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Full Length Research Paper

Effect of drying methods on the rheological characteristics and colour of yam flours

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The effect of drying methods (sun and oven-drying) on the rheological properties and colour of *amala*, a thick paste from yam flour, was investigated using two varieties of yam (*Dioscorea rotundata* and *Dioscorea alata*). The yam flour produced was later reconstituted to produce *amala* of different pasting characteristics, textural qualities and colour. *D. rotundata* produced *amala* of higher paste viscosities, and firmer gels were produced from *D. rotundata* than yam flour paste produced from *D. alata*. A higher water binding capacity (156.7%) was observed in yam flour paste produced from *D. alata* as compared with that of *D. rotundata,* while no significant difference was observed in the solubility index and swelling power of the two varieties. Blanching, a unit operation in yam flour processing, has a significant effect on the pasting characteristics of the reconstituted flour. It reduces the peak viscosity, holding strength, final viscosity, set back and elasticity but it has little or no significant effect on the adhesiveness, smoothness and cohesiveness of the paste. Sun and oven drying had no effect on the pasting characteristics or physicochemical properties. However, yam flour produced using sun drying method had a more elastic paste and a higher brown-index.

Key words: *Dioscorea alata*, *Dioscorea rotundata*, drying, rheological properties, brown index.

INTRODUCTION

Fresh yams are difficult to store and are subject to post harvest losses during storage (Otunsanya and Jeger, 1996; Afoakwa and Sefa-Dedeh, 2001a). These losses serve as an impetus for processing this staple food into a product of longer shelf life. Yam flour can be easily stored for a long period (12 - 18 months) if the flour is free from moisture; hence yam is commonly processed into flour by drying yam slices and milling. In recent years, much attention has been drawn to the quality of dehydrated food products. Drying methods and the physicochemical changes that occur in tissues during drying affect the quality of the dehydrated products. More specifically, the method used for drying affects properties such as colour, texture, density, porosity and sorption characteristics of materials (Krokida et al., 1998). High quality, convenient products are obtained efficiently at a fast rate and at competitive costs by several methods of drying.

Traditionally, yam slices are mainly dried in the open, under the sun. Sun-drying represents a low cost processing method of preserving agricultural produce in the tropics. Open sun drying, however, has some limitations. These include the inability to control the drying process and parameters, weather uncertainties, high labour costs, the requirement of a large drying area, insect infestation, and contamination with dust and other undesirable materials (Sankat and Mujaffar, 2004). A controlled environment, is therefore, recommended to improve the quality of the product.

Hot air drying is one of the most frequently used operations for food dehydration. It is a method in which heated air is blown over food materials with the aid of fan(s) to remove most of the moisture from the food material. The drying of wet materials induces a number of physico-chemical changes in the product, often reflected by colour. By choosing suitable drying methods and the appropriate conditions, the final product quality can be controlled. The objective of this study was to investigate the effects of the drying methods (sun and oven drying)

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Table 1. Means of pasting characteristics of *amala* (yam flour paste).

Drying method	Sample	Peak Viscosity	Holding Strength	Break Down	Final Viscosity	Set Back	Peak Time	Peak Temperature
Oven	Omolokun	311.83a	246.52a	60.88b	414.12a	140.98a	6.24a	64.63a
Sun	Omolokun	389.86a	260.44a	136.11a	397.66a	162.46a	4.51a	65.46a
Oven	Abuja	359.62a	163.42b	79.56a	431.77a	157.11b	5.90a	63.55a
Sun	Abuja	351.63a	271.47a	188.40b	374.29b	210.94a	4.42a	64.70a
Oven	Tda98/01166	336.98a	165.50b	37.85b	353.16a	86.52a	6.21a	63.93a
Sun	Tda98/01166	204.52b	277.63a	110.35b	247.25b	122.69a	5.98a	65.09a
Oven	Tda92-2	267.34a	144.62a	71.54a	271.83a	55.15b	5.82a	64.39a
Sun	Tda92-2	227.40a	183.33a	44.27a	202.91a	97.76a	4.76a	64.58a

Means with the same letters in a column are not significantly ($p \leq 0.05$) different.

on the pasting characteristics, physico-chemical properties and colour of yam flour.

MATERIALS AND METHODS

Cultivars of *Dioscorea alata* (Tda 98/01166 and Tda 92-2) were obtained from the International Institute of Tropical Agriculture, Ibadan (IITA) and cultivars of *Dioscorea rotundata* (Omolokun and Abuja) were purchased from a farmer at Bodija market, Ibadan, Nigeria. The yam tubers were hand-peeled and sliced to 10 mm thickness. Some of the slices were blanched using the method of Olurin et al. (2006) and other slices were sulphited by immersing them in 0.5% sodium metabisulphite solution for 5 min.

The blanched and sulphited slices were divided into two sets, one set was sun-dried for two weeks and the other set was oven-dried to constant weight in a convective air dryer operated at 60°C at an air velocity of 2.5 ms^{-1} until constant weight was obtained. The dried slices were milled with a hammer mill and then sieved under laboratory sieve of 600 μm aperture size.

The pasting characteristics of the yam flour were studied using the Rapid Visco Analyser (RVA) series 4 (Newpoint Scientific PTY, Limited) as described by Delcour et al. (2000).

The colour of the flours and pastes (obtained with a Rapid Visco Analyser) were measured using a Minolta portable chroma-metre. The hunter lab colour coordinates system L* a* and b* values were recorded and the brown index was calculated as (100-L*).

Statistical analyses were carried out for all the results by a general linear model procedure, using the SAS package (Statistical Analysis Systems). Differences between means were calculated with the Duncan Multiple Range Test and the significance difference was at 0.05.

RESULTS AND DISCUSSION

Peak viscosity is a measure of the ability of starch to form a paste; it indicates the highest value of viscosity during the heating cycle. No significant difference was observed in the peak viscosities of oven-dried and sun-dried yam flour of the Omolokun, Abuja and Tda 92-2 varieties, but there was a significant difference in the peak viscosities of sun-dried and oven-dried pastes of Tda 98/01166. This may be linked to the biological and morphological properties of Tda 98/01166 starch.

Holding strength measures the ability of starch to remain undisrupted when yam paste is subjected to a long duration of high, constant temperature during the process of steaming, which is an important unit operation in the processing of amala (reconstituted yam flour). No significant differences were observed in the holding strength of sun-dried and oven-dried Omolokun variety of *D. rotundata* and Tda 92-2 variety of *D. alata*, but significant differences were observed in the sun-dried and oven-dried pastes of the Abuja variety of *D. rotundata* and the Tda 98/01166 variety of *D. alata*, as shown in Table 1. However, higher values of holding strength were observed in sun-dried flour compared to oven-dried flour in all the yam varieties studied. This higher holding strength might be due to the strong associative forces between the starch granules of sun dried yam slices compared to oven-dried slices.

Breakdown measures the ability of starch to withstand breakdown during cooling, amala produced from sun-dried *D. rotundata* varieties (Omolokun and Abuja) and the *D. alata* variety (Tda 98/01166) has a higher breakdown point than oven-dried varieties, as shown in Table 1. Oduro et al. (2000) reported that starches with low paste stability or breakdown have very weak cross-linking within the granules. It therefore means that there is stronger cross-linking within the granules of sun-dried flour, probably due to the lower temperature of drying.

In addition, the drying method has a significant effect on the final viscosity of reconstituted yam flour paste. The final viscosity of the paste increased progressively as the temperature of the paste decreased during cooling. The final viscosity of the oven-dried paste of the sample is significantly different from other samples. The increment in the final viscosity of paste made from oven-dried sample during cooling indicates formation of a firm gel after cooking and cooling, rather than a viscous paste as in the case of sun-dried sample. Afoakwa and Sefa-Dedeh (2001b) reported that the drastic increase in viscosity of yam paste during cooling might have resulted from the high retrogradation property of yam starch during cooling.

Table 2. Physico-chemical properties of yam flour made from *D. rotundata* and *D. alata*.

Drying method	Sample	Water absorption capacity (%)	Solubility index (%)	Smelling power (g/g) %	Amylose content (%)
Oven	Omolokun	134.60a	12.41a	4.86a	22.83a
Sun	Omolokun	134.13a	12.19a	4.40a	23.09a
Oven	Abuja	132.23a	12.68a	4.85a	23.53a
Sun	Abuja	122.20a	12.70a	3.89a	22.49a
Oven	Tda98/01166	166.33a	12.81a	6.63a	23.17a
Sun	Tda98/01166	152.07a	11.66a	4.45a	23.01a
Oven	Tda92-2	162.33a	12.60a	4.34a	23.64a
Sun	Tda92-2	146.07a	12.03a	4.05a	23.49a

Means with the same letters in a column are not significantly ($p \leq 0.05$) different.

Table 3. Brown index of yam flour and amala.

Drying method	Sample	Yam flour	Yam flour paste
Oven	Omolokun	28.93a	57.72a
Sun	Omolokun	31.46a	62.38a
Oven	Abuja	21.87b	56.67a
Sun	Abuja	29.64a	62.55a
Oven	Tda98/01166	27.77b	52.26a
Sun	Tda98/01166	41.32a	65.95a
Oven	Tda92-2	34.57b	63.72a
Sun	Tda92-2	43.70a	68.54a

Means with the same letters in a column are not significantly ($p \leq 0.05$) different.

Setback measures the re-association of starch and is associated with cohesiveness of amala. The setbacks of Omolokun and Tda 98/01166 were not significantly affected by the drying methods used. The sun-dried samples of all the yam flours were more cohesive than the oven-dried yam flours. Kin et al. (1995) had earlier reported that a high setback value is associated with a cohesive paste while a low value is an indication that the paste is not cohesive. Hence, the paste made from sun-dried flour is more cohesive than pastes made from oven-dried yam flour.

The peak times and peak temperatures of flour of all the yam varieties studied were not significantly affected by the drying methods used, as shown in Table 1. There was no significant difference in the water absorption capacity of oven-dried and sun-dried flour of the yam species investigated. However, a lower absorption capacity was observed in the sun-dried yam flour samples (Table 2). Low water absorption capacity is attributed to a close association of starch polymers in the native granules (Lorenz and Collin, 1990).

Swelling power and solubility index provide evidence of the magnitude of interaction between starch chains within the amorphous and crystalline domains and also evidence of association bonding within the granules of yam starches. Drying methods do not have any significant effect on the solubility index and swelling power of the samples investigated. A low swelling power was observed in sun-dried flour, this may be due to stronger bonding force in its starch granules (Table 2). A higher solubility index was observed among the oven-dried flour samples compared to sun-dried flour. Soni et al. (1993) attributed high solubility indices in starches to the easy solubility of the linear fraction (amylose) which is linked loosely with the rest of the macro molecular structure, and released or leached out during the swelling process. A linear relationship was observed between the solubility index and the swelling power of sun-dried and oven-dried flour. Kittahara et al. (1996) explained that this linear relationship is because the swelling of starch granules above the gelatinization temperature is often accompanied by leaching of soluble polysaccharides hence, as the starch is swelling, soluble polysaccharides are being leached out.

Generally, there was an increase in the brown index when flour was reconstituted to produce *amala* as compared with the brown index value of yam flour and corresponding pastes as shown in Table 3. This is in agreement with the earlier finding of Akissoe et al. (2001). The brown index of the paste, increased due to the thermal degradation of the originally colourless complex polyphenols (proanthocyanidins and lignins) to coloured phenols (anthogaridins) during steaming of the paste. The brown indices of all the sun-dried samples were higher than those of the oven-dried samples. As shown in Table 3, the drying method has a significant effect on the brown index. There was no significant difference in the brown indices of omolokun, Tda 98/01166 and Tda 92-2 yam varieties. The increased brown index of sun-dried flour may be ascribed to the activity of polyphenoloxidases as a result of the prolonged drying period.

Conclusion

Although drying methods did not produce a significant difference on the peak temperature and time of all the yam flour samples investigated, sun-dried yam flour produced a paste of higher holding strength, breakdown and setback values; hence amala produced from sun-dried flour is more compacted and cohesive. Sun-dried yam flour has a higher brown index compared to oven-dried flour due to the activity of polyphenoloxidase over the longer drying period. Generally, all the flour samples produced amala with a high brown index due to the degradation of the colourless phenolic complex to coloured phenols.

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