Functional and pasting properties of cassava and sweet potato starch mixtures

P. A. ASARE, I. GALYUON, J. K. SARFO & J. P. TETTEH
(P.A.A. & J.P.T.: Department of Crop Science, University of Cape Coast, Cape Coast, Ghana; I.G.: Department of Molecular Biology and Biotechnology, University of Cape Coast, Cape Coast, Ghana; J.K.S.: Department of Biochemistry, University of Cape Coast, Cape Coast, Ghana)

ABSTRACT

Starch is an important carbohydrate contained in staple foods such as potato, wheat, maize, rice, and cassava. Native starches, irrespective of their source, are undesirable for industrial applications because of their inability to withstand processing conditions such as extreme temperature, diverse *p*H and freeze-thaw variation. In order to improve on the desirable functional properties, native starches are often modified. The functional and pasting properties of cassava starch and sweet potato starch mixtures at different ratios were investigated. Starches from four different cassava genotypes ('Adehye', AFS048, 'Bankye Botan' and OFF146) and one local sweet potato were used for the study. The swelling volume and swelling power of 'Adehye' and AFS048 starches decreased as the proportion of added sweet potato starch increased. The pasting and peak temperatures of cassava-sweet potato starch mixtures increased with higher proportions of sweet potato starch. However, peak viscosity and paste stabilities did not show any clear pattern. Ease of cooking of the starch was prolonged up to a ratio of 50:50 cassava-sweet potato starch mixture. The set back viscosity was improved for all the cassava varieties at a ratio of 20 per cent cassava starch to 80 per cent sweet potato starch. Overall results indicated that cassava and sweet potato starch mixtures could be employed industrially, where high pasting temperatures and low setback viscosity are required.

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Introduction

Starch is used as an additive in many food products to achieve certain characteristic properties, such as water holding capacity and specific rheological properties. For industrial starches, certain additives are often used to modify starch properties to make them suitable for particular end products. In many applications the properties of a native starch are not optimal, and for that matter, starch is often chemically modified in order to improve its performance (Jacobs & Delcour, 1998). Nowadays, market tendencies press the producers towards more natural food components, avoiding as much as possible the chemical treatments. Therefore, there is interest in finding new ways to improve the properties of native starches without using chemical modification. One possibility that was investigated in the study was the mixing of different starches as has been reported eslewhere (Ortega-Ojeda & Eliasson, 2001; Daramola & Osanyinlusi, 2006; Park *et al.*, 2009).

Each starch has unique functional properties, but for industrial application it is modified, giving a wider range of useful products. Modification of starch by blending adjusts the properties for specific applications, and to resit some of the undesirable characteristics of native starch (Jensen, 2009). For example, Stute & Kern (1994) have patented blends of starches for use in preparation of pudding, which claims that blends of unmodified pea and corn starches in ratios of 9:1 to 1:9 as gelling, and texturing agents in the formulation of food products reduce syneresis. Liu & Lelièvre (1992) studied the melting transitions of blends of native wheat and rice starches and found that at starch concentrations < 30 per cent the differential scanning calorimetry (DSC) curves of the blends were the sum of the outputs for each individual component of the mixture. However, when starch concentrations were high, a non-additive behaviour was observed. Under these conditions, competition for water occurred, and the starch with the lower gelatinisation temperature (wheat) melted first (Liu & Lelièvre, 1992).

Jane & Chen (1992) also blended amyloses and amylopectins from various botanical sources and reported synergistic effects on paste viscosities. When blends of a native or modified starch and a water-soluble gum are heated together in water, the general effects commonly seen are apparent lowering of the pasting temperature as determined in a Brabender ViscoGraph or a Rapid Visco-Analyzer, lower temperature of peak viscosity, higher peak viscosity, decreased rate of setback and gel strength, and more rapid increase in the storage modulus of the paste. Obanni & BeMiller (1997) reported that mixing starches reduces retrogradation, and the starches with lower pasting temperatures affect the properties of the mixed starch by increasing the gelatinisation temperature.

Cassava starch is suitable for use in food processing, textiles and paper industries, since it has excellent thickening and textural properties, forms clear gel, has good gel stability, low tendency to retrograde, and has very little protein contamination, if any (Ellis *et al*., 1998). However, these properties differ among cassava accession (Adomako, 2007) and native starch may not be suitable for industrial application (Cousidine, 1982). Sweet potato starch varies in properties depending on the amount of amylose (Kaur, Singh & Singh., 2006), size of the granules (Jangchud, Yuthana & Vichan, 2003) and time of harvest (Moorthy, 2001). A blending of the starches from cassava and potato may provide better quality starch for various applications. Therefore, the objective of the study was to assess the functional and pasting properties of starch mixtures of four cassava accessions and one sweet potato.

Materials and methods

Starch extraction

Four cassava genotypes ('Adehye', AFS048, 'Bankye Botan' and OFF146) and one local sweet potato genotype were used for the study. Five hundred grams of root tubers were used for both cassava and sweet potato. The pulp was cut into small cubes. Each sample was milled with excess distilled water in a Kenwood blender for 5-7 min to produce a fine milky pulp. The starch slurry was then filtered through a cheese cloth, folded in duplicate into a plastic container. More water was added and squeezed until no more milky starch came out. The filtrate was allowed to stand for 4 h to settle after which the supernatant was drained away. The pure white starch in the plastic container was dried in the sun to a constant weight, allowed to cool and then weighed using analytical electronic balance.

Preparation of mixtures

Cassava starch was blended with sweet potato starch (cassava starch : sweet potato) in ratios of 100:0, 20:80, 50:50, and 0:100. Mixing was on a weight basis as described by Zaidul *et al*. (2007). For pasting characteristics, 9.5 per cent starch concentration was used.

Functional properties of starch

The functional properties of starch, i.e. the swelling volume, swelling power and solubility of starch, were determined based on a modification of the method of Leach, Mcowen & Schock (1959). One gram of sample was transferred into a weighed graduated 50-ml centrifuge tube. Distilled water was added to give a total volume of 40 ml. The suspension was stirred just sufficiently and uniformly with a stirrer avoiding excessive speed, in order not to cause fragmentation of starch granules. The sample was heated at 85 °C in a thermostatically regulated temperature bath (Grant Instruments, England Ltd) for 30 min with constant stirring. The tube was removed, wiped dry on the outside and cooled to 25 °C under running water. It was then centrifuged for 15 min at 2200 r.p.m. in a centrifuge (Mistral 3000i UK). The solubility was determined by evaporating the supernatant in a hot air oven (BS Gallenkamp, England) and the residue weighed. The sedimented paste was also weighed. Determination of the swelling volume, solubility and swelling power was carried in triplicates as follows:

Swelling volume. Swelling volume was obtained directly by reading the volume of the swollen sediment in the tube.

Solubility. Soluble starch was decanted carefully into a cleaned glass crucible of known weight and evaporated in an oven at 105 °C. The percentage solubility was then calculated from the dried residue as:

$$\text{\% Solubilty} = \frac{\text{Weight of soluble starch}}{\text{Dry weight of sample}} \times 100$$

Swelling power. Swelling power was determined by weighing the sediment and expressing swelling power as the weight (g) of swollen sediment over weight of dry starch (g), that is, swelling power was determined using the following relationship:

$$\text{Swelling power} = \frac{\text{Wt of sedimented paste} \times 100}{\text{Wt of sample} \times (100 - \text{\%Solubility})}$$

Pasting characteristics

The pasting characteristics of the starch samples were determined using the Brabender Viscograph instrument (Brabender® OHG, Duisberg, Germany). First, the moisture content of each sample was determined using an electronic moisture meter. The value of the moisture content of a sample was fed into the software of the Brabender Viscograph and the instrument automatically indicated the weight of starch sample to be used, and the quantity of distilled water to be added to make starch slurry (suspension). The slurry was then put into the measuring bowl of the instrument and heated at a rate of 1.5 °C/min by means of a thermo-regulator. The start temperature was 50 °C. When the suspension reached 95 °C, it was held constant for 15 min (first holding period) while being continuously stirred. The paste was then cooled down to 50 °C at a rate of 1.5 °C/min, and held at this temperature for another 15 min (second holding period) (Fig. 1).

At the end of the process (90 min), the pasting temperature, pasting time, peak viscosity, viscosity at 95 °C, viscosity after 15 min at 95 °C, viscosity at 50 °C, viscosity after 15 min at 50 °C, paste stability at 95 °C, paste stability at 50 °C, setback viscosity and breakdown viscosity were read from the viscograph printed out by the instrument.

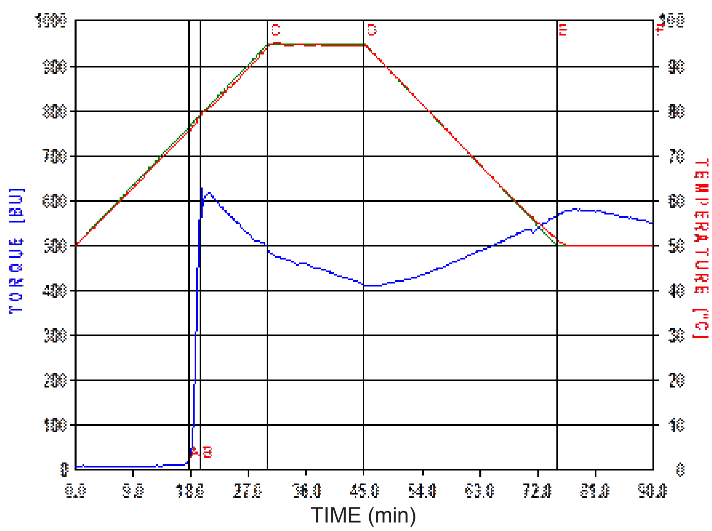
Paste stability at 50 and 95 °C were computed as the difference between viscosity at 50 °C and viscosity after 15 min at 50 °C; and the difference between viscosity at 95 °C and viscosity after 15 min at 95 °C, respectively.

Descriptive statistics of the data obtained were carried out using SPSS software version 16.0.

Results and discussion

Functional properties of cassava and sweet potato starch mixtures

The functional properties of cassava and sweet potato mixtures are shown on Table 1. Swelling volume of starch mixtures of 'Adehye' and sweet potato (Ad:Sp) and that of AFS 048 and sweet potato (AFS:Sp) decreased linearly as the proportion of sweet potato starch increased. However, OFF 146 and sweet potato (OFF:Sp) and 'Bankye-Botan' and sweet potato (BB:Sp) blends did not show any clear pattern (Table 1). This disparity might be due to varietal differences. The solubility val-



Evaluation

Point	Name	Time [HH:MM:SS]	Torque [BU]	Temperature [°C]
A	Begining of gelatinization	00:17:35	20	75.6
B	Maximum viscosity	00:19:35	640	79.1
C	Start of holding period	00:30:00	491	94.3
D	Start of cooling period	00:45:00	414	94.7
E	End of cooling period	01:15:00	566	51.4
F	End of final holding period	01:30:00	550	50.0
B-D	Breakdown		227	
E-D	Setback		151	

Fig. 1. A typical reading from Brabender viscoamylograph

TABLE 1

Functional Properties of Cassava Starch and Sweet Potato Starch Mixtures

Sample	*Swelling volume (ml g^{-1})* *mean ± s.e*	*Swelling power (g g^{-1})* *mean ± s.e*	*Solubility (%)* *mean ± s.e*
Cassava(Adehye)	32.2 ± 1.2	35.1 ± 0.3	10.3 ± 0.7
C8Sp2	24.5 ± 1.0	30.7 ± 0.7	15.0 ± 1.0
C5Sp5	23.3 ± 0.4	27.1 ± 0.6	16.0 ± 0.0
C2Sp8	22.2 ± 0.6	25.9 ± 0.4	14.0 ± 0.0
Sweet potato	20.7 ± 0.3	23.3 ± 0.4	12.3 ± 0.3
Cassava(OFF146)	23.0 ± 0.7	30.5 ± 0.9	27.7 ± 0.7
C8Sp2	26.8 ± 0.6	31.3 ± 0.7	13.0 ± 0.6
C5Sp5	25.2 ± 1.3	29.1 ± 1.6	11.3 ± 0.9
C2Sp8	21.7 ± 0.8	24.7 ± 0.4	12.7 ± 0.0
Sweet potato	20.7 ± 0.3	23.3 ± 0.4	12.3 ± 0.3
Cassava (B. Botan)	29.3 ± 5.6	35.3 ± 3.2	16.3 ± 13.9
C8Sp2	24.5 ± 0.6	30.7 ± 0.6	15.0 ± 0.3
C5Sp5	24.8 ± 0.7	31.5 ± 2.1	22.7 ± 1.5
C2Sp8	22.3 ± 0.7	26.4 ± 1.3	16.3 ± 0.9
Sweet potato	20.7 ± 0.3	23.3 ± 0.4	12.3 ± 0.3
Cassava (AFS 048)	27.3 ± 0.4	28.5 ± 0.3	11.7 ± 0.3
C8Sp2	26.2 ± 0.2	31.2 ± 0.4	15.4 ± 0.3
C5Sp5	25.7 ± 1.2	28.4 ± 0.8	14.0 ± 0.0
C2Sp8	22.3 ± 0.3	24.8 ± 0.2	11.3 ± 0.3
Sweet potato	20.7 ± 0.3	23.3 ± 0.4	12.3 ± 0.3

C8SP2 = 80 per cent cassava : 20 per cent sweet potato, C5SP5 = 50 per cent cassava : 50 per cent sweet potato, C2SP8 = 20 per cent cassava : 80 per cent sweet potato.

ues recorded for all the starch mixtures did not show any regular pattern.

Starch mixtures ((Ad:Sp) and (AFS:Sp)) exhibited linear decrease in swelling power as percentage of sweet potato starch in the sample increased. However, starch mixtures ((OFF:Sp) and (BB:Sp)) did not show any clear pattern just as for swelling volume. Besides, the swelling power values for these mixtures were higher than the values recorded for sweet potato starch alone. Daramola & Osanyinlusi (2006) recorded changes in the functional properties of cassava starch when blended with ginger starch. Park *et al.* (2009) also found changes in the pasting and functional properties of potato starch and waxy maize starch mixtures.

The solubility of sweet potato starch recorded in the study is similar to what Oduro *et al.* (2000) obtained when they studied the pasting characteristics of seven sweet potato starches. They found a solubility range of 6.82 per cent to 11.94 per cent. The maximum value of their range (11.94%) compares favourably with the value (12.3%) recorded (Table 1).

Pasting and viscosity characteristics of starch mixtures

The temperature characteristics of cassava and sweet potato starch mixtures are presented in Fig. 2 and 3. Pasting and peak temperatures exhibited a linear increase pattern. The pasting and peak temperatures were low in cassava starch alone. However, the temperatures increased as the proportion of sweet potato in the mixture increased. Thus, it would appear advantageous to blend cassava starch with sweet potato starch to obtain high pasting and peak temperatures. This result agrees with the findings by Daramola & Osanyinlusi (2006), who recorded increase in pasting and peak temperatures of cassava starch with increased concentration of ginger. According to Hegenbart (2009), the higher the amylose, the higher the gelatinization temperature. Potato starch contains higher amylose and that might have increase the amylose content of the starch mixture to cause the increased in temperature.

Starch that has been modified to cook at higher temperature can be useful in canning processes, where gelatinization at elevated temperature will facilitate quick heat penetration, while the canned content remains fluid, especially in the early heating stages (Daramola & Osanyinlusi, 2006). The current finding, therefore, suggests that blends of cassava and sweet potato starches can be exploited for use in the canning industries.

Peak viscosity, breakdown, setback, and paste stability did not show any clear pattern for all starch mixtures (Table 2). For 'Adehye' and OFF146, the peak viscosities of the mixtures were higher than those with no addition of sweet potation starch. In contrast, the starches for 'Bankye botan' or AFS048 alone had higher peak viscosities compared to starch mixtures. However, with the exception of C8Sp2 (BB:Sp) mixture, the remaining C8Sp2 mixtures, even though were not significant, experienced an increase in paste stability at 50 °C.

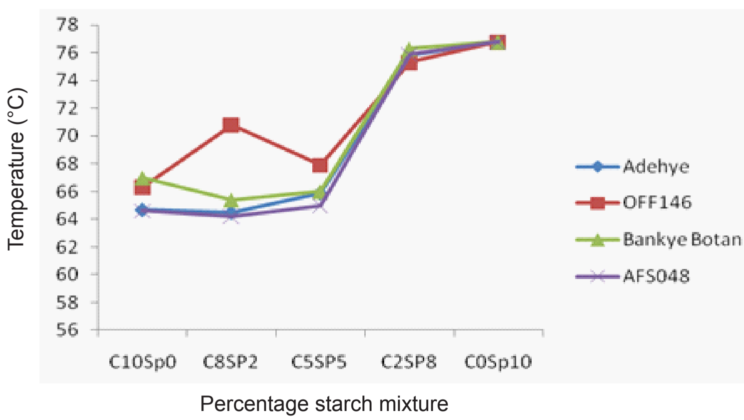


Fig. 2. Pasting temperature of starch mixtures

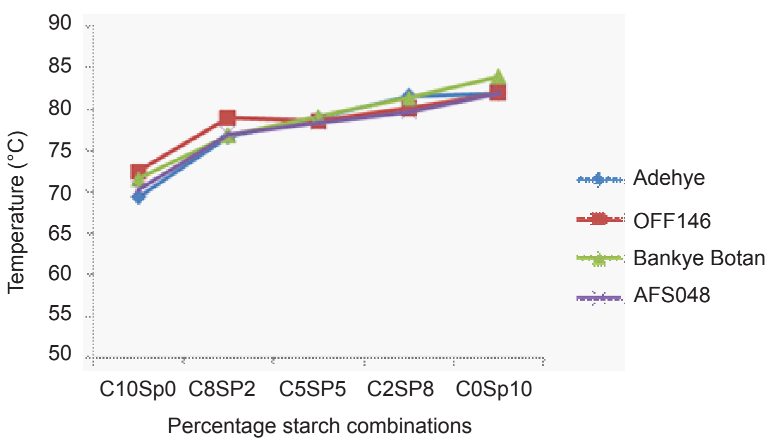


Fig. 3. Peak temperature of starch mixtures

TABLE 2

Paste Viscosity Characteristic of Cassava and Sweet Potato Starch Mixtures

Samples	*Peak viscosity (BU) mean ± s.e*	*Breakdown viscosity (BU) mean ± s.e*	*Setback viscosity (BU) mean ± s.e*
Cassava(Adehye)	534.0 ± 94	343.5 ± 59.5	125.0 ± 1.0
C8Sp2	707.5 ± 13.5	426.5 ± 7.5	206.0 ± 17
C5Sp5	571.0 ± 9.0	322.5 ± 6.5	168.5 ± 11.5
C2SP8	600.5 ± 12.5	222.5 ± 6.5	128.5 ± 23.5
Sweet potato	645.5 ± 59.5	284.0 ± 36.0	148.5 ± 6.5
Cassava(OFF146)	477.5 ± 31.5	334.5 ± 7.0	81.5 ± 28
C8SP2	679.0 ± 23	333.5 ± 24.5	193.5 ± 46.5
C5SP5	580.0 ± 9.0	310.5 ± 5.5	146.5 ± 10.5
C2SP8	607.0 ± 16	270.5 ± 20.5	143.5 ± 2.5
Sweet potato	645.5 ± 59.5	284.0 ± 36	148.5 ± 6.5
Cassava(B.Botan)	721.5 ± 32.5	463.0 ± 29.0	189.0 ± 18
C8SP2	540.5 ± 12.5	334.0 ± 15	123.5 ± 3.5
C5SP5	557.0 ± 8.0	325.0 ± 3.0	148.0 ± 15
C2SP8	604.5 ± 28.0	230.5 ± 36	128.0 ± 28.0
Sweet potato	645.5 ± 59.5	284.0 ± 36	148.5 ± 6.5
Cassava(AFS048)	813.0 ± 65.0	547.5 ± 70.5	157.0 ± 10.0
C8SP2	675.0 ± 12	436.5 ± 3.5	173.0 ± 21
C5SP5	615.0 ± 17	323.5 ± 11.5	145.5 ± 23.5
C2SP8	630.5 ± 9.5	246.5 ± 20.5	166.0 ± 14
Sweet potato	645.5 ± 59.5	284.0 ± 36	148.5 ± 6.5

A low setback or retrogradation viscosity value shows that the starch gives a non-cohesive paste which is useful in many industrial applications (Kim *et al*., 1995). With the exception of AFS048, all the cassava accessions recorded low setback viscosity at C2Sp8. This indicates that a combination of 20 per cent cassava starch with 80 per cent sweet potato starch could reduce the retrogradation of these starches. However, the lack of clear cut pattern recorded in the study for most of the parameters, might be due to close relatedness of cassava and sweet potato to each other, and their starches might possess similar properties.

Ease of cooking was appreciably shorter for OFF:Sp mixtures, whilst BB:Sp mixtures recorded the highest values. Ease of cooking of cassava starch was prolonged by the addition of sweet potato starch. It increased as the proportion of sweet potato starch was increased, recording the highest values at 50:50 ratios. However, beyond the 50:50 ratios the duration reduced or shortened (Table 3). It rendered mutual effects during pasting, especially, when the amounts of cassava and sweet potato starches were similar. Thus, where prolong heating/cooking is required, cassava-sweet potato starch mixtures could be employed but not beyond a 50:50 ratio. Paste stability at both 50 and 95 °C did not show any clear pattern. However, with the exception of C8Sp2 (BB:Sp) mixture, the remaining C8Sp2 mixtures experienced an increase in paste stability at 50 °C, though not significant.

TABLE 3

Paste Stability Characteristic of Cassava and Sweet Potato Starch Mixtures

Samples	*Ease of cooking (min) mean ± s.e*	*Paste stability at 95 °C mean ± s.e*	*Paste stability at 50 °C mean ± s.e*
Cassava(Adehye)	3.4 ± 0.5	77.5 ± 11.5	7.0 ± 12
C8Sp2	6.7 ± 1.5	123.0 ± 30.0	12.0 ± 2.0
C5Sp5	8.6 ± 0.6	138.5 ± 48.5	7.5 ± 1.5
C2SP8	3.3 ± 0.4	78.0 ± 0.0	14.5 ± 1.5
Sweet potato	2.5 ± 0.6	95.0 ± 0.4	15.5 ± 5.5
Cassava(OFF146)	4.7 ± 0.4	52.5 ± 11.0	9.0 ± 3.0
C8SP2	5.2 ± 2.8	75.5 ± 8.5	22.0 ± 9.0
C5SP5	6.1 ± 0.0	62.0 ± 6.0	16.5 ± 0.5
C2SP8	3.0 ± 0.0	82.5 ± 17.5	20.0 ± 1.0
Sweet potato	2.5 ± 0.6	95.0 ± 4.0	15.5 ± 5.5
Cassava(B.Botan)	4.5 ± 0.3	140.0 ± 24.0	17.5 ± 3.5
C8SP2	8.0 ± 0.7	93.0 ± 9.5	-7.0 ± 1.0
C5SP5	9.2 ± 0.8	94.0 ± 1.0	2.5 ± 1.5
C2SP8	3.4 ± 0.2	91.0 ± 11.0	5.5 ± 0.5
Sweet potato	2.5 ± 0.6	95.0 ± 4.0	15.5 ± 5.5
Cassava(AFS048)	3.3 ± 0.6	52.5 ± 10.5	-28.0 ± 0.0
C8SP2	7.5 ± 0.1	129.0 ± 42.0	4.5 ± 4.5
C5SP5	7.9 ± 0.7	94.5 ± 18.5	4.5 ± 4.5
C2SP8	1.8 ± 0.2	87.5 ± 10.5	11.0 ± 5.0
Sweet potato	2.5 ± 0.6	95.0 ± 4.0	15.5 ± 5.5

Conclusion

There was no major trend in the functional and pasting characteristics of cassava and sweet potato starch mixtures. However, pasting and peak temperatures for the mixtures were higher than cassava starch alone. Retrogradation was improved for starch of all cassava accession at the C2Sp8 combination. Therefore, the mixture could be assess further and employed in canning processes if consistent results are obtained. This would be particularly useful where gelatinization at elevated temperatures is required to facilitate quick heat penetration, while the canned content remains fluid during the early heating stages. Ease of cooking was prolonged up to a ratio of 50:50, hence, for processes that would require longer period of heating the mixture would be best.

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REFERENCES

Adomako, W. J. (2007) *Screening of local cassava germplasm for domestic and industrial purpose.* (PhD Thesis). Department of Crop Science, University of Cape Coast, Cape Coast.

Cousidine, D. M. (1982) *Foods and Food Pro-*

duction Encyclopedia. John Wiley Inc. NY.

Daramola, B. & **Osanyinlusi, S. A.** (2006) Investigation on modification of cassava starch using active components of ginger roots (*Zingiber officinale* Roscoe). *African Journal of Biotechnology* **5**(10), 917 – 920.

Ellis, R. P., Cochrane, M. P., Dale, M. F. B., Duffus, C. M., Lymm, A., Morrison, I. M. & **Tiller, S. A.** (1998) Starch production and industrial use. *J. Sci. Food Agric*., **77**, 289 – 311.

Hegenbart, S. (2009) Understanding starch functionality. *Retrieved from http// www.food-productdesign.com.*

Jane, J.-L. & **Chen, J.-F.** (1992) Effect of amylose molecular size and amylopectin branch chain length on paste properties of starch. *Cereal Chem*. **69**, 60 – 65.

Jangchud, K., Yuthana, P. & **Vichai, H.** (2003) Physicochemical properties of sweet potato flour and starch as affected by blanching and processing. *Starch*. **55,** 258 – 264.

Kaur, L., Singh, J. & **Singh, N.** (2006) Effect of cross-linking on some properties of potato (*Solanum terosum* L.) starches. *Journal of the Science of Food and Agriculture.* **86**, 1945 – 1954.

Kim, Y. S., Wiesenborn, D. P., Oir, P. H. & **Grant, L. A.** (1995) Screening potato starch for novel properties using differential scanning calorimetry. *Journal of Food Science* **60**, 1060 – 1065.

Leach, H. W., Mcowen, D. L. & **Schock, T. J.** (1959) Swelling and solubility patterns of various starches, structure of starch granule. *Cereal Chem*. **36**, 53 – 544.

Liu, H. & **Lelievre, J.** (1992) Transitions in frozen gelatinized-starch systems studied by DSC. *Carbohydr. Polym*. **19**, 179 – 183.

Jacobs, H. & **Delcour, J.** (1998) Hydrothermal modifications of granular starch with retention of the granular structure: A review. *Journal of Agricultural and Food Chemistry* **46**, 2895 – 2905.

Jensen, A. K. (2009) Starch modification. *http://ww.kmc.dk/Productsknowhow/Product%20technology/Modifiedstarch/index.as.htm. Retrived 16 January 2010.*

Moorthy, S. N. (2001) Behaviour of cassava starch in various solvents. *Starch/Starke* **37**, 372 – 374.

Obanni, M. & **BeMiller, J. N.** (1997) Properties of some starch blends. *Cereal Chem*. **74**, 431 – 436.

Oduro, I., Ellis, W. O., Aryeetey, S. K., Ahenkora, K. & **Otoo, J. A.** (2000) Pasting characteristics of starch from new varieties of sweet potato. *Trop. Sci.* **40**, 25 – 28.

Ortega-Ojeda, F. E. & **Eliasson, A.-C.** (2001) Gelatinisation and retrogadation behaviour of some starch mixtures. *Starch* **53**, 520 – 529.

Park, E. Y., Kim, J., Park, E. Y, Kim, H. N., Kim, J. Y. & **Lim, S-T.** (2009) Pasting properties of potato starch and waxy maize starch mixtures. *Starch* **61**, 352 – 357.

Stute, R. & **Kern, H.** (1994) Starch mixtures as pudding starches. *U.S. Patent* **5**,324 – 532.

Zaidul, I. S. M., Yamauchi, H., Kim, S. J., Hashimoto, N. & **Noda, T.** (2007) RVA study of mixtures of wheat flour and potato starches with different phosphorus content. *Food Chemistry* **102**, 1105 – 1111.