



Effects of Sodium Metabisulphite and Blanching Pretreatments on the Quality Characteristics of Yam Bean (*Pachyrhizus erosus*) Flour

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Authors' contributions

This work was carried out in collaboration between all authors. Authors ESB and WAP designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript.

Authors WAP and INO supervised the experimental studies conducted by Author ESB. Author TC supplied the samples for the experiment and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To determine the effects of sodium metabisulphite and blanching pretreatments on the quality characteristics of yam bean (*Pachyrhizus erosus*) flour.

Study Design: Evaluation of the effects of peeling, blanching and sodium metabisulphite pretreatments on the ease of drying, particle size distribution, colour and pH of yam bean flour using a 2 x 3 factorial design.

Place and Duration of Study: Yam bean roots were obtained from the CSIR-Crops Research Institute, Kumasi, Ghana. All reagents used were obtained from accredited suppliers in Accra,

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Ghana. Actual experimental studies were conducted at the laboratories of the CSIR-Food Research Institute, Accra, Ghana, between August 2012 and November 2013.

Methodology: We subjected peeled and unpeeled yam bean tubers (*Pachyrhizus erosus*) to three pretreatments involving blanching at 100°C for 3 min; soaking in 0.1% sodium metabisulphite solution for 3 min and no treatment control. Samples were dried at 55°C for 6 hours, cooled to room temperature, milled, sieved and the flour analyzed for ease of drying as indicated by the final moisture content, colour, pH, and ease of milling as indicated by particle size distribution.

Results: The pretreatment methods had significant ($p > 0.05$) effects on the colour of the flour samples. Peeling, followed by sodium metabisulphite pretreatment produced whitest yam bean flour (L^* -value of 90.89). Flour samples from unpeeled roots recorded lower pH ($p > 0.05$) than those from peeled samples. The combined effects of peeling and sodium metabisulphite or blanching pretreatments produced flours with desirable pH values. The blanched sample had coarser particles (50% > 100 μm) compared to the no treatment control and sodium metabisulphite treated flours (30% > 100 μm). Peeling, metabisulphite or blanching pretreatments did not affect the rate of drying significantly as indicated by their final moisture values.

Conclusion: A standard procedure for yam bean flour production has been suggested to include peeling and sodium metabisulphite pretreatment.

Keywords: Blanching; Sodium metabisulphite; Pretreatments; Yam bean, Peeling; Colour; pH; Particle size; *Pachyrhizus erosus*.

1. INTRODUCTION

Yam bean (*Pachyrhizus erosus* (L.) Urban), is known to have originated in Mexico and Central America [1]. Even though these are major growing centers, the plant is known to grow well in tropical and sub-tropical regions and has high potential in nitrogen fixation [2]. *P. erosus* is presently cultivated throughout the tropics. Currently in Ghana it is being cultivated by the CSIR – Crops Research Institute on experimental basis. The plant produces an enlarged taproot, like carrot, which is consumed raw or processed and is considered a good source of energy and easily digestible food [3]. Yam bean is a root crop of great nutritional and economic importance. *P. erosus* is known to contain 87.1% water, 1.2% protein, 0.1% fat, 10.6% carbohydrate and 0.7% crude fiber [4]. It has been reported that the tuber of *P. erosus* contains an appreciable amounts of macro and micro nutrients including magnesium, sodium, phosphorus, and calcium [5,6,7].

Improper harvesting and poor post-harvest handling of root and tuber crops are known to cause physical damage resulting in susceptibility to fungal attack, as well as increase in the rate of dehydration and browning. *P. erosus*, like other root crops are liable to harvesting, transportation, storage and chilling injuries. Also, slicing during processing promotes an increase in the enzymatic activities associated with the phenomenon of browning resulting in changes in the organoleptic properties and nutritional value

of the product [8]. Wounded and cut yam bean suffer greatly from textural changes, decay and internal browning caused by the fungi *Rhizopus stolonifer* and *Penicillium* sp., when stored at low temperatures (<10°C) and high relative humidity above 80% [9]. The problem of the crop's high moisture content and ease of bruising makes it impossible to store for long. It is therefore imperative that the roots are processed into various forms in order to increase their shelf life, facilitate transportation and marketing and increase their utilization base and thereby minimize losses.

Basically, roots and tubers are transformed into flour by a series of processes which include pretreatments like: sulphating to prevent browning, blanching to prevent enzyme action, drying and subsequently milling to obtain shelf stable flour. Sulphite inhibits enzymatic browning by reducing o-quinones to colourless diphenol [10,11] or by reacting irreversibly with o-quinones to colourless products [12]. Sulphur dioxide and its derivatives (sulphite, bisulphite and metabisulphite) are oxidizing agents that act as preservatives and stabilizers in some products but cause allergies to some people [11]. There has been a global tendency to replace chemical agents with natural products. This has however not been possible at the industrial level yet. Horsfall et al. observed that blanching of plantain slices in 1.25% NaHSO₃ solution resulted in bleaching of the product with reduced moisture and shelf stable flour [13]. According to Doymaz, pretreatment breaks the waxy cuticular surface,

resulting in reduced resistance to moisture movement and thereby increases the drying rate [14]. It is also reported that treatment with sulfur dioxide before drying improved the colour and reduced moisture content of the products [15].

There is however a dearth of literature on the effects of peeling and blanching or sodium metabisulphite pretreatment on the quality characteristics of Yam bean (*P. erosus*) flour; and this constitutes the purpose of the present study.

2. MATERIAL AND METHODS

Yam bean roots were obtained from the experimental farms of the CSIR-Crops Research Institute in Kumasi, Ghana. All reagents used were of analytical grade, and obtained from the accredited suppliers under the ISO 17025 accreditation programme of the CSIR-Food Research Institute laboratory methods.

2.1 Experimental Design

The experimental design used in this study was a 2x3 factorial design with three replicates involving the two factors of peeling and no-peeling and three pretreatments (blanching, soaking in sodium metabisulphite and a no treatment control).

2.2 Statistical Analysis

Statistical significance of differences between means was tested using a one-way analysis of variance (ANOVA) and post-hoc least significance test. Statistical analyses were done using Statistical Package for Social Scientists (SPSS, 16.0) software. Significance of statistical differences were tested at $P < 0.05$.

2.3 Production of Yam Bean Flour

Fig. 1 shows the process flow diagram for the development of the yam bean (*P. erosus*) flour. This process was based on modifications of the method described by Doporto et al. [16] for the production of *P. ahipa* flour. Selected fresh tubers of *P. erosus* were divided into portions which were randomly assigned to the various treatments of peeling and no-peeling with each of three pretreatments involving blanching or metabisulphite pretreatments. Based on the experimental design used, peeled and unpeeled samples were subjected to the following three pre-treatment options: soaking in 0.1% sodium

metabisulphite solution for 3 min, blanching at 100°C for 3 min and a control sample which had no treatment with sodium metabisulphite or blanching. These pretreatment options were applied to each of the two portions of peeled and unpeeled tubers. After the appropriate pretreatment, the samples were then sliced to about 3.0mm thickness using One-Touch Automatic Deluxe Vegetable Slicer (Model KC25, Daka Res. Inc., China) and weighed. The weighed samples were spread thinly on separate drying trays and dried in a mechanical dryer (Apex, Royce Ross Ltd., Construction Ltd. Chemical Eng., Soho Sq. London) maintained at 55°C for five and a half hours. The dried slices were weighed again and milled using a hammer mill (Jacobson Machine Works Inc., Minneapolis, Minn, 55427, USA) to an average particle size of 250µm. The resulting *P. erosus* flour samples were sealed in double laminated sealable polyethylene bags and stored in a freezer for further analysis.

2.4 Determination of Product Quality

The colour of flour samples was measured using the L*, a* and b* colour space (CIE LAB space) with Colorimeter CR-200 (Minolta, Model CR310, Minolta Camera Company Ltd., Osaka, Japan). The samples were poured into a transparent petri dish and the measuring head of the meter was carefully placed on three different locations on the petri dish. The measurements were determined in triplicate and the mean and standard deviations determined. The L* value indicates lightness, where L* = 0 is completely black and L* = 100 is completely white. The a* values represent red to green with positive a* and negative a* depicting red and green, respectively. The b* values on the other hand represent yellow to blue, with positive b* representing yellow and negative b* representing blue. The meter was calibrated with a white tile (L*=97.63, a*=-0.48, and b*=+2.12). ΔE values were calculated to indicate the extent of deviation of colour of samples from the standard tile colour used. ΔE is calculated as the square root of the sum of the squared deviations of L*, a* and b* values i.e. $\Delta E = \sqrt{[\Delta L^2 + \Delta a^2 + \Delta b^2]}$ [17; 18]. The pH of flour was measured in 10% slurry using the Genway pH meter (Model 3330, Felsted, Dunmuw, Essex CM6 3L13, UK). Each determination was done in triplicate. Moisture content was determined in accordance with the method of AOAC.925.10 [19]. Approximately 2 – 5 g well mixed test samples were accurately

weighed and transferred into previously dried and weighed metal moisture dishes and the moisture content determined after drying for 4 h in a thermostatically controlled moisture oven provided with an opening for ventilation and maintained at $103\pm 2^{\circ}\text{C}$. Particle size distribution of samples was determined using the method described by Ngoddy et al. [20] with a slight modification. One hundred grams of sample was weighed into the topmost sieve of a set of sieves (Meinzer II Mains Sieve Shaker, CSC Scientific Company Inc., 2799-C, Merrilee dr. Fairfax, VA 22031, USA) with a mesh range of $250\mu\text{m}$ to $100\mu\text{m}$, arranged in a decreasing order of mesh size.

The samples were subjected to shaking for 20 min and the proportions of the various fractions of flour retained on the sieves calculated as percent of the total weight of sample.

3. RESULTS AND DISCUSSION

The results from the study indicated that peeling with sodium metabisulphite pretreatment resulted in flour samples with highest L^* -values indicating high degree of lightness (Table 1). This implies that the sodium metabisulphite pretreatment results in some degree of bleaching or prevention of enzymatic browning of the flour.

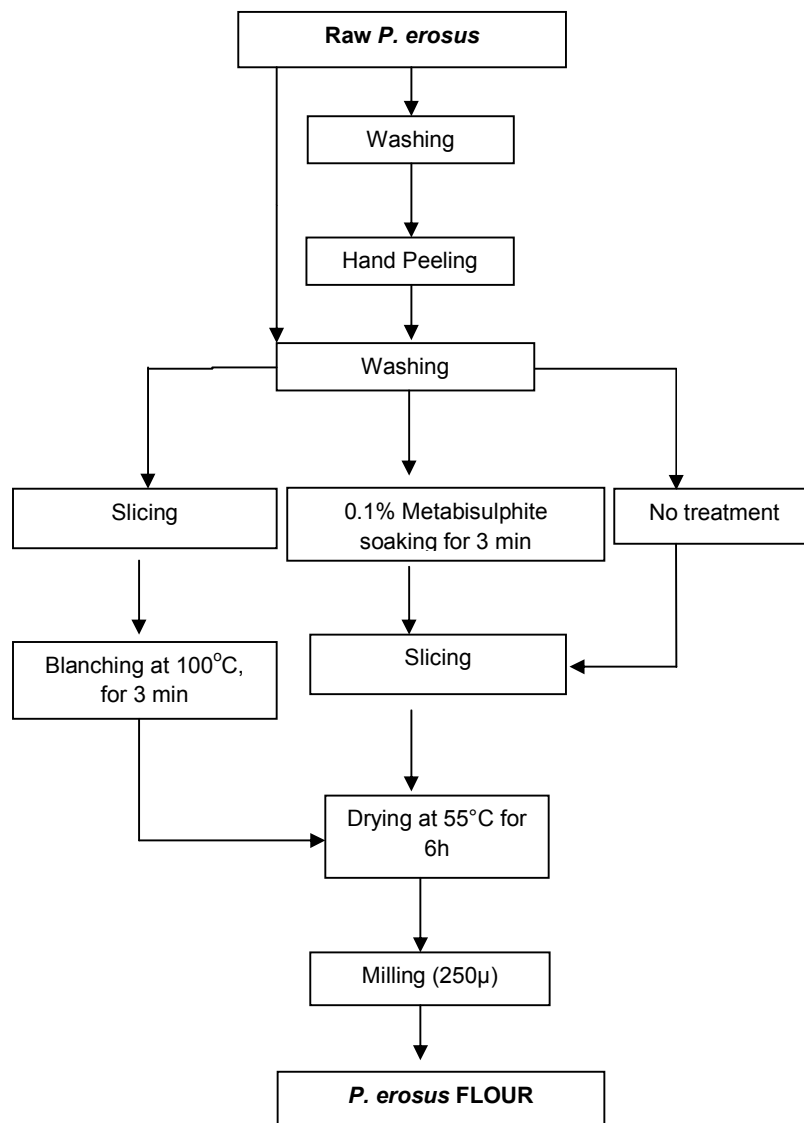


Fig. 1. Flow diagram for the development of *P. erosus* flour using different pretreatment methods as modifications of the method of Dorpoto et al. [16] for *P. ahipa* flour production

A similar situation was reported by Brekke and Allen [15] who used sulfur dioxide pretreatment before drying to improve the colour of dehydrated bananas. The whiteness of the metabisulphite pre-treated flour made it the only one that was comparable to commercial flours (L^* -value of 92.5) [21]. Again the sodium metabisulphite pre-treated *P. erosus* flour recorded the lowest b^* -value among the three treatments. The implication is that the metabisulphite pre-treated *P. erosus* flour was less yellow than the rest of the samples. However, its yellowness ($b^* = 8.84$) was higher than reported for commercial white flour with a b^* -value of 6.90 [18]. The various pretreatment methods had significant ($P > 0.05$) differences on the colour of the flour samples. The negative a^* -values obtained for flours from both peeled and unpeeled samples indicated that the colour is slightly on the greener side than red for all the samples.

However unpeeled samples tend more toward a positive a^* -value (indicative of a tendency towards red) than the peeled samples. This may be due to the presence of the slightly coloured peels in the flour. The b^* values for the two flours from peeled and un-peeled roots were not significantly different ($P < 0.05$). The positive values indicate slight yellow colouration in both samples. ΔE values indicate the extent of deviation of colour of samples from the standard tile colour used ($L^* = 97.63$, $a^* = -0.48$, and $b^* = +2.12$). From the results the unpeeled samples had a greater deviation ($\Delta E = 18.12$) from the standard colour value than the peeled samples ($\Delta E = 15.6$). Peeling, although a tedious unit operation in root crop processing, tend to give a better product as far as colour is concerned.

There were significant differences ($P < 0.05$) in the particle size distribution of all the samples with

the blanched pretreatment samples producing flour with relatively greater particle sizes compared to the control and sodium metabisulphite treated flours (Table 2). Approximately 50% of the blanched flour particles were less than $100\mu\text{m}$ while about 70% of the control and sodium metabisulphite treated samples were below $100\mu\text{m}$ (Table 2). Blanching apparently caused pre-gelatinization of the starch granules, which upon drying hardened and became more difficult to break into finer particles during milling [22].

Flour samples from unpeeled roots were significantly lower ($P < 0.05$) in pH (5.96 ± 0.01) than those from peeled samples (6.65 ± 0.00). The presence of peels apparently contributed to the increased acidity of the samples. This may be attributed to the presence of antioxidants in the peels [23]. For the peeled samples, both sodium metabisulphite and blanching treatments caused significant reduction in the pH of the flour samples, with the sodium metabisulphite treatment having the greatest pH reducing effect. However, the presence of peels before such treatments resulted in the opposite effect which cannot be readily explained.

Both blanching and sodium metabisulphite pretreatments resulted in more water retention during drying of peeled *P. erosus* roots. The untreated control sample dried to a lower moisture content of about 3% while the treated samples had as high as 5.5% in the final product (Table 3). The method of soaking or boiling in the pretreatment method used apparently caused a high intake of water before drying, hence the moisture content of the flour from the pre-treated roots. Additionally, in the case of the blanching pretreatment, partial gelatinization could cause case-hardening and consequent prevention of free moisture flow during drying.

Table 1. Effect of blanching and sodium metabisulphite pretreatments on colour of *P. erosus* flour samples

Treatments	Colour values ¹			ΔE
	L^*	a^*	b^*	
Peeled				
Control	85.01 ± 0.25^c	-1.01 ± 0.01^c	11.30 ± 0.37^c	15.61^d
Metabisulphite	90.89 ± 0.25^a	-1.45 ± 0.03^d	10.63 ± 0.09^d	10.90^f
Blanching	83.10 ± 0.23^d	-1.46 ± 0.03^d	14.18 ± 0.19^b	18.91^b
Unpeeled				
Control	81.86 ± 0.43^e	-0.67 ± 0.02^a	11.04 ± 0.05^c	18.12^c
Metabisulphite	87.76 ± 0.51^b	-0.87 ± 0.01^b	10.13 ± 0.02^d	12.72^e
Blanching	81.86 ± 0.36^e	-1.62 ± 0.08^e	18.02 ± 0.23^a	22.24^a

¹Values with same superscript letter in a column are not significantly different ($p > 0.05$)

Table 2. Effect of blanching and sodium metabisulphite pretreatments of *P. erosus* roots on the particle size of flour samples

Treatments	Particle size values (%) ¹				
	>300 µm	250 – 300 µm	150 – 250 µm	100 – 150 µm	< 100 µm
Peeled					
Control	0.75±0.07 ^b	0.08±0.04 ^d	16.40±0.28 ^d	11.90±0.14 ^e	70.00±0.28 ^b
Metabisulphite	0.70±0.14 ^c	0.40±0.02 ^c	18.60±1.28 ^c	11.20±0.57 ^e	68.90±1.17 ^c
Blanching	0.65±0.07 ^d	0.73±0.11 ^a	29.60±1.85 ^b	19.60±1.57 ^a	49.20±1.07 ^d
Unpeeled					
Control	0.08±0.00 ^e	0.60±0.28 ^b	14.40±0.98 ^e	13.10±0.12 ^c	70.60±1.53 ^a
Metabisulphite	1.30±0.14 ^a	0.60±0.07 ^b	14.80±0.85 ^e	12.20±1.41 ^d	70.70±2.69 ^a
Blanching	0.60±0.28 ^d	0.60±0.00 ^b	31.90±0.42 ^a	18.40±0.57 ^b	48.20±1.13 ^d

¹Values with same superscript letter in a column are not significantly different ($p > 0.05$)

The unpeeled samples did not show much difference in the final moisture values perhaps due to the presence of peels which prevented uptake of more water during the soaking or blanching pretreatments.

Table 3. Effects of blanching and sodium metabisulphite pretreatments of *P. erosus* roots on the pH and moisture content of flour samples

Treatments	Quality characteristics	
	pH	Moisture (%)
Peeled		
Control	6.65±0.03 ^a	2.89±0.08 ^b
Metabisulphite	6.13±0.01 ^c	5.42±0.36 ^a
Blanching	6.42±0.02 ^b	5.54±1.62 ^a
Unpeeled		
Control	5.96±0.01 ^c	2.24±0.18 ^b
Metabisulphite	6.48±0.01 ^b	1.94±0.04 ^c
Blanching	6.73±0.01 ^a	2.39±0.14 ^b

¹Values with same superscript letter in a column are not significantly different ($p > 0.05$)

4. CONCLUSION

Peeling and short soaking in 0.1% sodium metabisulphite are necessary pretreatments in the production of high quality flour from *P. erosus*. Peeling treatment of *P. erosus* roots produces whiter flour with higher pH than unpeeled samples. However a slightly longer drying period is required for the pre-treated samples to achieve the low moisture content observed in the unpeeled samples. Metabisulphite pretreatment further enhances the white colour of the final product apparently by preventing enzymatic browning.

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CONSENT

Not applicable.

ETHICAL APPROVAL

Not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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