tailed)	.	0.950	0.000	0.000	0.000	0.000	.
	N	140	140	140	140	140	140	140

a. Cannot be computed because at least one of the variables is constant. **. Correlation is significant at the 0.01 level (2-tailed).

The effect of fermentation period (**Table 2**) shows a significant difference between solubility and all days of fermentation is for water absorption capacity. Days 0, 2, 3, 4, 5, and 6 show no significant difference but there was significant difference between Day 1 and 2 respectively. The test also shows a significant difference between swelling power and Days 0, 1, 2, 3, 4 and 5 respectively, where Days 5 and 6 show no significant difference.

Table 2. Effect of fermentation on the functional properties.

Fermentation Period	N	Solubility	Water Absorption Capacity	Swelling Power
Day 1	40	37.0920c	0.9160b	1.5130a
Day 2	40	52.0465f	0.8837a	1.9225d
Day 3	40	52.8080g	0.9482c	2.2782f
Day 4	40	51.5305e	0.9503c	2.0375e
Day 5	40	41.2220d	0.9740c	1.7908c
Day 6	40	33.5398a	0.9700c	1.6400b
Day 7	40	35.4157b	0.9603c	1.6113b
Sig.		1.00	1.00	1.00

Solubility: The error term is Mean Squire (Error) = 0.238; Water absorption capacity: The error term is Mean Squire (Error) = 0.005 Swelling power: The error term is Mean Squire (Error) = 0.029; Mean with the same sub script in not significant.

3.4. Discussion

Effect temperature of moisture content:

The moisture content of any produce will depend on factors such as the end uses of the product, period of storage, processing method and season. A lower moisture content in flour is a good indication of microbial stability and may also contribute to reducing the tendency of staling in baked food products [19]. Generally, temperature is critical factor for cassava starch gelatinization as cassava has very low gelatinization temperature (600°C to 700°C) compared to other starchy crop like yam. From the result obtained (**Figure 2**) temperature shows no significant effect on SLICASS 11 single and double stage, but SLICASS 6 shows significant effect and difference on moisture content between the two stages of drying (double and single stage) and gratering band, where single stage was observed to have higher moisture content than double stage for SLICASS 6, this may be as a result of their different in starch content where SLICASS 11 is a yellow fresh and SLICASS 6 is not yellow fresh.

Effect of fermentation on the functional properties:

From the result obtained for solubility (**Figure 1**) fermentation period effect was significant difference between the fermentation method for SLICASS 11, but no significant difference between the fermentation methods for SLICASS 6, and the solubility pick was observed at Day 2 for SLICASS 11 both aerobic and anaerobic, where SLICASS 6 picks for anaerobic was observed at Day 6 and aerobic Day 2. Maximum fermentation effect for WAC (**Figure 2**), was observed at Day 6 for both fermentation method and varieties with aerobic superior of anaerobic.

Swelling power (**Figure 3**) presented a similar fermentation effect SLICASS 11 aerobic and anaerobic and the maximum swelling power was observed between Days 2 to 3, where SLICASS 6 obtained its pick for anaerobic at Day 6 and aerobic at Day 3.

From (**Figure 6**) the interaction between solubility and swelling power, it was observed to have linear connection where swelling power increases with increase in solubility.

From (**Table 1**) Statistical analysis of functional properties shows a significant and positive relationship between the following parameters; solubility shows a positive correlation for (fermentation method and period, swelling power and gratering bands), but a negative correlation for WAC, also WAC shows a significant and positive correlation for (gratering band, fermentation period and fermentation method), Likewise swelling power shows significant correlation for fermentation method and period, water absorption capacity and solubility.

ANOVA analysis (**Table 2**) observed fermentation period effect to be significantly differences for solubility from Day 1 to Day 7, where WAC shows no significant effect from Day 3 to Day 7. Likewise swelling power presented significantly differences from Day 1 to Day 5.

4. Conclusions

Conclusively, the functional properties play a very important role in determining

the quality of starch, where fermentation influences the attribute of the physico-chemical properties of starch as demonstrated by this study. This study clearly shows that effect of fermentation period was no significantly different between the two stages of drying for SLICASS 11, but SLICASS 6 shows a significant difference in moisture content between the two stages of drying (double and single stage) and grating band.

The correlation matrix shows a positive and strong interaction between Fermentation period, water absorption capacity and solubility but a negative correlation for swelling power. Also statistical analysis shows a significant effect of fermentation method and period on functional properties. Also maximum picks were observed on Day 5 for solubility and WAC with slight differences for grating bands. Moreover, swelling power is observed to increase consistently as temperature increases.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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