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Evaluating the Effects of Sweet Potato Varieties on Flour Quality

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Abstract:- Sweet potatoes are a highly nutritious food group, they continue to gain interest on account of the diversity of the tuber and the number of products that can be developed from the tuber itself. This is true on the global scale, however; locally the amount of such products on market is minimal. Such should be available to cater to gluten intolerant and celiac disease niches and also exhaust the favorable SP production cycle. The overall purpose of this study is to determine the best variety and treatment for flour production, for use in the formulation of a sweet potato based instant porridge. Seven varieties of sweet potato tubers: Chingovha (white flesh), Delvia (orange flesh), Irene (yellow flesh), Victoria (orange flesh), Namanga (orange flesh), Alicia (yellow flesh) and Tsumaya (pale yellow flesh) were harvested at physiological maturity and processed to flour on a lab-based pilot via thermal processing. The fresh tubers were washed, sliced and treated with Ascorbic acid to prevent browning. Following ascorbic acid pretreatment; for treatment 1 fresh tubers were dried immediately, slices for treatment 2 were parboiled for 10 minutes before drying whilst slices for treatment 3 were fermented prior to drying for 1-3 days in 5% brine and 1% sucrose solution. Post-drying: the slices were ground to fine powder and the flour product assessed on both functional and physiochemical properties with particular emphasis for use in instant porridge formulation. A Randomized Block Design was used for the experiment while sensory evaluation wase used to determine product acceptability. The product was assessed according to flour quality (color, emulsification stability, oil and water holding capacity, foreign matter and moisture content), treatment effect (before and after processing based on protein content, starch content, phenolic content, gluten content, Beta carotene content). Together these parameters determined that the ideal mode of treatment for flour production was fermentation in that it exhibited the least nutritive reductive effect across all varieties. There were significant differences (p-value) between varieties with respect to flour quality amongst oil and water holding capacities, moisture content but not for emulsification stability. The most ideal treatment was fermentation in that amongst the analyzed parameters; the greatest nutrient retention was observed for fermented samples. Tsumaya was observed to produce favorable samples for all treatments. Sensory evaluation established that fermentation was a favored pretreatment option whilst Victoria, Tsumaya and Chingovha were amongst the popular varieties and as such should be formulated into sweet potato based instant porridge.

Keywords:- Water and Oil Holding Capacity, Emulsification Stability, Acceptability.

I. INTRODUCTION

➢ *Background to Study*

The Great Famine of Ireland of 1845 to 1849 (Kianely, 1997); the drastic and tumultuous crumbling of the Irish economy and government is termed throughout history as a result of natural events. Potato blight infected all potato crops to the point of significantly slashing the nation's population, stirring uprisings and causing widespread unrest throughout Europe (Kelly & Fotheringham, 2011). Although drastic; the 'Hard Times' emphasized the significance of tubers and even related them to the well-standing of the European economies. As the time lapsed with growing populations and increased food demand, this prompted further classification of crops and their relevance. A study was carried out (Bhattachary, 2011) in which sweet potato was ranked position 5 for crops that feed the world. The study concludes that Ipomoea batatas although highly under-utilized had vast potential in that it maintained agricultural relevance in withstanding adverse abiotic and biotic stresses, nutritional composition, ease of propagation, source of subsistence, 'famine relief' and immense industrial value such as in the extraction of starch for the production of animal feed. The study further emphasized the significance of the tuber especially relative to the nutritional composition with respect to derivatives that could be attained from the tuber and an outline of the ease of processing.

With that in mind; it is unfortunate that the vast of Africa, which contains the most developing countries (Rampa. F., 2011) , regard the crop as 'poor person' food, which as a result has caused the lag in exhausting tuber properties by means of sweet potato processing. In fact, in Africa from the period before 2010 the crop was mostly grown for subsistence through backyard farming.

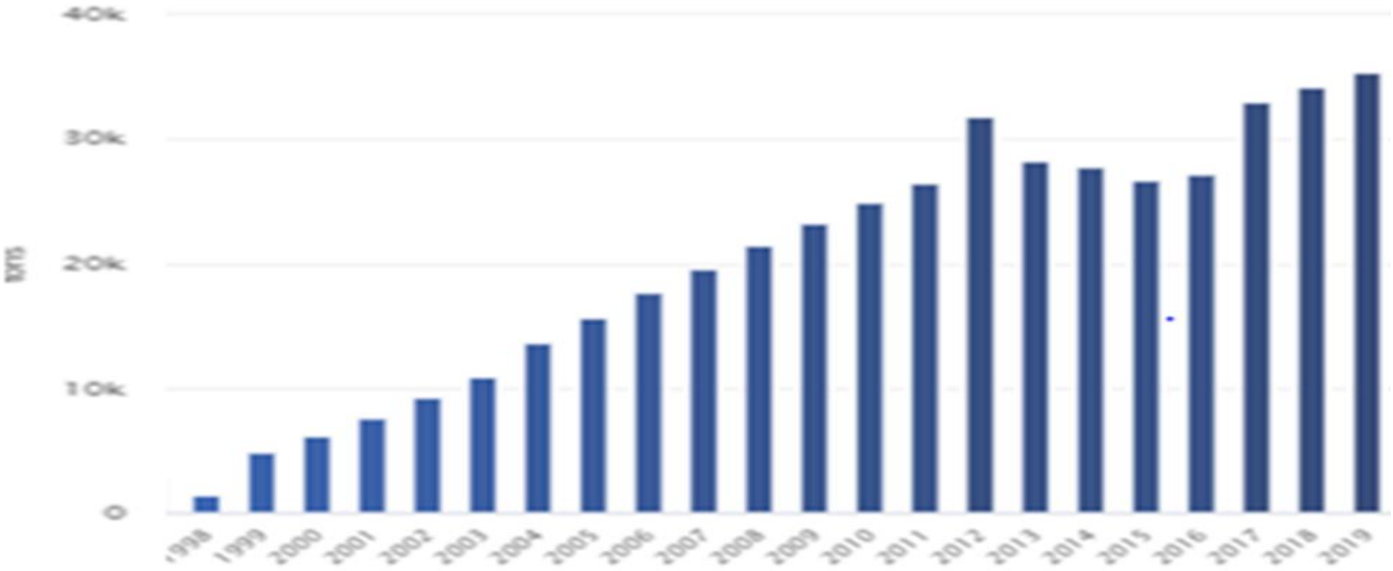

Fig 1 Sweet potato production quantity curve in Zimbabwe for the period 1998 to 2019
(Zimbabwe: Sweet potatoes production quantity (tons), 2020)

To support this, it was highlighted that during the period between 2005-2011 Zimbabwe's sweet potato production was an estimated 2% whilst China was well above 75% (Stathers, 2018). The great gap in production yield could be attributed to the public perception of the bulk tuber in Africa and the large scope availability of post-harvest technologies in China. China attributes its large sweet potato production to the presence and means for post-harvest processing technologies. The development of such technologies has led to various processing products in China, for example, sweet potato noodles, vermicelli and sheet jelly, wedges, chips, starch, flour and organic products including ethanol (Zhang, 2009). Contrarily the local perception is centered largely on the bulk alone; the tuber is mostly harvested, transacted and consumed as is and no processing technologies have been publicized to date.

Flour is one of the products that can be harnessed from the tubers processed via thermal processing. The qualities that make up 'good' or 'acceptable' flour vary immensely. It has been alluded that certain characteristic may be used as quality indicators. (Zhygunov. D., 2019) sums up and estimates the quality indicators as follows: whiteness 1-71 units, gluten deformation index 40-100 units, gluten content 2-36%, protein content 9.8-18.2%, ash content 0.31-2.23% and water absorbing capacity from 53.5 – 69.7. Such information is key in using weighted average quality indicators to comply to specific standards for and when grading. However, the chief indicator used in grade determination is whiteness or color acceptability. On the other hand, some indicators such as ash content are significant in cereals since they control separation of brans from the endosperm in assessing flour quality.

In another study (Samsher, 2013) where the functional properties of different flours were assessed between wheat flour, rice flour, green gram flour and potato flour. The identified functional properties evaluated included swelling capacity, water absorption capacity, oil absorption capacity, emulsion activity and stability, foam capacity and stability, least gelation concentration, gelatinization temperature and bulk density and moisture content. The study highlighted that some functional properties such as those that can be found in potato and green gram flour can enhance the nutritional quality of value-added products, such as fat, vitamins and minerals. Functional characteristics are fundamental physicochemical properties which in turn provide an indication of purpose. Such include foreign matter, nutritional value, quality and product acceptability.

Foreign matter is used as a highlight of product purity and assessor of effect of processing. It is often identified as any kind of outside contaminant introduced to a food product at any point in its production or distribution. (Dogan. H., 2010). As such foreign matter provides an indication of how safe the food may be for consumption by identifying the consequence of processing. In processing glass is common under foreign matter. For example; under cereal processing, foreign matter is accounted for under refractions, of which these are to include filth and any particles separated from product during processing: sieved filth- particles of specific size ranges separated quantitatively from product by use of sieves. (FSSAI., 2016).

- *Problem Statement*

The onset of the year 2020 was met with wheat shortages in Zimbabwe; nationwide. This in turn resulted in bread shortages and the unprecedented halts in confectionery-based businesses, bakeries and businesses alike (Demaree-Saddler. H., 2020). In response to the imminent starvation; the government called for wheat substitutes from which sweet potato ranked top of the list (FEWS NET., 2020). This however was met with reluctance from the public on account of how the tuber is perceived locally. The bulk of Africa consume the tuber traditionally, that is, it is harvested and consumed as is; 'from the ground to the pot' (Mmasa. J.J., 2012). The amount of sweet potato derived products should be well exhausted within the national market. Such should be able to cater to many

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niches; for example, as table condiments, infant feed, animal feed, vitamin supplements, beverages and so on, so much that it substitutes and reduces the significantly high national demand on wheat and maize and their derived products. As it stands there are no local product variations to the sweet potato tuber, which highly contribute to its under-utilization in developing countries, particularly in Zimbabwe. The sweet potato is harnessed, transacted and consumed as is; in its raw unprocessed form. Granted such variations become readily available, this would eventually mean; for every wheat or maize derived product there is a sweet potato equivalent; such would reduce the constraints on the current mainline crops which have become subject to high demand and shortages. This would mean any predicted or sudden shortages will not impact and affect the nation immensely on the account that a sweet potato product will be readily available in place of any maize or wheat derived product. As a result, the range of consumer options will be enhanced which in turn will fast-track the production of more sweet potato products, create an all-new market and introduce a new processing avenue for sweet potatoes in Zimbabwe.

II. MATERIAL AND METHODOLOGY

The plant material used throughout this study: Chingovha, Delvia, Irene, Victoria, Namanga, Alicia and Tsumaya. were grown at Chinhoyi University of Technology Farm and harvested at physiological maturity. Mature tubers were randomly picked for each cultivar.

A. Experiment 1: Flour Production

- *Experiment 1: Effect of Sweet Potato Variety on Flour Production Quality and Yield:*

The sweet potato tubers were washed under running water to remove all dirt and soil debris, care was taken not to immerse the tubers in water for prolonged periods. The tubers were sliced transversely into slices of about 1 cm in width. (9x) 200g of each sweet potato variety were weighed and 3 samples assigned to treatments either 1, 2 or 3. The initial mass was recorded and used as the wet mass for analysis. The slices were immediately transferred and **pretreated** in a solution of 7% Ascorbic acid for a period of 10 minutes to prevent browning (Ojeda. G. A., 2014).

Table 1 Set up of Experiment

	1	2	3
Treatment	**Fresh**	**Fermentation**	**Parboiling**
Number of varieties to undergo treatment	7	7	7
Replicates for each variety	3	3	3
Number of samples for each treatment	3	3	3
Total number of samples for each treatment	21	21	21
Total number of samples for each variety	9	9	9

For treatment 1 after pretreatment the slices were transferred to an oven for thermal treatment, for treatment 2, after pretreatment, the slices were transferred to boiling water for 5-10 minutes, then transferred to ice cold water to stop the cooking process. Once cooled the slices were then transferred to the oven for thermal treatment (Fetuga. G. O., 2013). Lastly for treatment 3, after pretreatment the slices were chopped roughly into flakes and transferred to anaerobic vessels for natural fermentation in 5% salt and 1% sucrose concentration at rtp (28-30℃) for 1-3 days (Yuliana. N., 2020) after which they were rinsed under running water and transferred to the oven for thermal treatment. For all treatments the slices were dried at 60℃ (Farinu. A., 2007) until a constant mass was achieved and the final mass recorded and the slices ground to fine powder.

- *Preparation of Raw Sample*

A mass of 50g from each sample was weighed and labelled accordingly. They were washed in clean water to remove all soil and debris and sliced transversely into 1cm width slices. The slices were pretreated in a 7% solution of Ascorbic acid for a period of 10 minutes after which they were chopped further finely and ground by mortar and pestle into a fine paste. These samples were used for pre-process analyses.

- *Preparation of Fermentation Broth Samples*

For each fermenting sample, the fermentation broth was extracted at 24hr intervals and stored at 4℃ for use during analysis of fermentation kinetics.

Table 2 Sample Identification

SAMPLE ID	DESCRIPTION
A	Chingovha
B	Delvia
C	Irene
D	Victoria
E	Namanga
F	Alicia
G	Tsumaya

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➢ *Baseline Survey for Sensory Evaluation.*

The baseline survey was conducted using a questionnaire (**Appendix 2: questionnaire**). The aim of the questionnaire was to collect information on the consumption of SP and assess familiarity of SP processing technology in New Strathaven, Avondale in Harare. The questionnaire was given to volunteers who upon further agreement were provided with sensory evaluation form and flour samples from experiment 1 for sensory analysis. This information was used to determine the most preferred SP product that could be formulated into an instant porridge. The questionnaire was administered to 30 residents of New Strathaven, Avondale, Harare. Due to the COVID 19 restrictions and appointed lockdowns, the panelists were selected by means of proximity and guidelines observed and practiced.

III. STATISTICAL ANALYSES AND METHODS

➢ *Determination of Flour Quality*

- *Determination of the Effect of Treatment on Product Color.*

For each variety, the samples were analyzed according to skin and flesh color and the overall color of the tuber for characterization. Color software was used to determine the initial color of the raw tubers using Color Picker online/ Hex Color Picker/HTML Color Picker (https://imagecolorpicker.com/en).

- *Determination of Emulsification Stability.*

Emulsification stability was observed using the visual method as outlined by Yin Hu et al (Hu. Y. T., 2016) using water and sunflower oil. 2g of each flour sample were transferred to a tube where 5ml of distilled water and 5ml of sunflower oil were added the tubes were mixed well by vortex and left to stand at rtp. Immediately after mixing, the timer was set to start to measure the time taken for creaming or sedimentation.

- *Determination of WHC*

WHC was determined by transferring a 0.5g of each flour sample into a pre-weighed centrifuge and 5ml of distilled water added. The samples were vortexed for 1 minute and allowed to stand at rtp, after which they were centrifuged at 1000g for 15 minutes. The excess water was decanted by inverting the tubes over tissue paper to drain for 10 minutes, final mass measured and expressed as a percentage increase from the initial mass (Giami. S. Y., 1994) (Ladjal. E. Y., 2015) .

The WHC was determined as follows:

$$\text{Holding Capacity: } \frac{\text{Final weight} - \text{Initial Weight}}{\text{Initial Weight}} \times 100$$

- *Determination of Oil Holding Capacity*

OHC was determined by transferring a 0.5g of each flour sample into a pre-weighed centrifuge and 5ml of distilled water added. The samples were vortexed for 1 minute and allowed to stand at rtp, after which they were centrifuged at 1000g for 15 minutes. Excess oil was decanted by inverting the tubes over tissue paper to drain for 10 minutes, final mass measured and expressed as a percentage increase from the initial mass as used by Ladjal et al (Ladjal. E. Y., 2015)

The OHC was Determined as follows:

$$\text{Holding Capacity: } \frac{\text{Final weight} - \text{Initial Weight}}{\text{Initial Weight}} \times 100$$

- *Determination of Moisture Content*

(AOAC, 2000); 200g of each variety was weighed, treated and dried to a constant mass and the final mass recorded. The moisture content was calculated as follows:

$$\frac{\text{Wet Mass} - \text{Dry Mass}}{\text{Wet Mass}} \times 100 \text{ (which will be recorded under percentage moisture)}$$

- *Determination of Foreign Matter*

(FSSAI, 2016) A mass of 50g of the flour was weighed and sieved through sieves of aperture; 600µm and 710µm for each sample product.

- *Determination of Gluten content*

Gluten content was determined using the method outlined in cereal and cereal products method for analysis (FSSAI., 2016). 10g of each sample was weighed into a dish and a volume of water added to make a dough. The formed dough was gently kept in a beaker filled with water and allowed to stand for 1 hour. The dough was removed and placed in a piece of bolting silk cloth/ cheese cloth (with an aperture of 0.16 mm) and washed with a gentle stream of water until water passing through the silk did not give a blue color with a drop of iodine solution. The silk cloth was spread tight on a porcelain plate to facilitate scraping and the residue collected using a blade to form a ball. Excess water was removed by forming a ball and squeezing in the palms to remove excess water, then transferring to a petri dish and kept in the oven at 105±1°C for drying. When partially dried, the mold was removed and cut into several pieces with scissors and kept in the oven to dry then cooled in a desiccator and weighed. The pieces were returned to the oven for half an hour, cooled and weighed and process repeated until a constant weight was achieved. The data was analyzed as follows:

$$\text{Gluten on dry weight basis} = \frac{\text{Weight of dry gluten} \times 100 \times 100}{\text{Exact wt. of sample} \times (100 - \text{Moisture content})}$$

➢ *Evaluation of the Effect of Treatment on Selected Chemical Properties*

- *Evaluation of Protein Content (LOWRY Method)*

✓ *Extraction of Protein from sample*

The protein content in raw SP was measured and compared to that in the raw, fresh, parboiled and fermented flour products using the Lowry Method (Waterbog. J H., 1996). 5g of each sample were weighed and placed in

centrifuge tubes and a volume of 5ml Phosphate buffer added and the tubes vortexed for 1 minute to ensure adequate mixing. The tubes were then centrifuged at x15000 rpm for 15 minutes after which the samples partitioned into pellet and supernatant (used for the analysis)

✓ *Standard Solution Preparation*

50mg of BSA was dissolved in 50ml of sterile distilled water to make a 1mg/ml BSA Stock Solution from which serial dilutions were made.

2ml of each sample (supernatant) were transferred; each to a clean tube. To each tube, a volume of 4ml of Biuret solution was added and gently swirled. The tubes were allowed to stand at rtp for a period of 10 minutes. A volume of 500µl of Folin Ciocalteu Reagent was then added to each tube, swirled immediately for mixing and allowed to stand for 30 minutes in the dark. Contents from each tube were transferred to a clean cuvette and absorbance read at a wavelength of 660nm and sterile distilled water used as a blank.

- *Evaluation of Total Phenolic Content*

The TPC was determined according to the Folin Ciocalteu Spectrophotometric method (Singleton. V. L., 1965) as applied in determination of phenolic compounds (Ngamsuk. S., 2019) on raw sample, fresh, parboiled and fermented flour products.

- *Extraction of Phenolics from Sample.*

5g of the sample was weighed and placed in a centrifuge tube and a volume of 5ml of Methanol was added into each tube. The tubes were vortexed for 1 minute and the tubes centrifuged at x15000 rpm for 15 minutes. The samples partitioned into pellet and supernatant and the supernatant used for the analysis.

- *Preparation of Standard Solution.*

0.5g of dry gallic acid was weighed and placed into a clean beaker and a volume of 10ml of Ethanol added to the beaker to dissolve the powder. A volume of distilled water was added to the beaker to the 100ml mark to prepare a 5g/L solution and used for serial dilutions.

- *Preparation of Sodium Carbonate Solution*

7.5g of Sodium Carbonate was dissolved in 100ml distilled water.

20µl of the extracted sample was pipetted into a clean test tube, 1 580µl of sterile distilled water was used to dilute each sample, mixture was swirled gently for adequate mixing and allowed to stand for at least 30 seconds at rtp. 100µl of FC Reagent was added to each tube, mixed gently by swirling and allowed to stand at rtp for 8 minutes. A volume of 300µl of Sodium Carbonate Solution was then added to each tube, followed by gentle shaking and the tubes allowed to stand for 30 minutes at 40°C. The absorbance of each solution was read at 765nm. Determination of phenolic concentration was based on gallic acid standard linear graph plotted absorbance versus concentration.

- *Evaluation of B Carotene Content*

Total Beta carotene content was extracted using ethanol at rtp (Calvo. M.M., 2006) and the concentration determined by spectrophotometry and Beer Lambert's Law in which the molar extinction was used as 125.3 based on studies (Nubel. U., 2000) (Oren. A., 1995).

- *Extraction of Carotene*

5g of each sample were weighed and placed in a small glass beaker and a volume of 30ml of absolute ethanol added (1:6 ratio). The solution was then left to stand for an hour at rtp, covered in Aluminum foil and left in the dark. Stirring and shaking was done at 10 minutes intervals to facilitate extraction. The solution was then filtered into a clean beaker using Whatman filter paper and carried over for analysis. The absorbance was read at 486nm and a 5ml volume of chloroform used as the blank and the and the results read and recorded Carotene extraction was carried out on the day of analysis for minimum degradation of sample.

- *Evaluation of Sugar Content*

✓ *Sample Preparation and Sugar Extraction*

Sugar was extracted from flour; (Marangoni. A. C., 1997) and fermentation broth and the results determined by UV/VIS Spectrophotometry at 340nm.

- 1g of the sample was weighed and transferred to clean reaction tubes. Mixing and homogenization of sample was conducted in methanol (8 ml) for 2 mins by vortexing and the homogenate treated with 0.5g of carbon (activated charcoal) and shaken for 18-20 min at rtp by bench top orbital shaker and filtered through Whatmann filter paper. (Javed. M.S., 2020)

- For each fermented sample; a small volume of the media was retained and stored at the end of each 24hr interval (24hrs, 48hrs and 72 hrs.). 1ml of each volume was added to a clean beaker and 8ml of Methanol was added and the mixing carried out for 2 minutes by vortexing, 0.5g of activated charcoal was added and the contents shaken for 18-20 minutes in a bench top orbital shaker and then filtered through Whatmann filter paper.

✓ *Preparation of Standard Stock*

1g of glucose was dissolved into 100ml distilled water to prepare a 1% stock solution used for serial dilutions.

➢ *Evaluation of Product Acceptability*

- *Pilot Study*

The target population was determined by proximity on account of the lockdown restrictions. A pilot study was carried out in which 8 individuals representative of each age group (under 21, 22-31, 32-40 and over 40) were selected and provided with the questionnaire. The goal of the pilot was to detect and allow revisions of questions deemed unclear and allow for revisions. (Van Teijingen. E. D., June 2002).

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- *Data Gathering*

An introduction section indicating that the research would be specifically for academic purposes was attached to the questionnaires. Before answering the questionnaires, the respondents were told the main objectives of the study as indicated under section 1.3.1 and how their input would assist in realizing the research objectives. Questionnaires were administered at the completion of experiment 1 and prior to sensory evaluation from which ordinal data is to be gathered. The panel comprised of 30 untrained voluntary respondents. Evaluation was based on a 5-point hedonic system with highest count 5 representing 'great' and the lowest count of 1 representing 'awful'. The parameters evaluated by the panelists included; color, texture and smell with the option of commenting.

- *Data Analysis*

Ordinal data was summarized using descriptive statistics from which the maximum and minimum number of responses per sample was used in Multiple Samples Sensory Ranking categorize samples according to respondent's preference. (Carabante. K. M., 2018)

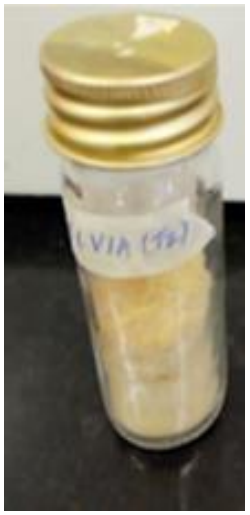
IV. RESULTS AND DISCUSSION

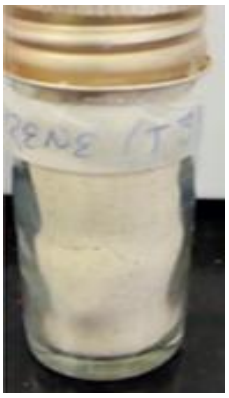
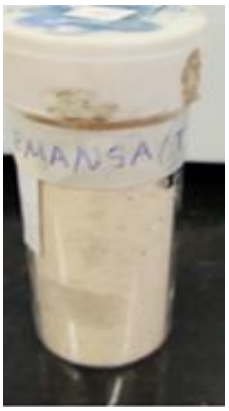
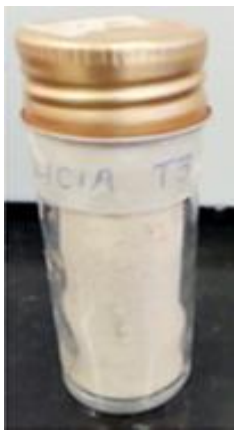
A. Determination of Flour Quality

➢ *Determination of the Effect of Treatment on Product Color*

The pretreatment with ascorbic acid prevented enzymatic browning in that all treated products were comparable to their initial color. This was mostly shown from the sample products in treatment 1 and 3. The color profiles of the parboiled varieties presented a deepened off-color profile as compared to treatment 1 samples which could be due to the additional heat treatment; This is illustrated in the table below;

Table 3 Effect of Treatment on the Final Product Color

	INITIAL	TREAT 1	TREAT 2	TREAT 3
A	 Brown Skin; white flesh			
B	 Brownish orange (burnt orange) skin; carrot flesh			

C	 Purple (wine) skin; Yellow (old gold) flesh			
D	 Orange (sandy brown) flesh; Brown (cinnamon)skin			
E	 Orange (bronze) Flesh; Brown (light brown) skin			
F	 Brown (copper) skin;Yellow (buff yellow) flesh			

G	 Light brown skin; Pale yellow flesh			

KEY

A	CHINGOVHA	TREAT1	Fresh
B	DELVIA	TREAT 2	Parboiled
C	IRENE	TREAT 3	Fermentation
D	VICTORIA		
E	NEMANGA		
F	ALICIA		
G	TSUMAYA		

Generally ascorbic acid has been identified as an agent for retention of carotenoids (Minuye. M., 2021) being heat sensitive. Studies suggest that the heat sensitive nature of ascorbic acid in treatment generally makes it non-ideal as a pretreatment to be followed by boiling (Mercali. G. D., 2014). For this reason, the parboiled dried flakes had an unappealing discoloring outwardly which could be attributed as browning, whilst the interior retained some of its natural coloring. For this reason; some studies that have coupled ascorbic acid as pretreatment to thermal drying have favored the use of sulfur dioxide and sodium metabisulfite solutions instead (Shawky. A. S., 2020). The fermented products maintained a color profile comparable to the treatment 1 products due to the fermentation conditions. The fermentation procedure used throughout the scope of this study was predetermined to mimic natural spontaneous fermentation, to achieve this, there was no heat input and the procedure was carried out under rtp. A study (Yuliana. N., 2019) was carried out in which natural fermentation in 5% brine showed potential; both as a preservation technique and in the induction of lactic acid fermentation. Fermentation has been rendered ideal in SP with regard to the starch content whereas Lactic acid production capabilities have been identified as well (Pagana. I., 2013). Additionally, saline solutions as that used in fermentation treatment have been observed to have properties that prevent browning in selected foods and additional antimicrobial properties. (Baiano. A., 2003). The best color profiles were observed for the fermented products which in turn indicates positive interactions between ascorbic acid pretreatment and saline conditions in fermentation treatment in preventing browning (Baiano. A., 2003). Contrastingly, the color profiles of the parboiled products could indicate negative interaction between the ascorbic acid pretreatment and the heat treatment.

➢ *Determination of Emulsification Stability*

The analysis determined that the flour product had low emulsification stability. The determined mean was 11.41s (to 2d.p) and a median of 11s with the minimum value of 6.4s and the maximum value; 17.4s. For all samples, regardless of treatment and variety phase partitioning was observed and the results illustrated as follows:

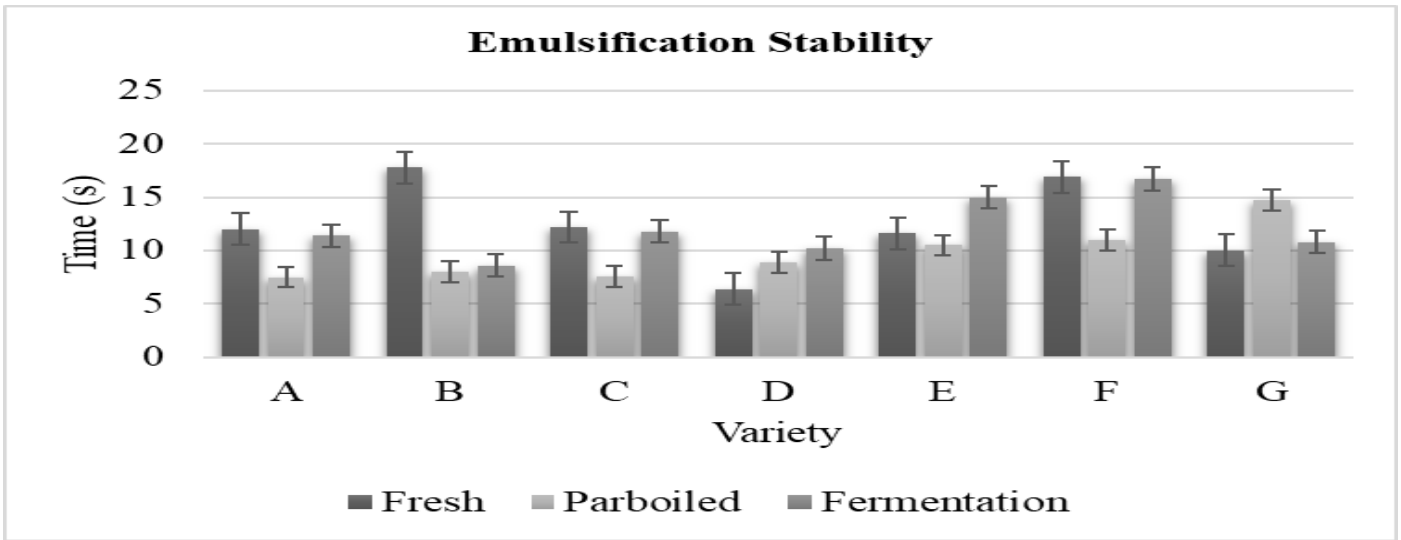


Fig 2 Effect of Sweet Potato Variety and Post-Harvest Tuber Treatment on Emulsification Stability of Flour Products

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Generally, the emulsification stability of the parboiled varieties demonstrated the most values below or along the mean value of 11. This could be attributed to the product size. It was observed that particle size of flour products from fresh and fermentation treatments were smaller and finer compared to the parboiled flour products. Studies have alluded that the smaller the particle size the more emulsions as compared to the larger counterparts (Iyer. V., 2015). On the other hand, none of the flour samples demonstrated ability in the prevention of phase partitioning. Emulsification stability is a measure on the delay or prevention in immiscibility between water and oil (Sjoblom. J., 2013). This in turn is determined experimentally as the rate of phase separation, for this reason the presence of phase separation indicated low emulsification stability (Tekin. Z. H., 2020). Since the samples exhibited low emulsification stability throughout assessment, this in turn highlights their limitations as emulsifiers.

Furthermore, Analysis of Variance indicated that generally there was no statistically significant difference in varieties with respect to emulsion stability ($p>0.05$).

- *Determination of WHC*

WHC also known as water absorption capacity refers to the is the ability of food to hold its own or added water during the application of force, pressure, centrifugation, or heat (Mu. T., 2017). The WHC of the different samples was determined as a percentage of the initial mass of the dry product at rtp. It was determined experimentally that on average flour samples across all treatments had a WHC of 312. 517%; flour could retain more than 300% of its initial mass worth of water. However, it was observed that the attained percentages for the parboiled samples all fell below the identified mean value. The minimum value of 102% was observed in parboiled samples whilst the maximum value of 557% was observed for treatment 1. The attained results are outlined in the table as follows:

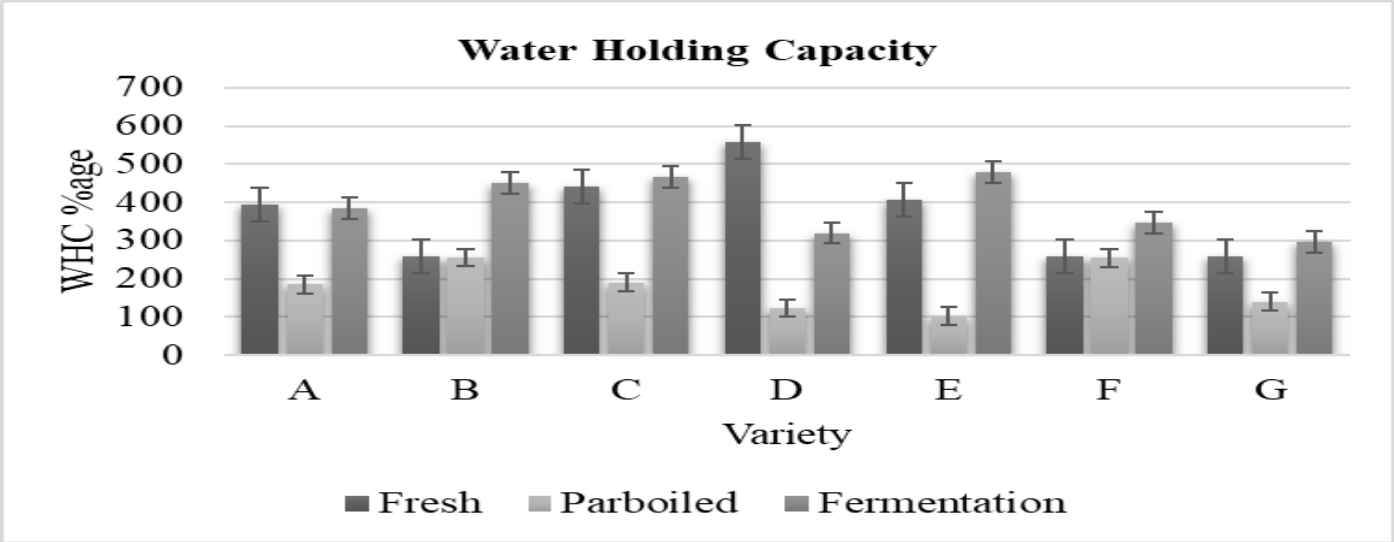

Fig 3 Effect of Sweet Potato Variety and Post-Harvest Tuber Treatment on Water Holding Capacity

In any case WHC demonstrates the relationship and interaction between protein and water in food systems. The protein within the sampled product achieves this by absorbing, retaining and entrapping water against gravity and by so doing prevents water from being expelled (Rakszegi. M., 2014). Towards the development of cereal and instant porridge, wetting and hydration as that demonstrated through determination of WHC is significant in demonstrating interactions. For example; rice and maize are the most popular ingredients for gluten free foods, but they tend to exhibit limited technological properties especially with regard to cohesive interactions (Boucheham. N., 2019). This in turn highlights that any product intended to substitute wheat in any cereal-based product should exhibit functional properties somewhat comparable or consistent with that of wheat. There is a correlation between the WHC of a flour and the solvent retention capacity, these combined properties establish the functional profile of the flour product (Kweon. M., 2011). Generally, it has been determined that gluten can absorb liquid water more than 2 times its initial weight, the results attained indicate that sweet potato in turn holds a comparable WHC (Doporto. M. C., 2012). For this; reason, sweet potato holds potential in being a chief ingredient in formulating instant porridge.

The p value< 0.05 (Appendix 4: table 11) highlights the significant differences between varieties with respect to water holding capacity.

- *Determination of OHC.*

The OHC of the different flour samples as shown below are expressed in grams per 100g fresh sample. It was determined that the statistical mean was 169.36% (correct to 2 d.p). The analysis also highlighted that all values attained under treatment 2 of parboiling fell below the estimated mean value, the same for fermentation treatment except for Tsumaya. In that same light, the minimum value 57.50% was found for parboiled Chingovha variety. Generally, there was a significant difference between the OHC for the different samples as suggested by the p value ($\alpha<0.05$): Appendix 4; table 12. The attained results are presented as follows:

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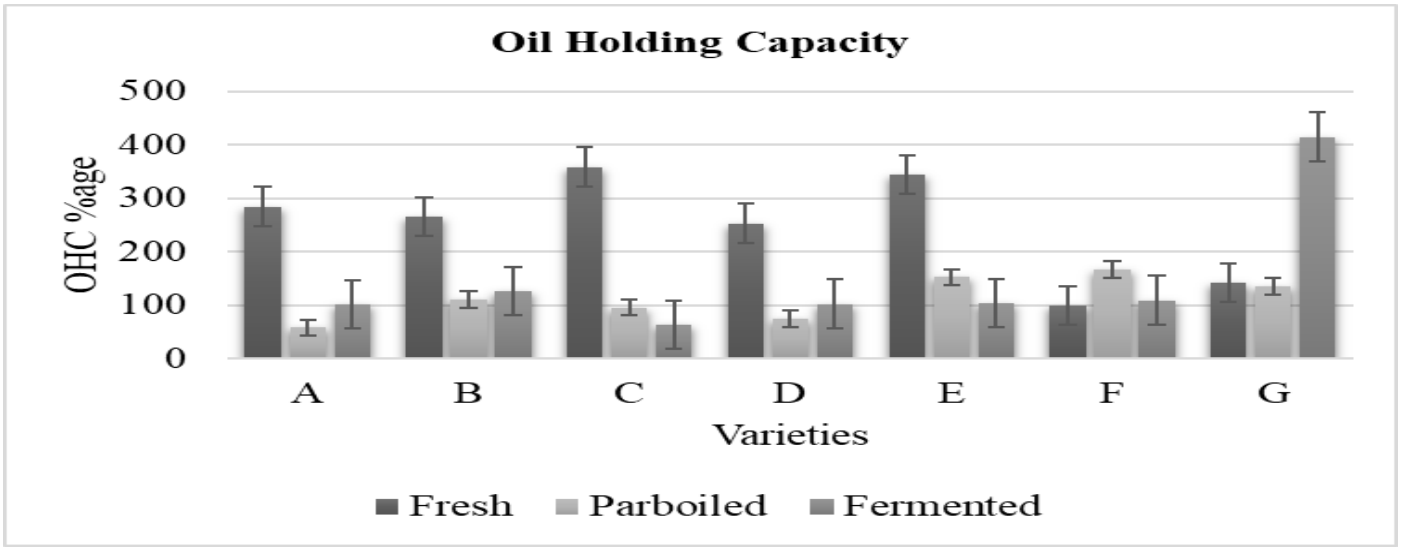

Fig 4 Effect of Sweet Potato Variety and Post-Harvest Tuber Treatment on the Oil Holding Capacity

OHC is a measure of the interactive properties between the samples in question and oil. This has been described as to the amount of oil that a sample can absorb per unit of weight (Ladjal. E Y., 2015). As such OHC is a relevant measure on how well the texture of a product will be. The analysis is crucial in that it provides an indication of application. Generally, it is expected that boiled flours ought to portray greater oil entrapment capacity compared to the other treatments (Ma. Z., 2011). However, in this experiment it is exhibited below the statistical mean. This is because OHC is a direct measure on the surface availability of hydrophobic amino acids and non-polar chains (Benitez. V., 2013). Since the consequence of gelatinization was exhibited for parboiled samples, this affected particle size; flour particles from parboiled treatments were larger after grinding. On the other hand, OHC for treatment 1 for Chingovha, Delvia, Irene, Victoria and Namanga were significantly higher across all treatments. This illustrates the availability of non-polar chains and hydrophobic amino acids within the raw dried tubers. The differences in OHC across the different treatments for the same varieties indicate the intricate differences and consequences of the treatment options).

- *Determination of Moisture Content (According to AOAC Method 1995)*

Generally, SP have a predetermined moisture content of 62.58 – 64.34 ±0.42% (Vimala. B., 2011). In this experiment the minimum value for treatment 1, treatment 2 and treatment 3 were 62.8% (Alicia: treatment 1), 59.57% (Namanga; treatment 2) and 31.98% (Victoria treatment 3), whilst the maximum values were 74.7% (Tsumaya; treatment 1), 88.76% (Tsumaya; treatment 2) and 72.284% (Alicia; treatment 3) respectively. The acquired mean value for each treatment was 68.99%, 75.94% and 56.69% respectively. From these values it is determined that Namanga and Tsumaya had the moisture content that fell above the treatment 1 mean, Delvia and Namanga had the moisture content that fell below the treatment 2 mean and Victoria and Namanga had the moisture content values that fell below the treatment 3 mean. This is shown in Fig 7:

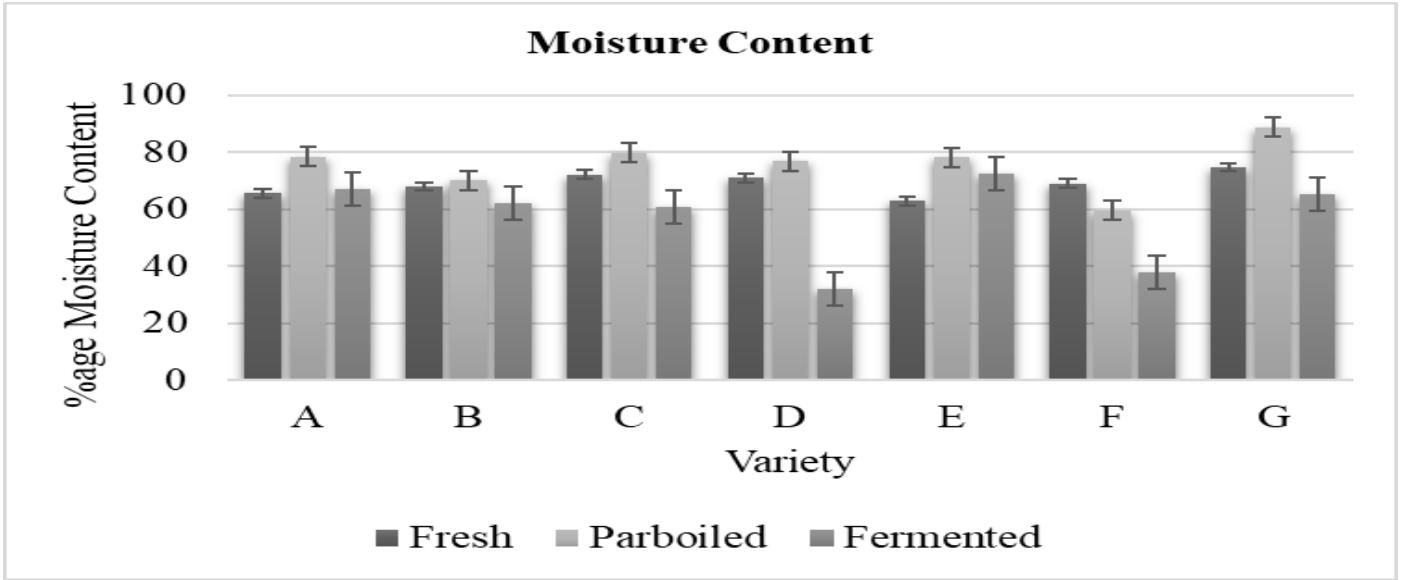

Fig 5 Effect of SP Variety on Moisture Content

Moisture content is an analysis based on the water content of a product in question. The primary treatment of drying which is applied to the tubers generally is aimed at the expulsion of water to produce a dehydrated form of the product (Mermelstein. N. H., 2009). Moisture content maintains an inverse relationship with product feasibility; the higher the moisture content the less feasible product development becomes as production becomes uneconomical (Kuka. M. G. K., 2018). The Moisture Content of Chingovha, Alicia, Delvia, Irene, Alicia and Tsumaya maintained a close relation across all three treatments. Although slight differences were observed, the results of the aforementioned remained close within a specific range. However, the results suggest that the fermentation treatment for Victoria and Namanga significantly reduced the mass loss during drying treatment. This supports the claim from the study of natural fermentation carried out on soy that natural fermentation decreases moisture, carbohydrate and fat contents (Obadina. A. O., 2013)

The results attained indicate significant differences ($p \leq 0.05$; ***Appendix 4; table 13***) and that generally Tsumaya (G) regardless of treatment option has a higher moisture content. Studies have shown that moisture content typically varies according to the physical properties of the tubers (Senkumba. J., 2017). Generally fibrous varieties tend to have lower water content as compared to the fleshy varieties, the bulkier and more compact varieties have less water content as compared to the softer and juicier varieties. The results also indicated that varietal differences tend to have an implication on the choice of drying temperature. 60°C was used throughout the experiment, although adequate for fresh and fermented samples, the same was not observed for the parboiled varieties. Amongst all the samples; parboiled Tsumaya dried to the point of hard and brittle, other varieties although achieving constant mass remained soft. This means for samples A to F; starch gelatinization was a consequence of the pretreatment option. Gelatinization has been defined as the loss of molecular order of starch granules, the point at which starch granules swell and absorb water (BeMiller. J. N., 2019). The gelatinization temperature of sweet potatoes has been considered to fall within the range of 60 °Cto 65°C (BeMiller. J. N. a. W., 2009). This means the allocated timeframe of 10 minutes parboiling treatment was not an ideal as a uniform treatment option. The determination of drying temperatures post parboiling should have put into consideration factors such as gelatinization and pasting temperatures as well as sample texture.

Table 4 Texture Profiles of the Different SP Varieties

Sample	Texture
A	Smooth and Compact
B	Smooth and Soft
C	Smooth and Soft
D	Smooth and Soft
E	Smooth and Compact
F	Rough and Compact
G	Fibrous

Oven drying proved an ideal means of thermal processing and preservation in that it introduced containment and restricted the introduction of foreign matter. Other thermal options such as sun-drying tend to introduce contaminants to the final product that can be detrimental to consumer health, and introduces a variable that cannot be controlled in research (Eswara. A. R., 2013). In fact, it has been alluded that; although sun drying is an economic choice, its challenges can be addressed by integration into controlled and automated systems to make for a more plausible treatment option (Feili. H.R., 2012) especially in agriculture and food processing.

Moisture content is primarily important in that there is correlation in diminished or reduced water content and product preservation (Guine. R. P. F., 2018) and allows for product development. The initial step in numerous product development protocols is drying. This is because it reduces product bulkiness; water loss is associated with mass transfer and facilitates storage and transportation by eliminating the need for cooling systems and halts chemical and enzymatic changes (Guine. F., 2008).

- *Determination of Foreign Matter*

When products were ground into fine powder and sieved through sieves with aperture of 600µm and 710µm no foreign material was detected. From the experiment it was demonstrated that the option of thermal treatment and process of flour production did not introduce foreign matter. This was conclusive for all samples regardless of the treatment option. For the purposes of this experiment foreign matter was defined as physical contaminants such as hair, filth, bark or wood, insects, and any food particles that are not part of the sample (Goodwin. D., 2014). The analysis fulfils a requirement as an indication of food safety as that governed by FDA authorities in food production (Lupo. L., 2020). Typically, the choice for thermal treatment using oven instead of sun drying is favored on account that it reduces the likelihood of environmental contamination (Famurewa. J. A. V., 2011).

- *Determination of Gluten Content.*

The results attained indicate absence of gluten in the SP samples processed down to flour. When dough placed in silk cloth was washed under running stream, residue was broken down slowly until no excess was left, and no residue was available for drying. The results suggest that within the full mass of each sample, no gluten was present. This in turn

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is supported by studies that have identified sweet potatoes as gluten free; (Alfani. N. N. A., 2019), studies that incorporate sweet potato into wheat-based products as a means of gluten reduction (Ayo-Omogie. H., 2020), and studies that completely substitute gluten flours with sweet potato derived flour; (Giri. N. A., 2019). For this reason, sweet potato proves ideal for the growing gluten intolerant population and patients of celiac disease (Degeorge. K., 2017).

B. Evaluation of the Effect of Treatment on Selected Chemical Properties

➢ *Evaluation of Protein Content (Lowry Method)*

It was determined that there was a significant difference in the effect of treatment on protein content (p value≤ 0.05; ***Appendix 4; table 14***). From this it was determined that the statistical mean was 0.432 (to 3d.p), the highest protein concentration was observed for fermented flour products, with the overall highest being in Namanga and the lowest protein concentration observed for parboiled Alicia. The results were recorded as follows:

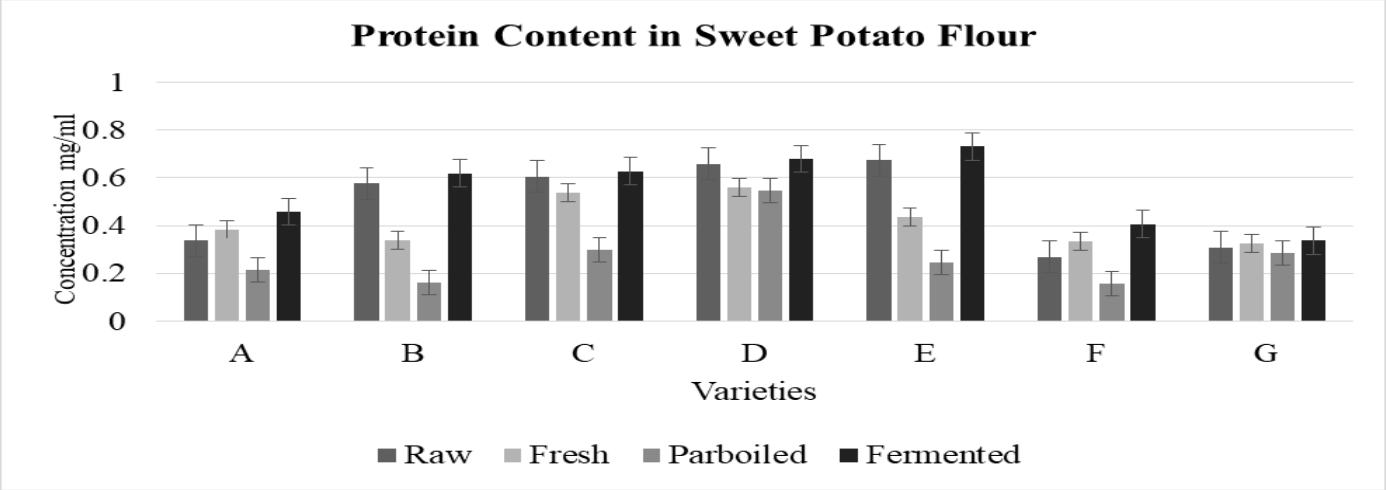

Fig 6 Effect of Pre-Thermal Treatment on Sweet Potato Flour Protein Content

The protein content in raw SP samples was first determined. It has been determined that protein in SP is dominantly sporamin A and B, which are subject to increase and decrease during sprouting, maturation and storage (Maeshima. M., 1985). However; SP are generally not regarded as a rich protein source, (Shireen. K. F., 2001). For this reason, the objective of introducing processing techniques should be focused on methods that retain the most nutritional composition of the starting product (Lyimo. M. E., 2010).

Generally parboiled flour samples exhibited a significant decline in protein content when compared to the raw values (with an exception for Victoria and Tsumaya). Throughout the analysis they uniformly maintained a decline with respect to the analysis. This detail suggests damage and destruction to the protein constituents as a consequence of the heat treatment. Generally boiling has been identified to have a detrimental impact on protein (Shehu. D. M., 2018). On that same note; the raw values are comparable to that for fresh (treatment 1), this suggests that the heat input used to dry the raw tubers (treatment 1) was not extensively aggressive to the point of denaturing proteins. The rises and declines observed between raw and treatment 1 can be attributed to the conclusions drawn by Maeshima (Maeshima. M., 1985). On the other hand, the effect of gelatinization on particle size as observed for the parboiled samples may have contributed to the low availability of protein for measurement. Spectrophotometry based methods exploit extraction procedures prior to measurement as a means for selective detection. This means the spectrophotometry values are only based on the amount of substance that has been successfully extracted from the given sample. The low values observed for parboiled flour may have been a consequence of ineffective protein extraction. Studies have shown that particle size has a significant impact on the rate of extraction (Russin. T. A., 2007) (Yuliani. S. H., 2019).

Fermentation on the other hand is typically held in regard as a nutritional enhancer (Samtiya. M., 2021). For this reason; the protein content in fermented samples was both expected and observed to be higher than that from the raw samples. This is synonymous in a study carried out in Indonesia that explored improving flour properties by fermentation (Yuliana. N., 2016). Similarly, fermentation is favored on SP with respect to the high starch content of the tubers; (Bach. D., 2021) and introduction of flavors.

➢ *Evaluation of TPC (Folin Ciocalteu Spectrophotometric Method)*

The results indicated there was a significant difference in the effect of treatment on TPC (p≤0.05***; Appendix 4; table 15)***. The statistical mean was found to be 0.789 (to 3 d.p), the maximum value; 1.689 (to 3 dp) was observed for raw Victoria (before processing) whilst the minimum phenolic value was observed for Alicia having undergone treatment 1. The results are shown as follows:

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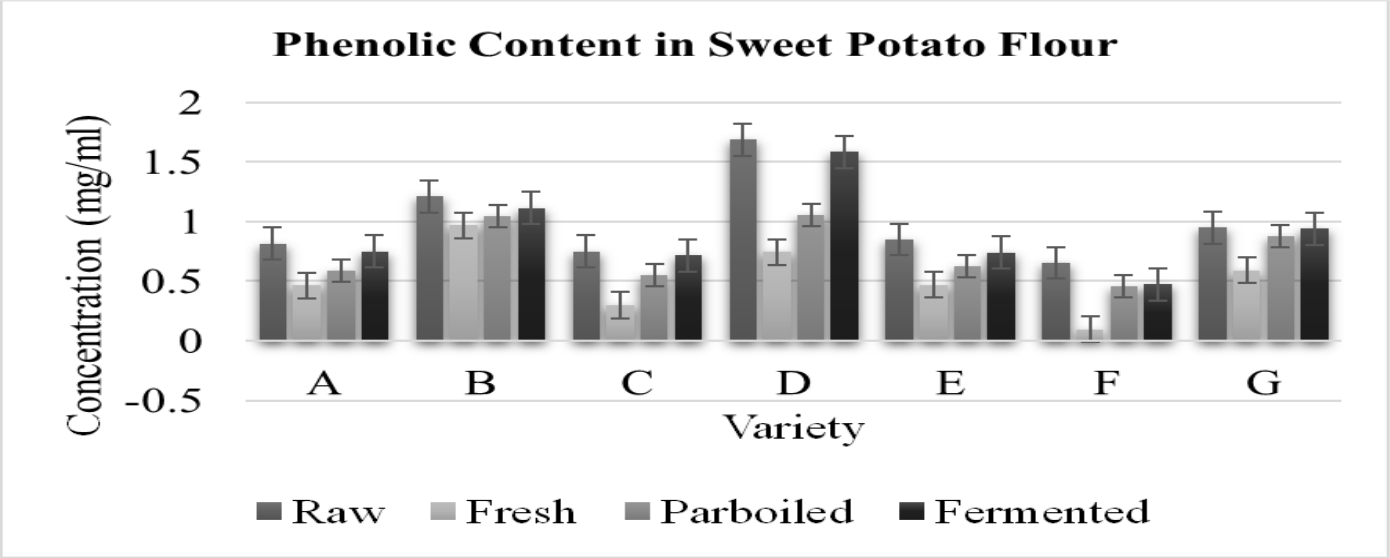

Fig 7 Effect of Pre-Thermal Treatment on Sweet Potato Flour Phenolic Content

Generally phenolic content in tubers is subject to factors such as: cultivar, environmental conditions, cultural practices, postharvest practices, processing conditions, and storage (Chandrasekara. A., 2016). For this reason, the initial TPC in the raw samples vary. Chingovha had the lowest values across all treatments, whilst the orange varieties had amongst the highest values, this supports the evidence that highlight that flesh color as an indicator of TPC (Musilova. J., 2017) The decrease of these values across all treatments was typical as expected on account of their unstable structures and hence easily prone to degradation (Minatel. I. O., 2017). As such the TPC in raw samples had the highest values across all treatment and were comparable to the values obtained post fermentation (treatment 3). The increase demonstrated under treatment 3 is as a result of the choice of treatment. Fermentation has been identified to demonstrate a marked increase in the TPC for the product in question (Adetuyi. F. O., 2014). Fermentation is the favored option with respect to food processing in that it increases the bioavailability of phenolic compounds in food and generation of compounds that impact flavor (Rodriguez. H., 2009). Parboiled flour samples exhibited lower values as compared to the raw samples. The subjection of thermal processing in water results in changes in phenolic composition in that certain degrees of boiling are associated with phenolic retention which can be attributed to higher extractability, rupture of polyphenolic complexes and inactivation of polyphenol oxidase (POD) (Minatel. I. O., 2017). The choice of drying method generally induces reduction of phenolic compounds, and brings into account factors such as drying temperature, drying time and air velocity (Miranda. M., 2010). The rate of degradation brings into account other factors such as handling and quality of tubers and type of phenolic acid in question.

➢ *Evaluation of B Carotene Content*

It was determined that the mean concentration across all treatments was 0.017 (to 3 dp) and the maximum and minimum values; 0.031 and 0.000144 respectively. The attained results are shown below:

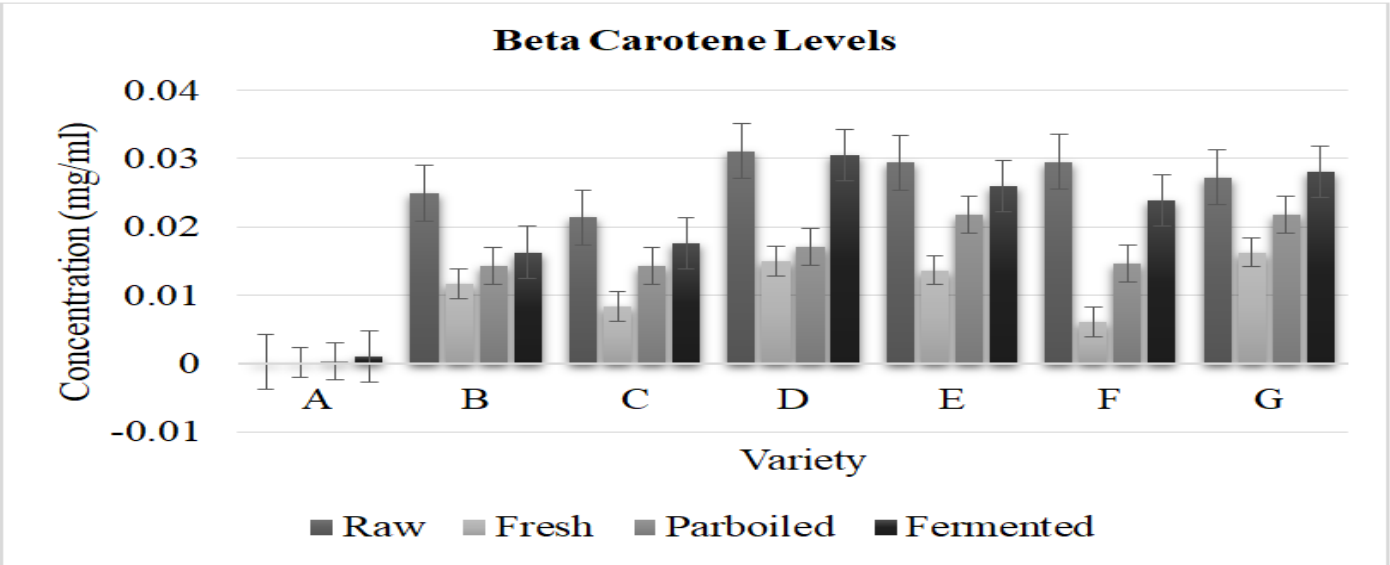

Fig 8 Showing Effect of Pre-Thermal Treatment on Sweet Potato Flour Beta Carotene Quantity

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Chingovha (white flesh) had the lowest beta carotene values across all treatments, all of which fell under the experimental mean and the overall minimum value being observed from treatment 1 sample (fresh) (Hussein. S. M., 2014). For this reason, it may prove as a candidate for biofortification in processing particularly for augmenting beta carotene content. In contrast the orange fleshed varieties Delvia (B) Victoria (D), and Namanga (E) and yellow fleshed varieties (Irene (C), and Alicia (F) Tsumaya (G) exhibited a significantly higher beta carotene level with the maximum value being in Victoria. This is supported by characterization studies which conclude that the order of carotenoid concentration is least in white fleshed varieties, increases in yellow fleshed varieties and is highest in the orange fleshed varieties (Kammona. S., 2014). Generally, all treatments demonstrated a reductive effect in beta carotene content across all varieties, however with varied extents (Bechoff. A., 209). In this study the choice of processing; thermal drying resulted in a decline in concentration as compared the initial raw concentration; demonstrated by treatment 1-fresh. This is because carotenoid degradation is a consequence of heat treatment in addition polymerization of sidechains (Qui. D., 2009). Similar findings have been produced in cherry tomatoes (D'Evoli. L., 2013), fruit and vegetables (Penicaud. C., 2011) (Marx. M., 2003). Similarly, parboiled sample concentrations were also significantly lower than the initial concentration in raw samples, but higher than values for fresh (Wu. X., 2008). The effect of boiling at short intervals on SP has been shown to increase beta carotene concentration (Buratti. S., 2020). This can be explained in terms of enhancement of extractability as a result of boiling (Dincer. C., 2011). The concentration in raw samples and fermented samples were comparable in that for each variety the range in difference was smaller as compared to the other treatments. This suggests that the enhancement of nutritional composition as that offered by fermentation technology has an advantageous effect on the product beta carotene levels in terms of both retention and bioavailability (Mapelli-Brahm. P., 2020). The p-value indicated that there were significant differences on the carotene quantity with respect to the pretreatment choice ***Appendix 4; table 16.***

➢ *Evaluation of Sugar Content*

- *Evaluation of Sugar Content in Flour*

The mean of sugar was determined as 0.017 (to 3 d.p), and the median 0.017 (to 3 d.p) and the maximum and minimum values 0.031 and 0.00014 respectively and p-value demonstrated to be less than the α- value ***(Appendix 4; table 17***). The results attained are provided in the graph as follows:

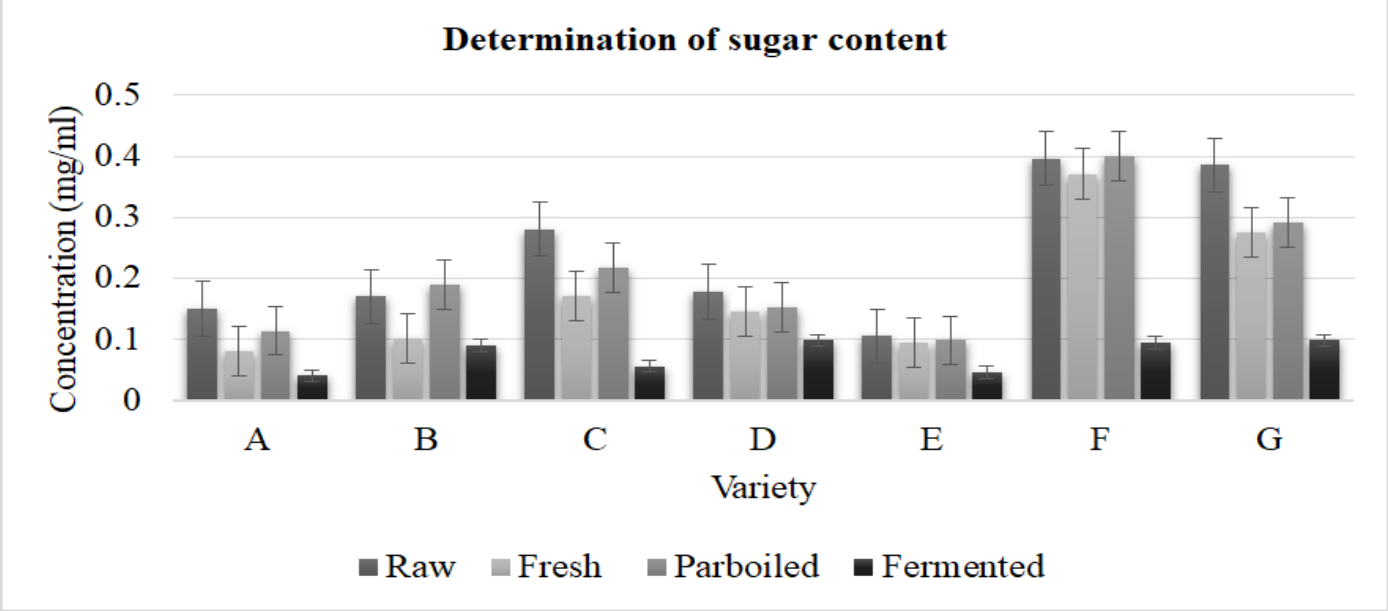

Fig 9 Showing Effect of Pre-Thermal Treatment on Sweet Potato Flour Sugar Content

The above results show differences in varieties as exhibited by initial sugar concentration differences in raw samples. For this reason; F and G (Alicia and Tsumaya had the highest initial sugar concentrations). This has also been alluded in other studies that observe the implication of varietal differences on nutritional composition of different sweet potato varieties (Ingabire. M. R., 2011). Such differences are key in the determination of product formulation, development and design (Elmadfa. I., 2010). In this analysis; total soluble sugar content comprises of glucose, fructose and sucrose. Naturally accumulation of such sugars is as a result of maturation and storage. As such the variability on sugar content has been alluded to be due to type of cultivar and the effects of harvest time and storage (Adu-Kwarteng. E., 2014). Sweet potato is generally superior as compared to other starches on account of richness in vitamins, minerals and dietary fibre, bioactive compounds, whilst possessing a low glycemic index. Sweetness in sweet potato is due to presence of endogenous sugars present during harvest and the effect of processing treatment (Kays. S. J., 2005). Generally drying independently and boiling prior to drying are expected to

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increase the total sugar content in flour (Haruna. S. A., 2018). However, in this study the contrary may be true in that the maximum values for each treatment were observed for the raw tuber. In this study Ascorbic acid treatment was applied as a means for browning prevention, this illustrates a loss in sugar content during and prior to treatment. Parboiling (treatment 2) exposes sweet potato slices to high temperatures and exposure to water which creates an atmosphere for sugar to leach out (Olatunde. G. O., 2015). On the other hand, fermentation values across all treatments were the lowest for each variety. This suggests the occurrence of natural fermentation. The utilization of sugars as an energy source is observed as a decrease in the overall sugar content after treatment. This in turn is in agreement with works reported that suggest that although coupled with nutritional composition and enhanced bioavailability; sugar decrease is accounted for as an expense in fermentation processing (Dos Reis. B. A., 2013), (Samtiya. M., 2021).

- *Evaluation of Sugar Content in Fermentation Broth*

Changes in sugar content, biomass build up and end product accumulation are amongst the dynamic changes expected characteristic of the fermentation process by both bacteria and yeast (Yuliana. N., 2018). The sugar content in fermentation broth was assessed at 24hourly intervals and the O D Readings recorded as follows:

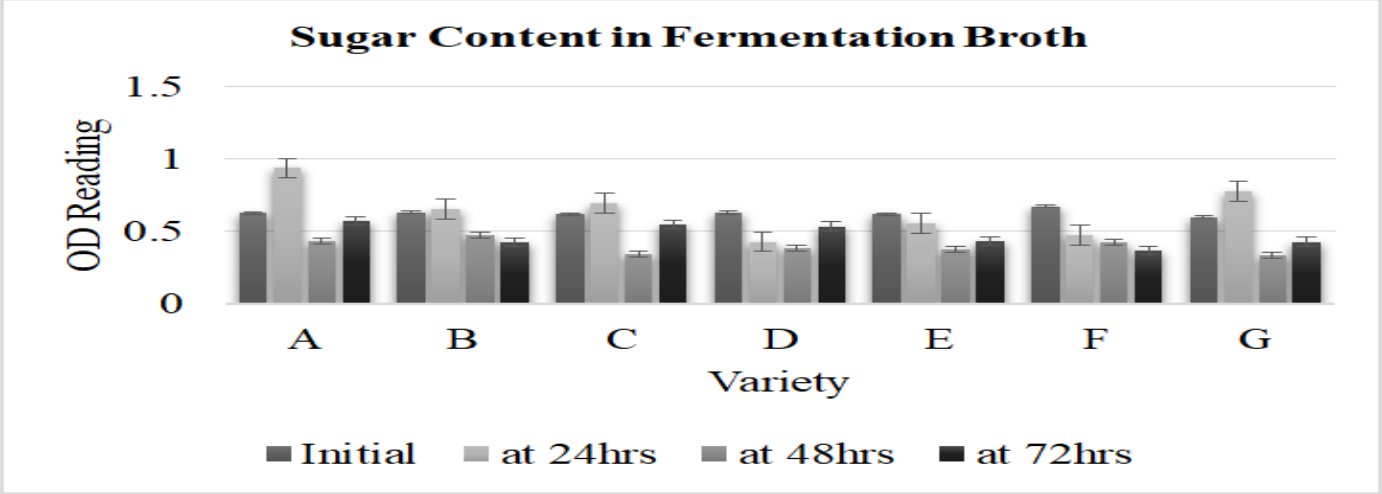

Fig 10 Showing Changes in Total Soluble Sugar Content During Fermentation at 24hr Intervals

Generally, sugar is gradually consumed during fermentation which during spectrophotometry can be observed as decrease in the OD reading. A decline in absorbance value was observed for each variety at 24-hour intervals. For varieties A, B, C and G there is a peak in the values followed by gradual decline at t=48hrs and t=72hours. Whilst A, C, D, E and G exhibit peaks at the t=72hour intervals. Similar peaks have been observed in fermentation studies involving both yeast and bacteria. In bacteria the peak or plateau in concentrations are suggested to be as a result of the utilization and replacement of sugar via microbial metabolism, whilst a continuous decline would have been observed upon sugar depletion with no replacement (Horvath. B. O., 2020). The sugar reduction rates are not synonymous on account of the differences in varieties and their independent reaction kinetics, initial sugar content, concentration of fermenting agents, fermentation conditions and the microbe in question (Sharma. R., 2020). This was implied with the p-value≤0.05 ***(Appendix 4; table 18)***. The color changes were also observed and noted down as follows:

Table 5 Color Changes in Media Broth During Fermentation at 24hr Intervals

SAMPLE	@24hrs	@ 48hrs	@ 72hrs
A	colorless cloudy	colorless cloudy	colorless cloudy
B	pale yellow cloudy	pale yellow cloudy	dark brown cloudy
C	colorless cloudy	yellow cloudy	light brown cloudy
D	brown cloudy	brown cloudy	brown cloudy
E	light brown cloudy	brown cloudy	brown cloudy
F	brown cloudy	brown cloudy	light brown cloudy
G	light brown cloudy	brown cloudy	light brown cloudy
O	colorless	colorless	colorless

C. Determination of Product Acceptability

From the pilot it was determined that all the questions and responses were clear and concise, no revisions were made.

➢ *Results of Survey Work.*

The survey data revealed that all participants were familiar with at least one variety of SP and that the majority of respondents were unaware of SP processing and derived products. The results are provided:

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Table 6 Information Collected on SP During Baseline Survey and Percentage Respondents

	Information collected	Percentage respondents
Age	Under 21	30
	22-31	27
	32-40	20
	Over 40	23
Sex	Male	50
	Female	50
Education	O Level	10
	A Level	23
	Degree	53
	Masters	10
	PhD	3
Enjoy eating SP	Yes	63
	No	3
	Indifferent	33
Familiar SP cultivars	White flesh	100
	Yellow Flesh	20
	Orange Flesh	47
	Purple Flesh	3
SP processing in household	No processing; strictly consumption	100
	Boiling then drying	0
	Boiling the freezing	7
	None of the above	0
Familiarity with SP derived products	Yes	7
on market	No	93
Have you tried or would you be open	Yes	97
to trying SP derived products	No	3
Probability of purchasing SP derived	Extremely likely	23
products in place of competing maize	Very likely	30
and wheat products	Somewhat likely	43
	Not so likely	0
	Not at all likely	3
Sensory evaluation panelist	Yes	100
	No	0

The data highlights the popularity of the raw tubers within households and limited availability and information of SP processing or their derived products.100% of the respondents were familiar with the white fleshed SP variety, however the same could not attributed to the other varieties, especially the purple-fleshed variety; where 1 in the 30 respondents was familiar with the variety. SP was largely prepared within the respective households at a need-to-eat basis; strictly for consumption in which no freezing or drying followed after. Although the number of respondents who had come across SP derived products within the market was low, the number of respondents open to purchasing and potentially replacing wheat and maize competing products was well into the 90th percentile. This could be alluded as the respondents being open to new products, or the respondents being exhausted from the current selection on the maize and wheat competing products.

Generally, all respondents exhibited a keen interest in the potential product as all respondents proceeded to be panelists for the sensory evaluation.

- *Results of Sensory Evaluation*

Descriptive statistics ***(Appendix 4; table 19)*** was used to define the maximum and minimum values with respect to each point within the hedonic scale and a sensory parameter and the results are outlined as follows:

Table 7 Ranking of Most Popular Samples from Sensory Evaluation

	AWFUL	BAD	MODERATE	GOOD	GREAT
Color	Par Alicia	Ferm Irene	Par Victoria	Fresh Chingovha	Ferm Victoria
				Fresh Tsumaya	Ferm Tsumaya
Texture	Par Delvia	Par Alicia	Par Tsumaya	Ferm Victoria	Ferm Delvia
Smell	Fresh Victoria	Par Namanga	Par Delvia	Fresh Chingovha	Ferm Tsumaya
	Ferm Victoria				

(Based on Maximum Values)

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The most preferred samples were identified as those that had undergone either treatment 1 or treatment 3 (good and great) whilst the parboiled samples ranked most in the lower scales (awful to moderate) and Victoria, Tsumaya and Chingovha being the most favored varieties. The information was relevant in that it indicated potential consumer decision with respect to perception and preference (Yang. X., 2016). This in turn highlighted the choice varieties and pre-treatment option for SP flour product for chief ingredient in instant porridge. This is because flour quality and nutrient retention post processing can be favorable and most ideal, however these factors have the potential to remain unnoticed in a given product should the product not meet consumer acceptability (Garces. G. A., 2016).

Table 8 Ranking of Least Popular Samples from Sensory Evaluation

	AWFUL	BAD	MODERATE	GOOD	GREAT
Color	Par Tsumaya	Ferm Delvia	Fresh Tsumaya	Par Tsumaya	Par Chingovha
	Ferm Victoria	Ferm Victoria		Ferm Tsumaya	Par Delvia
	Ferm Tsumaya	Fresh Tsumaya			Par Namanga
	Fresh Victoria	Ferm Tsumaya			Par Alicia
	Fresh Chingovha				
Texture	Ferm Delvia	Fresh Chingovha	Par Victoria	Par Irene	Fresh Chingovha
	Par Victoria	Fresh Delvia		Par Chingovha	Par Namanga
	Ferm Victoria	Ferm Delvia		Fresh Alicia	Par Alicia
		Fresh Victoria		Par Alicia	
		Ferm Tsumaya			
Smell	Par Chingovha	Fresh Chingovha	Par Tsumaya	Par Chingovha	Par Chingovha
	Fresh Irene	Par Tsumaya			Par Irene
	Ferm Irene				Par Victoria
	Fresh Alicia				Ferm Namanga
	Ferm Alicia				Par Alicia
	Fresh Tsumaya				Ferm Alicia
	Par Tsumaya				
	Ferm Tsumaya				
	Fresh Namanga				
	Par Namanga				
	Ferm Namanga				

(Based on Minimum Values)

KEY
Par Parboiled
Ferm Fermented

The lowest preferences were observed mostly for the parboiled flour samples with the exception of parboiled Tsumaya which ranked least awful with respect to both color and smell. Interestingly Tsumaya variety across all treatments had the least awful ranking. This highlights a fundamental distinction of the raw tuber in that choice of pretreatment option did not have a severely detrimental effect on the sensory attributes of the flour product.

V. CONCLUSION AND RECOMMENDATIONS

SP tubers are an essential diet component, the nutritional diversity and constitution of the tuber makes it ideal for product development in the form of SP derived products. Such products would maintain the health benefits of the tuber whilst introducing variety in the form of exciting and ready to eat products with the potential to compete with mainline crop-based derivatives specifically instant porridge. The questionnaire revealed a lag in the availability and knowledge of such products while the sensory evaluation demonstrated a keen interest on such products. The study showed that thermal processing in SP flour production could be coupled with pretreatments such as parboiling and fermentation. However, each pretreatment choice had varying implications on nutrition loss or retention and general sensory appeal. The number of respondents familiar with SP varieties other than the white-fleshed was significantly low. This highlighted the need for targeted efforts and strategies in raising awareness on the different SP varieties and their health benefits. The study has demonstrated strategies towards production of SP flour and in so doing has highlighted areas for optimization. Although fermentation was demonstrated to be the most ideal pretreatment relative to flour quality, effect of treatment on chemical properties and product acceptability, there is need for standardization of the processing procedure to achieve quality SP flour product prior to formulation into instant porridge for example in defining fermentative pathways. This is expected to result in increased demand for SP tubers and development of a protocol for post-harvest tuber handling and storage prior to processing. It is also recommended that the parboiling pretreatment be further improved and optimized to suit variations in SP tuber texture so as to avoid the consequence of gelatinization as opposed to ruling it out completely as a pretreatment option.

Based on the results from this study, the potential of incorporation of SP flour as the key ingredient in instant porridge has been demonstrated with respect to nutrient enhancement or retention and product appeal. As such the study has demonstrated that variety and pretreatment option had a significant effect on the attributes of sweet potato flour (SPF).

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LIST OF APPENDICES

A. Appendix 1

➢ *Manual for Analysis of Cereal and Cereal Products*

Standards for cereals, pulses and their products are laid down in Section 2.4 of Food Safety and Standards (Food Product Standards and Food Additives) Regulations, 2011. These include standards for food grains, their milled products and processed cereal products. In addition, standards for malted foods and solvent extracted edible oilseed flours are also included under this item. (Welfare., 2016). https://old.fssai.gov.in/Portals/0/Pdf/15Manuals/CEREALS%20AND%20CEREAL%20PRODUCTS.pdf

B. Appendix 2

➢ *Baseline Survey Questionnaire*

Description: Below is a questionnaire on sweet potato. This is an academic study intended to provide information on the individual's general perception of the tuber. Should you decide to proceed; sensory evaluation will follow, whereby the respondent will be provided with flour samples derived from different SP varieties from which the respondent is to rank each sample with respect to color, texture and smell according to how well they like the sample with the least being 1 for awful and highest being 5 for great.

Thank you for Agreeing to Answer this Short Questionnaire. Please Answer all Questions by Ticking the Most Appropriate Response. Tick in the Boxes Provided. all Responses are Strictly Confidential and Anonymous

- *How Old are you*

  □ Under 21
  □ 22-31 years
  □ 32-40 years
  □ Over 40

- *What is your Sex?*

  □ Male
  □ Female
  □ Non binary

- *What is your Highest Level of Education?*

  □ Ordinary level
  □ Advanced level
  □ Degree
  □ Masters
  □ PhD

- *Do you Enjoy Eating Sweet Potato Tubers?*

  □ Yes
  □ No
  □ Indifferent

- *Which Sweet Potato Cultivars are you Mostly Familiar with?*

  □ White flesh
  □ Yellow flesh
  □ Orange flesh
  □ Purple flesh

- *How do you Process Sweet Potatoes within your Household?*

  □ No processing; strictly consumption
  □ Boiling then drying
  □ Boiling then freezing

☐ None of the above

- *Have you come Across any Sweet Potato Derived Products Currently within your Local Markets, Such Products Include; Flour, Paste, Beverages, Alcohol, Dried Flakes Etc.*

☐ Yes
☐ No

- *Have you Tried or Would you be Open to Trying Such Sweet Potato Derived Products?*

☐ Yes
☐ No

- *If Sweet Potato Derived Products were Available Today, how Likely would you be to Purchase them Instead of Competing Products Currently Available from Maize and wheat?*

☐ Extremely likely
☐ Very likely
☐ Somewhat likely
☐ Not so likely
☐ Not at all likely

- *Would you be Interested in being Part of a Sensory Evaluation Panel on the Best Sweet Potato Variety for Flour to be Incorporated Into an Instant Porridge Formulation?*

☐ Yes
☐ No

C. Appendix 3

➢ *Sensory Evaluation Form*

Table 9 Sensory Evaluation Form

Sample Code	Color					Texture					Smell				
1A	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2A	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3A	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1B	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2B	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2B	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1C	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2C	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3C	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1D	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2D	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3D	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1E	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2E	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3E	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1F	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2F	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3F	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1G	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2G	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3G	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5

KEY	**1**	**2**	**3**	**4**	**5**
	Awful	Bad	Moderate	Good	Great

Comment:……
……

D. Appendix 4:

➢ *Tables and Figures*

Table 10 One Way ANOVA for the effect of SP variety on Emulsification Stability

ANOVA: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	7	86.9	12.41429	15.33476		
Column 2	7	68.2	9.742857	6.682857		
Column 3	7	84.5	12.07143	7.949048		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	29.5781	2	14.78905	1.48055	0.253937	3.554557
Within Groups	179.8	18	9.988889			
Total	209.3781	20				

Table 1 One Way ANOVA for the effect of SP variety on WHC

ANOVA: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	7	25.72286	3.674695	1.332299		
Column 2	7	12.50277	1.786109	0.368832		
Column 3	7	27.40608	3.915154	0.550449		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	19.03395	2	9.516975	12.6804	0.000366	3.554557
Within Groups	13.50948	18	0.750527			
Total	32.54343	20				

Table 2 One Way ANOVA for the effect of SP variety on OHC

ANOVA: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	7	17.46041	2.494344	0.94248		
Column 2	7	7.910666	1.130095	0.162749		
Column 3	7	10.19417	1.45631	1.445375		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7.105245	2	3.552623	4.178566	0.032312	3.554557
Within Groups	15.30362	18	0.850201			
Total	22.40887	20				

Table 3 One Way ANOVA for effect of SP variety on Moisture Content

ANOVA: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
65.62089	6	417.2919	69.54865	16.61968		
78.42386	6	453.169	75.52816	97.58671		
67.10305	6	329.7093	54.95155	259.9594		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1344.454	2	672.2272	5.389807	0.017223	3.68232
Within Groups	1870.829	15	124.7219			
Total	3215.284	17				

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Table 4 One Way ANOVA for Determination of effect of treatment on protein content.

ANOVA: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Column 1	7	3.428046	0.489721	0.0312		
Column 2	7	2.912987	0.416141	0.009728		
Column 3	7	1.909186	0.272741	0.017769		
Column 4	7	3.857889	0.551127	0.022377		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.30196	3	0.100653	4.966037	0.008037	3.008787
Within Groups	0.486441	24	0.020268			
Total	0.788401	27				

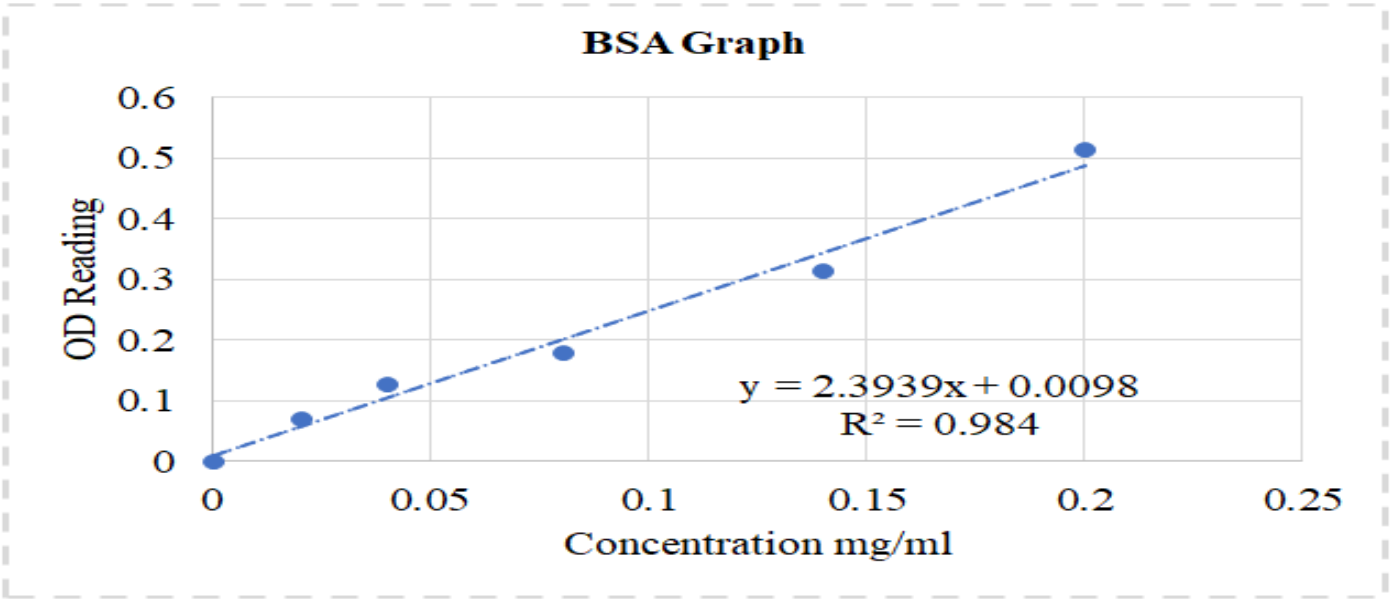

Fig 11 Standards calibration curve for the determination of protein concentration

Table 5 One Way ANOVA for Determination of effect of treatment on TPC

ANOVA: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	7	6.922265	0.988895	0.126542		
Column 2	7	3.633667	0.519095	0.081481		
Column 3	7	5.20398	0.743426	0.059808		
Column 4	7	6.318747	0.902678	0.12984		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.894638	3	0.298213	2.999593	0.05046	3.008787
Within Groups	2.386024	24	0.099418			
Total	3.280662	27				

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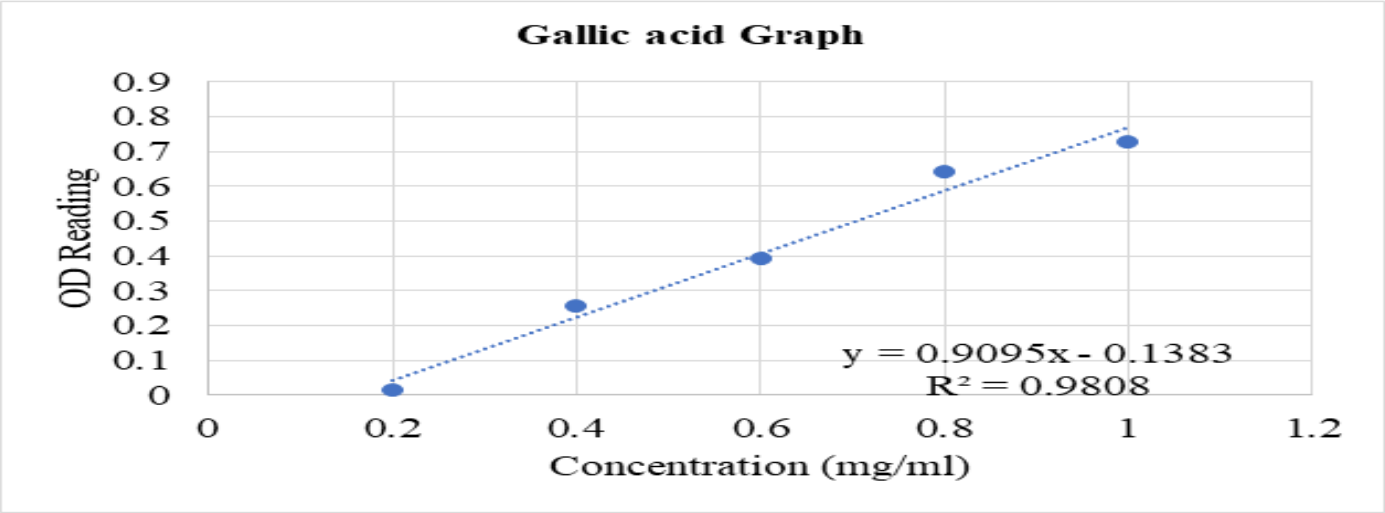

Fig 12 Standards calibration curve for the determination of phenolic concentration

Table 6 One Way ANOVA For Determination Of Effect Of Treatment On Beta Carotene Content

ANOVA: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	7	0.163891	0.023413	0.000115		
Column 2	7	0.071191	0.01017	3.28E-05		
Column 3	7	0.104099	0.014871	5.22E-05		
Column 4	7	0.143358	0.02048	0.000101		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.000729	3	0.000243	3.233935	0.040021	3.008787
Within Groups	0.001804	24	7.52E-05			
Total	0.002534	27				

Table 7 One Way ANOVA for Determination of effect of treatment on sugar content in flour

ANOVA: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Column 1	7	1.6653	0.2379	0.013702		
Column 2	7	1.238	0.176857	0.011678		
Column 3	7	1.465	0.209286	0.011419		
Column 4	7	0.5223	0.074614	0.000692		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.106485	3	0.035495	3.787134	0.023482	3.008787
Within Groups	0.224942	24	0.009373			
Total	0.331427	27				

Table 8 One Way ANOVA for Determination of sugar content in fermentation broth at 24-hour intervals

ANOVA: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Column 1	7	4.393	0.627571	0.000504		
Column 2	7	4.521	0.645857	0.031729		
Column 3	7	2.761	0.394429	0.002752		
Column 4	7	3.305	0.472143	0.006256		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*

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Between Groups	0.311991	3	0.103997	10.08695	0.000174	3.008787
Within Groups	0.247441	24	0.01031			
Total	0.559432	27				

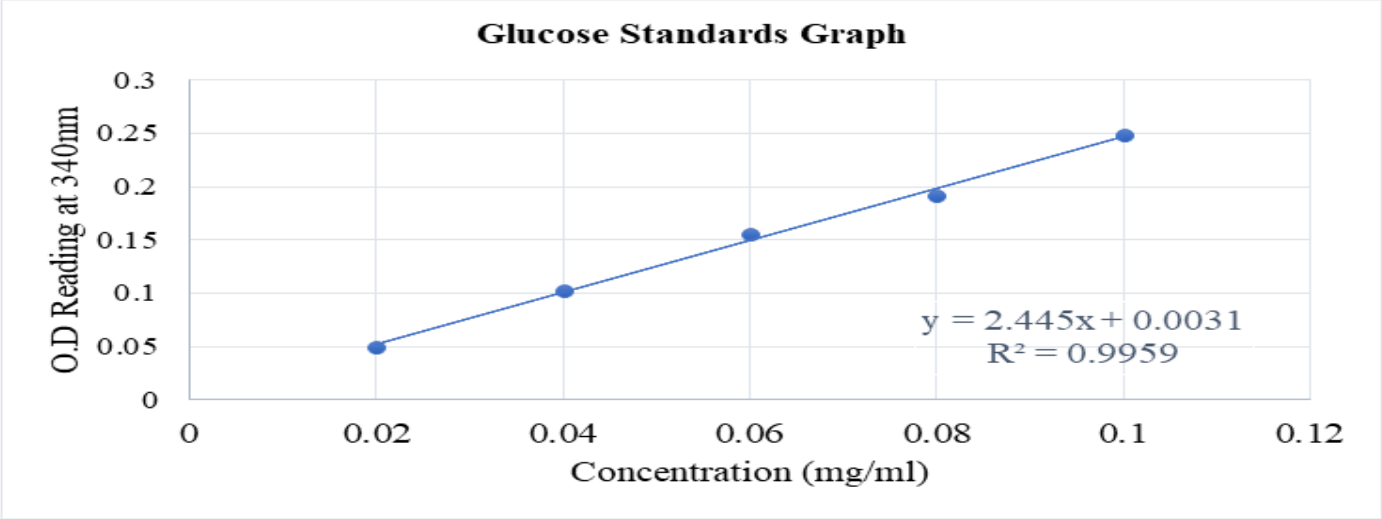

Fig 13 Standards calibration curve for the determination of sugar concentration

Table 9 showing summary of descriptive statistics for sensory evaluation panelist's responses

	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
Mean	5.809524	5.714286	7.571429	6.428571	4.47619	4.952381	7.285714	5.190476	8.333333	4.238095	0.571429	3.904762	14.09524	6.904762	4.52381
Standard E	1.382921	1.102255	0.919553	1.520607	1.269831	1.136989	1.625896	0.97497	1.906547	1.5336	0.147542	0.572816	1.453902	1.09741	0.855289
Median	3	6	7	2	1	4	6	4	6	1	0	4	15	6	3
Mode	0	0	6	2	1	1	0	1	0	1	0	6	10	6	1
Standard D	6.337342	5.051167	4.213923	6.968296	5.819098	5.210338	7.450791	4.467875	8.736895	7.027836	0.676123	2.624972	6.662618	5.028964	3.919427
Sample Va	40.1619	25.51429	17.75714	48.55714	33.8619	27.14762	55.51429	19.9619	76.33333	49.39048	0.457143	6.890476	44.39048	25.29048	15.3619
Kurtosis	0.200723	0.140175	0.022741	-0.2315	-0.61076	0.821084	0.279163	0.146419	-0.40052	3.002594	-0.35019	-0.96083	-0.81555	0.872945	1.830545
Skewness	0.993821	0.751215	0.690734	1.074153	1.124148	1.265293	0.975842	1.006106	0.911132	2.09698	0.788162	0.132579	-0.18044	0.901407	1.431081
Range	21	17	16	20	15	18	25	15	28	23	2	9	23	20	14
Minimum	0	0	1	0	0	0	0	0	0	0	0	0	2	0	1
Maximum	21	17	17	20	15	18	25	15	28	23	2	9	25	20	15
Sum	122	120	159	135	94	104	153	109	175	89	12	82	296	145	95
Count	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Largest(1)	21	17	17	20	15	18	25	15	28	23	2	9	25	20	15
Smallest(1)	0	0	1	0	0	0	0	0	0	0	0	0	2	0	1
Confidence	2.884724	2.299264	1.918155	3.17193	2.648822	2.371717	3.391559	2.033752	3.976987	3.199033	0.307768	1.194873	3.032787	2.289157	1.784102

- Key

A	Awful
B	Bad
C	Moderate
D	Good
E	Great
1	Color
2	Texture
3	Smell

All statical analysis used throughout this study were carried out and exported from Microsoft excel.