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The role of sweetpotato root and starch characteristics on thermally processed products

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Abstract. The significance of processing sweetpotato (SP) was investigated by assessing the characteristics of three new sweetpotato varieties (Tanzania, New Kawogo and Naspot 5) and a UK commercial (Jewel) variety. The characteristics of the roots (dry matter, sugar and amylase contents) and their respective starches (gelatinisation and pasting temperature parameters) were analysed. Tanzania and Naspot 5 SP root pulp had comparable dry matter (37.0-37.8%), reducing sugar (0.5%) content and alpha amylase activity (2.60-2.66 $mg.g^{-1}.min^{-1}$) as opposed to New Kawogo. Jewel variety had the lowest dry matter (19.0%), highest reducing sugar content (2.6%) and alpha amylase activity (7.78 $mg.g^{-1}.min^{-1}$). Variation in SP root characteristics might indicate post harvest changes or due to variety differences. The same ranking order of the starch varieties was followed for gelatinisation and pasting temperature parameters, with Naspot 5 having the highest, followed by Tanzania, New Kawogo and Jewel starches. Jewel and New Kawogo similarly showed comparable onset temperatures of gelatinisation and pasting that differed from Naspot 5 and Tanzania. Naspot 5 (15.6 J/g) and Tanzania (15.2 J/g) starches exhibited higher enthalpy of gelatinisation than Jewel (13.2 J/g) and New Kawogo (12.4 J/g), indicating that they may require high energy to disrupt their crystalline granule order. Jewel SP processed products are likely to have inferior sensory properties. Individual starch characteristics did vary but may be used to select sweetpotato varieties for specific products.

Introduction

There is an increased interest in adding value to sweetpotato (SP) roots such that a broad range of SP products are provided to the consumer (Hagenimana and Owori, 1997; Hagenimana *et al.,* 1998). Presently SP is consumed as either boiled, roasted or baked. Dried SP chips and flour are popular products available in Eastern Uganda (CIP, 1998). The stability of these products during processing and storage are dependent on the composition of the roots and SP starch characteristics (Katayama *et al.*, 1999). Starch is the major constituent (60%)of the dry matter, and therefore the basis of SP products. However, other constituents such as sugars, lipids, and amylases influence the functional behaviour of SP starch during processing. Sweetpotato contains α-amylase that is concentrated at the periphery of the root tuber and b-amylase distributed throughout the root (Hagenimana *et al.*, 1992). These amylolytic enzymes have been utilised as a processing aid in the production of dehydrated SP flakes, mashes and purees, and may be used for production of ethanol (Vijaya and Basappa, 1997). On the other hand SP α-amylase has the ability to hydrolyse native (raw) SP starch, such SP functional properties are modified before it is further processed to stable products. Sugars are another SP constituent that affects the functional behaviour of starch during processing by inhibiting starch gelatinisation (*starch conversion process*) and also cause browning of the processed products.

The above SP products are thermally processed via baking, roasting, steaming or drying (Susheelamma *et al.*, 1994), which involve gelatinisation of starch to various degrees depending on processing parameters. For this reason the composition of SP raw material will have an effect on the sensory attributes of its respective products, depending on the postharvest history of the roots. This paper provides an interpretation of the sensory quality attributes of the thermally processed products based on the SP root pulp and starch characteristics.

Materials and Methods

Varieties. Four SP varieties were procured for the study. Three of these were new viz. Tanzania, Naspot 5, and New Kawogo are Ugandan varieties, while the fourth, Jewel is a UK variety.

Starch extraction procedure. Starches from the SP roots were extracted according to the procedure of Collado and Corke (1997). Sweetpotatoes were washed under tap water, peeled and shredded using a food processor. The shredded SP pulp was added to 0.01% mercuric chloride, which was used as an enzyme inhibitor for amylases (Madamba *et al.*, 1975), at a ratio of 1:1 (w/w) and blended for 1 min at medium speed. The blended pulp was then filtered through a cheese cloth and the residue discarded. Starch in the filtrate was passed through a 250 mm sieve and left to settle at 18°C for 18 h. The supernatant was discarded and the sediment resuspended in distilled water and left to settle for another 2-3 h period. This step was repeated twice and starches left to dry at room temperature (18°C) for 18-19 h. Naspot 5 was resuspended in distilled water a fourth time to eliminate the intense orange colour. The dry starch mass pellet was broken to form a powder, gently ground with a mortar and pestle, and a 250 mm sieve fraction retained.

Dry matter content. The dry matter content of SP root pulp was measured by drying samples (2 g) in a vacuum oven (Gallenkamp Oven 300 series, UK) at 80°C to a constant weight for about 20 h.

Amylase activity. Amylase (α- and β-) activity of the root pulp was assayed by incubating an aliquot (0.1 ml) of the enzyme extract at 40°C as described by Hagenimana *et al.* (1994 a). Enzyme extracts were prepared by blending 150 g of shredded SP pulp for 1 min in 450 ml of 20 mM sodium phosphate buffer (pH 6.0), containing 0.3% NaCl, 0.2% $CaCl_2$ and 5 mM β-mercaptoethanol (Hagenimana *et al.*, 1992). The blended material was filtered through four layers of cheesecloth. The filtrate was then centrifuged at 1350 *g* (3000 rpm) for 20 min (MSE Centrifuge, Multex, UK) and the supernatant kept in ice-cold water prior to the assay. The enzyme activity for α- and β-amylases was measured separately by determining the increase in reducing sugars of a 1% soluble starch solution gelatinised by boiling. For the α-amylase assay, soluble starch was dissolved in 16 mM sodium acetate buffer (pH 6.0) containing 5 mM $CaCl_2$ and 0.04% NaCl while for β-amylase assay in 16 mM sodium acetate buffer, pH 4.5 (Bernfeld, 1955; Hagenimana *et al.*, 1994 a). The optical density of the samples was measured at 540 nm using the LKB Biochrom spectrophotometer (LKB Biochrom, UK). A standard curve prepared using glucose (0-1.2 mg/ml) was used to convert the absorbance readings to total reducing sugar as mg glucose equivalents. Amylase activity level was reported as mg of glucose per g of dry SP pulp per min.

Sugar content. Sugars (*sucrose, maltose, glucose and fructose*) found in SP were measured enzymatically using Boehringer Mannheim GmbH, Biochemicals enzyme kits (R-Biopharm GmbH, Darmstaadt, Germany) as described by Namutebi (2002) and recorded as reducing and total sugar contents.

Rapid viscosity analysis. Pasting profiles of starch suspensions were measured by a Rapid Viscosity Analyser (RVA) RVA-4 model (Newport Scientific, NSW, Australia). Starch samples (3 g), after correcting for the initial moisture of the starches, were dispersed in 25 g of distilled water in an aluminium RVA can to give 10.7% starch concentration. Starch suspensions were held at 50°C (1 min 15 s); heated from 50 to 95°C (7 min 30 s); held at 95°C (5 min); cooled from 95 to 50°C (7 min 30 s) and held at 50°C (1 min 45 s). The pasting and peak temperature parameters were recorded.

Differential scanning calorimetry (DSC). A Perkin Elmer DSC 7 (Perkin-Elmer INC., Beaconfield, UK) calibrated using indium (156.8°C) and cyclohexane (6.7°C) standards was used to study the gelatinisation behaviour of starches in excess water. An empty pan similar to the one used for the sample was used as the reference. Starch samples (2.5 mg) on a dry weight basis (dwb) were weighed into aluminium pans followed by 7.5 mg of distilled water and left to equilibrate overnight. The DSC thermograms were acquired over a temperature range of 10 to 100°C at 10°C min^{-1} and gelatinisation parameters were computed using the Perkin Elmer Pyris software.

Statistical analysis. The data were subjected to a one-way analysis of variance to determine differences among the starch varieties at P=0.05.

Results and Discussion

Properties of sweetpotato root pulp. Table 1 shows the properties of the SP root pulp measured. Dry matter contents of the new SP roots ranged from 33.20 to 37.83 %, while Jewel SP (a commercial variety) had a dry matter content of 19.00 % (Table 1). All SP varieties had dry matter contents that were within the range (17.8-36.5 %) reported for other SP varieties (Oboh *et al.*, 1989; Hagenimana and Owori, 1997; Hagenimana *et al.*, 1998). The dry matter contents for Tanzania and Naspot 5 were however higher than the values reported by Ssebuliba *et al.* (2001). This could be attributed to different geographical localities and harvesting season for these new varieties. The low dry matter content for Jewel SP variety could be attributed to the post harvest history that was unknown or to varietal effects.

It is known that SP contains free sugars that arise when the SP plant is developing or during the post harvest handling of the root crop (Babu *et al.*, 1994; Hagenimana *et al.*, 1994 b; Morrison *et al.*, 1993). All SP varieties studied contained sugars, with the total sugar contents ranging from 9.5 to 14.3% (dry solids basis). The reducing sugar level was highest for the Jewel variety. Sucrose (non-reducing sugar) was the predominant sugar these varieties (Table 1). For most SP varieties, sucrose constitutes the bulk of sugars found in SP roots, followed by low amounts of

Table 1: Measurements# on sweet potato pulp.

Sweet potato variety	Dry matter (%)	Total sugars (%)	Reducing sugars (%)	α-amyalse activity ($mg.g^{-1}.min^{-1}$)	β-amylase activity($mg.g^{-1}.min^{-1}$)
Tanzania	37.83±0.84	9.53±0.24	0.52±0.20	2.63, 2.70(2.66)	2.99, 3.06(3.02)
New Kawogo	33.20±0.96	7.96±0.23	0.74±0.10	2.21, 3.28(2.74)	3.39, 3.43(3.41)
Naspot 5	37.03±0.23	10.36±0.10	0.47±0.10	2.57, 2.63(2.60)	1.97, 3.12(2.54)
Jewel	19.00±0.36	14.30±0.52	2.55±0.33	6.53, 9.03(7.78)	6.00, 6.56(6.28)

#Values are reported on a dry weight basis (dwb) of the sweet potato pulp.

fructose and glucose, with the exception of a few SP varieties that were found to contain maltose as the predominant sugar.

Reducing sugars are a key factor for non-enzymatic browning of products. Browning of products may impart an appealing or negative sensory quality attribute, depending on the products being processed. In addition, sugars affect the starch conversion process by reducing the gelatinisation temperature of starch subsequently influencing the processing parameters. It has been observed that heat processed products from SP result in highly browned products as compared to cereal flours (Namutebi, 2002) or even cassava flour. For thermally processed products, Jewel SP with highest reducing sugar content (Table 1) would undergo intensive browning compared to the other varieties which contained less than 1% reducing sugar level (dwb).

Each SP variety contained both α- and β-amylases (Table 1), which is typical of SP (Hagenimana *et al.*, 1992). Among the new SP varieties, New Kawogo had the highest α- and β-amylase activity, 2.74 and 3.41 mg. $g^{1}.min^{-1}$, respectively compared to Tanzania and Naspot 5 SP. This would suggest that starch from New Kawogo might be prone to amylase hydrolysis if the roots are not appropriately handled after harvest. Jewel SP, the commercial variety, had substantially high mean levels of α- and β-amylase activities, 7.78 and 6.28 $mg.g^{-1}.min^{-1}$, respectively (Table 1). High sugar and amylase activity levels as found in Jewel SP variety have similarly been reported for the orange flesh US traditional cultivar known to have high amylase activity and sugar levels (Morrison *et al*,. 1993). However, it is possible that the high levels of amylase activity and sugar of the Jewel SP were due to its postharvest history, which was unknown. Hence the low dry matter, which could have been affected by the high α-amylase activity.

Gelatinisation parameters. Generally, thermal processing of starch involves moist heating of starch in a medium of water. Gelatinisation is the process of heating starch in excess water, where starch granules lose their native structure. Gelatinisation parameters of the starches were obtained by Differential Scanning Calorimetry (DSC). Table 2 shows the gelatinisation temperature parameters of the SP starches. Figure 1 shows the enthalpy of gelatinisation (DH) of starches, which is an indication of the amount of energy released when the amylopectin structure is disrupted during starch conversion. Naspot 5 starch had the highest DH, followed by Tanzania then Jewel. New Kawogo starch had the lowest DH (data not presented). This indicated that Naspot 5 and Tanzania starches require a higher energy input to disrupt their crystalline granule order compared to Jewel and New Kawogo starches. The DH for these SP varieties (12.5-15.6 J/g) were similar to DH

Table 2: Gelatinisation parameters and rapid viscosity Analyser (RVA) temperature parameters of sweetpotato starches.

Sweet potato variety	[1]DH (J/g)dwb	[1]To (°C)	[1]Tp (°C)	[2]RVA pastetemp (°C)	[2]RVA peaktemp (°C)
Tanzania	15.1, 15.3(15.2)*	71.77, 71.94(71.86)	75.33, 75.33(75.33)	75.02±0.28	85.60±0.30
New Kawogo	12.3, 12.6(12.5)	64.30, 64.70(64.50)	68.30, 69.30(68.80)	69.20±0.05	77.6±0.20
Naspot 5	15.8, 15.4(15.6)	73.15, 73.17(73.16)	78.33,78.33(78.33)	76.73±0.03	85.80±0.10
Jewel	13.6, 13.1(13.4)	58.20, 58.21(58.20)	72.67, 73.00(72.83)	71.28±0.21	84.80±0.20

1. DSC gelatinisation parameters.
2. RVA temperature parameters.
*Values in parenthesis are means of the two respective values.
dwb: dry weight basis.

values reported for other SP starch varieties (Noda *et al.*, 1992; 1996; 1998).

Jewel and New Kawogo starches had low onset and peak gelatinisation temperatures (Table 2) showing they would gelatinise much earlier than Naspot 5 and Tanzania starches under similar processing conditions. Starches with high amylose content are assumed to show low onset (To) and peak (Tp) gelatinisation temperatures, and low DH due to a low proportion of amylopectin, the crystalline region. Although, Naspot 5 starch with the highest amylose content of 23.5±0.5%, had the highest DH and gelatinisation temperature parameters compared to New Kawogo with the lowest amylose content of 19.1±0.3% (Namutebi, 2002). Previous work has shown that DSC gelatinisation parameters do not necessarily correlate with the proportion of crystalline starch granule regions, that is the amylose-amylopectin ratio but rather are influenced by the molecular architecture of crystallites related to the distribution of amylopectin unit chains, specifically the short unit-chains (Noda *et al.*, 1998). Noda and co-workers (1998) showed that starch with low DH, low onset and peak temperatures of gelatinisation had relatively abundant short unit-chains of amylopectin within the same botanical origin.

It is well established that sucrose increases the onset temperature of starch gelatinisation through an anti-plasticising effect on the amorphous fraction of the native starch granules when compared with water as the solvent. These varieties contained sucrose (non-reducing sugar) as the predominant sugar, therefore the processing conditions of SP starches will not only depend on the sugar content, but type of sugar. The monosaccharide sugars have been found to have a greater effect on the starch conversion process than disaccharide.

Rapid Viscosity Analyser parameters. The paste and peak temperature parameters of the starches give an indication of the processing conditions of specific starchy products. Naspot 5 starch had the highest RVA paste and peak temperatures followed by Tanzania, then Jewel and New Kawogo (Table 2). Since pasting of starch in the RVA canister is a thermal event similar to gelatinisation of starch granules in excess water in the DSC pans, the DSC To and Tp temperature parameters of the four SP starch varieties followed a similar trend (Table 2). Varietal differences in RVA temperature parameters were observed for these SP varieties and have similarly been noted for other varieties (Katayama *et al.*, 1999). The RVA paste temperatures of the Tanzania and Naspot 5 starches were however higher than those reported by Katayama *et al.* (1999). New Kawogo and Jewel starches with low RVA paste and peak temperatures will cook faster than the Tanzania and Naspot starches under similar processing conditions.

Conclusions

Technologically starch is an important polysaccharide for a number of products where it serves as a binding or thickening agent to modify the textural property of products. Starch being the predominant component of sweetpotato influences the characteristics of SP products, which will however, depend on the structure of starch during its postharvest history.

This study endeavoured to interpret the relationship between SP root and starch characteristics to the processing and storage conditions and the likely sensory attributes of thermally processed products. Jewel SP variety with high amylase activity and sugar content, implies excessively browned products are obtained compared to the other varieties. Since Jewel SP variety is known to possess high amylase activity, it therefore would require specific handling conditions to minimise the effects of amylase on the starch. Likewise the high sugar content of Jewel indicates that it is not a suitable raw material for products, where minimal browning maybe an important sensory attribute.

However, with regard to starch characteristics, Jewel starch variety did not apparently show marked differences in gelatinisation and pasting parameters from New Kawogo. Implying the two would have similar processing functional properties. However, the composition of the respective roots that differed would influence their performance.

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