Research paper

Effect of Heat Treatments on Pasting Properties of Local Thickening Seeds and Blending Ratios of Cocoyam Flour

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Received 18 January 2019; Accepted 11 February, 2019

The effects of pre-milling heat treatment types on the pasting properties of the resultant flour blends of some indigenous thickening seeds and cocoyam (ede-ocha) at various percentages were examined. Flours of indigenous thickening seeds of achi, ofo and ukpo, and that of cocoyam were used in this work. The mean values of the pasting properties were assessed as functions of Indigenous Thickening Seeds (ITS), Treatment Types (TT) and Blending Ratios (BR), which fitted into a 3(ITS) X 4(TT) X 5(BR) factorial design. The data obtained from the analyses were analyzed statistically using the Analysis of Variance (ANOVA) method with the application of SPSS Version 20. The difference between the mean values was determined by Tukey test. Significance was accepted at 5% probability level. Pasting determinations showed that the blend type of achi-Cocoyam flour had better pasting ability among the other variables of the BT factor (peak viscosity, PV = 272.85 RVU; trough viscosity, TV = 234.25 RVU; final viscosity, FV = 436.51 RVU; and setback viscosity, SV = 202.26 RVU; flour of the steamed samples (with respect to treatment type factor) ranked best among the other variables (PV = 245.61RVU; TV = 215.04 RVU; FV = 355.10 RVU and SV = 140.07 RVU while the control samples (among the Blending type factor) exhibited better pasting properties than the other variables. Further work should be directed to investigate this experiment with another species of cocoyam to check whether remarkable improvements can be obtained in the characteristics of the resultant flour blend with achi, ofo, ukpo.

Keywords: Food thickeners, heat treatment, pasting temperature, peak viscosity, final viscosity

INTRODUCTION

Thickening agent is the term applied to substances which increase the viscosity of a solution or liquid/solid mixture without substantially modifying its other properties. It can be any ingredient or agent that is added to other food ingredients in order to create a stiffer or a more dense food mixture (Onyeso et al., 2016). Several food materials have been implicated over the years to have thickening potentials, and the legumes in particular are quite obvious here (Nwosu, 2012).

Legumes refer to the edible seeds of leguminous plants belonging to the leguminosae family (Chukwu et al., 2017; 2018a, b). They are usually referred to as pulses and include all forms of beans and peas from the fabacee botanical family (Mbanali et al., 2018). They are grown primarily for their food grain seed (e.g., beans and lentils or generally pulse) they are major sources of dietary proteins legumes seeds are also rich in other nutrients such as starch, dietary fibre, protective photochemical, oil, vitamins and minerals such as phosphorus and iron (Shimelis et al., 2006).

Brachystegia Eurycoma is one of the lesser known legumes which have not been fully utilized to alleviate protein-energy malnutrition common in developing counties such as Nigeria (Uhegbu et al., 2009; Ikekewu et al., 2010). Nutritionally, Brachystegia Eurycoma (achi) contains 10.47% protein, total carbohydrate content 71.94% (Olayemi and Jacob, 2011). Uhegbu et al. (2009) reported that it is a good source of water soluble
vitamins (ascorbic acid thiamine, riboflavin and hiaein) and minerals such as Ca, P, K, Mg, Na, ZnFe and Cu thereby playing a major role in the nutritional status of consumers. Ajayi et al. (2006) reported *Brachystegia eurycoma* is rich in carbohydrate, protein and crude fiber, with high amount of essential unsaturated fatty acids.

*Detarium microcarpum* is an unexploited legume indigenous to drier regions for West and Central Africa (Contu, 2012). It is variously called sweet dattock or Tallow tree (English), *Dankh or Petitdetar* (French), *Ojo* (Igbo), *Taura* (Hausa) and *Ogbogho* (Yoruba) (Ayozie, 2010; Mbanali et al., 2018). It is rich in vitamin C (3.2mg), with 4.8g protein and 64.5g of sugar per 100g. The fruit pulp has been found to have high proportions of carbohydrate (40-42%) and protein (29.1-30.9%) (Abdalbasit et al., 2009). It has good nutritional quality and acceptable functional properties, thus confirming their suitability for use in various food preparations and formulations (Bhat and Karim, 2009).

The enormous legume family contains species of tropical vines, but some of the most interesting belong to the genus *Mucuna* (Armstrong, 2010). *Mucuna sloanei*, as a food thickener, is known to originate from Asia and was later introduced into the western hemisphere via Mauritius (Nkpa, 2004). *Mucuna* seeds, as a rich in protein supplement in food and feed, has been well documented (Oguwike, et al., 2017). The crude protein content is known to vary between 20 and 31.44g/100 g (Ezeagu et al., 2003; Bhat et al., 2008). It has been reported that crude protein (20.2–29.6%) according to Vijayakumani et al. (2002). Higher concentrations of essential amino acids (555mg/g protein) in *mucuna* seeds has been reported by Adebowale et al. (2005). *Mucuna sloanei* seed is processed into flour and used as soup thickener and stabilizer, where its gelation properties impart gummy texture in soups (Oudhia, 2002, Diallo and Berhe, 2003). However, research efforts are being directed towards identifying and evaluating unexploited areas regarding the optimal utilization of the legume seeds. Some legumes such as the *Brachystegia eurycoma*, *Detarium microcarpum* and *Mucuna solanei* amongst others have been found to be most efficient as emulsifiers and thickeners in food formulation, especially in traditional soups (Ezeoke, 2010). Flours from ‘achi’, ‘ukpo’ and ‘ofo’ have been found to be used in most States in Nigeria including Imo, Abia, Anambra, Akwa-Ibom and Ondo States. They are used as thickeners in traditional soups (for eating gari, pounded yam or cocoyam and *fufu*). They are equally used as emulsifiers and flavouring agents in traditional soups due to their gum content. These gums are called the seed gum and food gum (hydrocolliods). These are not true gums but are of simpler structures. These seeds gums are extracted from the seeds when crushed to flour and when in powder form have the ability to swell in water and thus are able to influence the viscosity of the liquid. Apart from this culinary use, it is possible for these gums when used as additives in other foods to impact desirable textural and functional properties to the finished food product particularly the "convenience foods" (Ajayi et al., 2006; Nwosu, 2012). Cocoyam is referred to as *Ede* in Ibo land of Nigeria. Cocoyams (Taro and Tannia) have remained the two varieties majorly grown in Nigeria. The *taro* varied botanically known as *Colocasia Esculenta* and commonly called coco-India, originated from Asia, while tannia *Xanthosoma Sagittifolium* originated from America, but were both introduced and grown in West Africa (Brown, 2000). These two species *Colocasia Esculenta* (Taro) and *Xanthosoma Sagittifolium* (Tannia) are the most widely accepted and cultivated varieties in Nigeria and other parts of the tropics and sub-tropic of Africa (Nwagbo, 2013; Bolarin et al., 2018). Taro coroms contains considerable amount of starch (70-80g/100g dry taro) (Quach et al., 2001). Lebot, (2009) reported that taro coroms are rich in starch (61-88%DM) but little of protein (2.3 – 14.8% DM). The corom contains mainly starch and water together with small quantities of protein, fat, ash, vitamins B and C. The carbohydrate content of taro cultivated in different locations varies. Cocoyam is most commonly grown for its starchy edible roots. Containing several vitamins and minerals, cocoyam also has an appreciable content of crude fiber which aids in digestion and makes the elimination of stool very easy, as well as playing major hole in preventing cancer (Nwagbo, 2013). With appropriate processing method, cocoyam could be a rich source of starch for food and industrial applications and coroms have potential for new product development. Stabilizing cocoyam tuber and adding value could greatly improve its utilization in cocoyam producing countries as reported (Owusu-Darko et al., 2014). Cocoyam is almost a neglected crop in Nigeria. It does not compete favourably with other root crops (such as yam and cassava) in terms of production and consumption. *Achi*, *ofo* and *ukpo* suffer the fate as their usefulness have been limited to local traditional culinary practices, which makes them under exploited and at the same time received little attention and recognition from researchers as compared to other legumes such as soybeans, melon, cowpea etc. This work is aimed at determining the effect of heat treatments on pasting properties of local thickening seeds and blending ratios of cocoyam flour. Since the food thickeners are under exploited and utilized, investigating their pasting properties especially as affected by heat treatments and subsequent blends with the cocoyam flour would no doubt increase their level of acceptance and utilization both locally and globally.

**MATERIALS AND METHODS**

**Materials procurement**

The food thickeners were *achi* (*Brachystegia eurycoma*), *ofo* (*Detarium microcarpum*), *ukpo* (*Mucuna sloanei* and
coco yam (*Colocasia esculenta*) were obtained from Afor-Umuaka Market in Njaba Local Government Area of Imo State, Nigeria. The chemicals and equipment/facilities used for this work were obtained from the Department of Food Science and Technology, Federal University of Technology, Owerri, Imo State and Central Laboratory, University of Ibadan, Oyo State, Nigeria.

**Preparation of samples**

The various seeds/corms of the aforementioned food thickeners were sorted and cleaned to remove dirt and unwholesome ones. The seeds of *achi*, *ofo* and *ukpo* were soaked in cold water at ambient temperature for 24 h to soften the seed coat, which was later removed with stainless steel knife. The cocoyam corms, on the other hand, were simply peeled with stainless steel knife. The dehulled seeds were further divided into four portions each to obtain samples for boiling, steaming, roasting and raw (raw is the control). The peeled cocoyam corms were simply boiled at the loading rate of 50 g/l of water for 5 min. Meanwhile, the seed-samples which were to be boiled were also done at the same loading rate as the cocoyam corms for 5 min. The remaining three portions were individually roasted at 100°C for 30 min, steamed for 10 min and the third portion kept as the control. Thereafter, all the portions were dried at 60°C for about 3 h in a Genlab Moisture Extraction Oven (Model-MINO/50) and milled into flour using a disc attrition mill (Figure 1). The resultant flours (*achi*, *ofo* and *ukpo*) varieties and the cocoyam flour were blended together in five different ratios of the flour in (Table 1), packaged in airtight containers and labeled accordingly for analyses of their pasting properties.

**Determination of pasting properties**

Pasting characteristics were determined with a rapid
Visco Analzer (RVA) (Model RVA 3D+, Newport Scientific Australia). First, 2.5 g of samples were weighed into a dried empty canister; then 25 ml of distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was well fitted into the RVA as recommended. The slurry was heated from 50-95°C with a holding time of 2 min followed by cooling were at a constant rate of 11.25°C per min. Peak viscosity, trough, breakdown, final viscosity, set back, peak time and pasting temperature were read from the pasting profile with the aid of thermocline for windows software connected to a computer (Newport Scientific, 1998). The viscosity was expressed in terms of Rapid Visco Units (RVU), which is equivalent to 12 centipoises (Mbanali et al., 2018).

Statistical analysis of data

The mean values of the physio-chemical properties were assessed as functions of Indigenous Thickening Seeds (ITS), Treatment Types (TT) and Blending Ratios (BR), which fitted into a 3(ITS) X 4(TT) X 5(BR) factorial design (Table 2). The data obtained from the analyses were analyzed statistically using the Analysis of Variance (ANOVA) method with the application of SPSS Version 20. The difference between the mean values was determined by Tukey test. Significance was accepted at 5% probability level.

RESULTS AND DISCUSSION

Pasting properties

Pasting properties are very important indices in predicting the pasting behavior during and after cooking. It is an important index in determining the cooking and baking qualities of flours (Ajatta et al., 2016). Tables 3, 4 and 5 show the pasting behaviors of the flour samples of components of the TT, BT and BR factors.

Pasting temperature

Pasting temperature is one of the pasting properties that

| Table 1. Blending ratios of indigenous thickening-seeds flour and cocoyam flour. |
|-----------------------------|-----------------------------|
| Indigenous Thickening Seeds (ITS) (achi, ofo, ukpo) Flour (%) | Cocoyam Flour (%) |
| 100 | 0 |
| 75 | 25 |
| 50 | 50 |
| 25 | 75 |
| 0 | 100 |

| Table 2. Factorial design of experiment: A(3) by B (4) by C(5) |
|-----------------------------|-----------------------------|
| A | B₁ | B₂ | B₃ | B₄ | C |
| A₁ | A₁B₁C₁ | A₁B₂C₁ | A₁B₃C₁ | A₁B₄C₁ | C₁ |
| A₁ | A₁B₁C₂ | A₁B₂C₂ | A₁B₃C₂ | A₁B₄C₂ | C₂ |
| A₁ | A₁B₁C₃ | A₁B₂C₃ | A₁B₃C₃ | A₁B₄C₃ | C₃ |
| A₁ | A₁B₁C₄ | A₁B₂C₄ | A₁B₃C₄ | A₁B₄C₄ | C₄ |
| A₁ | A₁B₁C₅ | A₁B₂C₅ | A₁B₃C₅ | A₁B₄C₅ | C₅ |
| A₂ | A₂B₁C₁ | A₂B₂C₁ | A₂B₃C₁ | A₂B₄C₁ | C₁ |
| A₂ | A₂B₁C₂ | A₂B₂C₂ | A₂B₃C₂ | A₂B₄C₂ | C₂ |
| A₂ | A₂B₁C₃ | A₂B₂C₃ | A₂B₃C₃ | A₂B₄C₃ | C₃ |
| A₂ | A₂B₁C₄ | A₂B₂C₄ | A₂B₃C₄ | A₂B₄C₄ | C₄ |
| A₂ | A₂B₁C₅ | A₂B₂C₅ | A₂B₃C₅ | A₂B₄C₅ | C₅ |
| A₃ | A₃B₁C₁ | A₃B₂C₁ | A₃B₃C₁ | A₃B₄C₁ | C₁ |
| A₃ | A₃B₁C₂ | A₃B₂C₂ | A₃B₃C₂ | A₃B₄C₂ | C₂ |
| A₃ | A₃B₁C₃ | A₃B₂C₃ | A₃B₃C₃ | A₃B₄C₃ | C₃ |
| A₃ | A₃B₁C₄ | A₃B₂C₄ | A₃B₃C₄ | A₃B₄C₄ | C₄ |
| A₃ | A₃B₁C₅ | A₃B₂C₅ | A₃B₃C₅ | A₃B₄C₅ | C₅ |

A = Indigenous Thickening Seed Flour; i = 1-3 (achi, ofo, ukpo); B = Treatment Types on the ITS; J = 1-4 (Boiled, Steamed, Roasted, Raw); C = Blend Ratios with Cocoyam (CY) flour; k = 1-5 (100:0, 75:25, 50:50, 25:75, 0:100).
Table 3. Mean values of the pasting properties of the resultant flour blends of local thickening seeds and cocoyam as affected by pre-milling heat treatments.

<table>
<thead>
<tr>
<th>Treatment Type, TT</th>
<th>Parameters</th>
<th>Treatment Type, TT</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(P_{\text{TEMP}}(\degree \text{C}))</td>
<td>(P_{\text{TIME}}(\text{min}))</td>
<td>(PV (\text{RVU}))</td>
</tr>
<tr>
<td>Boiled</td>
<td>70.76 ± 18.45 (^a)</td>
<td>6.02 ± 0.88 (^a)</td>
<td>101.80 ± 80.81 (^d)</td>
</tr>
<tr>
<td>Steamed</td>
<td>70.05 ± 0.49 (^a)</td>
<td>6.27 ± 0.30 (^a)</td>
<td>245.61 ± 248.39 (^a)</td>
</tr>
<tr>
<td>Roasted</td>
<td>73.11 ± 18.36 (^a)</td>
<td>6.75 ± 0.40 (^a)</td>
<td>71.21 ± 50.45 (^c)</td>
</tr>
<tr>
<td>Raw</td>
<td>76.49 ± 166.84 (^a)</td>
<td>6.23 ± 16.15 (^a)</td>
<td>191.08 ± 208.54 (^a)</td>
</tr>
<tr>
<td>LSD</td>
<td>7.564</td>
<td>0.4386</td>
<td>94.6228</td>
</tr>
</tbody>
</table>

Mean values with different superscripts along the same column are significantly different at \(p<0.05\).

Keys:
P\text{temp} = Pasting Temperature
P\text{time} = Pasting Time
PV = Peak Viscosity
TV = Trough Viscosity
FV = Final Viscosity
BD = Break Viscosity
SB = Setback Viscosity
LSD0.05 = Least Significant Difference at 95% level of confidence

Table 4. Mean values of the pasting properties of the resultant flour blends of local thickening seeds and cocoyam as affected by blend type.

<table>
<thead>
<tr>
<th>Blend Type, BT</th>
<th>Parameters</th>
<th>Blend Type, BT</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Achi-CY)</td>
<td>81.97 ± 10.11 (^a)</td>
<td>6.58 ± 0.55 (^a)</td>
<td>272.85 ± 299.32 (^a)</td>
</tr>
<tr>
<td>(Ofo-Cy)</td>
<td>62.74 ± 17.12 (^b)</td>
<td>5.99 ± 0.95 (^b)</td>
<td>133.56 ± 87.79 (^b)</td>
</tr>
<tr>
<td>(Ukpo-CY)</td>
<td>73.11 ± 18.96 (^a)</td>
<td>6.39 ± 0.52 (^a)</td>
<td>50.86 ± 30.50 (^a)</td>
</tr>
<tr>
<td>LSD</td>
<td>6.5506</td>
<td>0.3799</td>
<td>0.1934</td>
</tr>
</tbody>
</table>

Mean values with different superscripts along the same column are significantly different at \(p<0.05\).

Keys:
P\text{temp} = Pasting Temperature
P\text{time} = Pasting Time
PV = Peak Viscosity
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BD = Break Viscosity
SB = Setback Viscosity
LSD0.05 = Least Significant Difference at 95% level of confidence

provide an indication of the minimum temperature required for sample cooking, energy costs involved and other components stability (Shimelis \textit{et al.}, 2006). From the result shown in (Tables 3, 4 and 5), each of the BT and BR factors constitute critical determinant for the pasting temperature of flours of cocoyam blend with the local thickenings seeds of \textit{achi}, \textit{ofo} and \textit{ukpo}, while the TT factor does not. Making comparison on the components of each factor, the results showed that with respect to BT, \textit{achi-Cy} showed a higher pasting temperature (81.97\degree C), followed by \textit{ukpo-Cy} (73.11\degree C) and lastly, \textit{ofo-Cy} (62.74\degree C) at 95% confidence level. Among the BR factor, 100% CY flour blend was significantly higher with pasting
Table 5. Mean values of the pasting properties of the resultant flour blends of local thickening seeds and cocoyam as affected by blending ratios.

<table>
<thead>
<tr>
<th>Blend Ratio, BR (%)</th>
<th>PTEMP (°C)</th>
<th>PTIME (min)</th>
<th>PV (RVU)</th>
<th>TV (RVU)</th>
<th>FV (RVU)</th>
<th>BD (RVU)</th>
<th>SB (RVU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0: 100</td>
<td>65.19 ± 15.89 (^a)</td>
<td>6.38 ± 0.92 (^ab)</td>
<td>244.39 ± 264.95 (^a)</td>
<td>191.14 ± 195.22 (^ab)</td>
<td>473.39 ± 240.48 (^a)</td>
<td>53.25 ± 72.77 (^a)</td>
<td>282.25 ± 135.90 (^a)</td>
</tr>
<tr>
<td>25:75</td>
<td>72.36 ± 17.04 (^b)</td>
<td>6.63 ± 0.68 (^a)</td>
<td>223.78 ± 80.81 (^ab)</td>
<td>195.48 ± 227.57 (^a)</td>
<td>372.57 ± 260.08 (^a)</td>
<td>28.30 ± 31.41 (^a)</td>
<td>153.88 ± 90.99 (^a)</td>
</tr>
<tr>
<td>50:50</td>
<td>66.41 ± 15.59 (^b)</td>
<td>6.29 ± 0.75 (^ab)</td>
<td>166.47 ± 159.47 (^bc)</td>
<td>155.00 ± 158.97 (^ab)</td>
<td>325.43 ± 283.07 (^a)</td>
<td>11.47 ± 8.78 (^a)</td>
<td>170.43 ± 127.77 (^c)</td>
</tr>
<tr>
<td>75:25</td>
<td>65.36 ± 13.79 (^b)</td>
<td>6.33 ± 0.81 (^ab)</td>
<td>112.65 ± 105.44 (^c)</td>
<td>98.34 ± 88.31 (^b)</td>
<td>199.04 ± 173.37 (^c)</td>
<td>14.32 ± 21.90 (^c)</td>
<td>123.92 ± 118.66 (^b)</td>
</tr>
<tr>
<td>100:0</td>
<td>93.70 ± 0.00 (^a)</td>
<td>5.97 ± 0.00 (^b)</td>
<td>14.83 ± 0.00 (^cd)</td>
<td>13.08 ± 0.00 (^c)</td>
<td>25.88 ± 0.00 (^d)</td>
<td>1.75 ± 0.00 (^d)</td>
<td>12.79 ± 0.00 (^c)</td>
</tr>
<tr>
<td>LSD</td>
<td>8.4568</td>
<td>0.4904</td>
<td>105.7915</td>
<td>84.5223</td>
<td>99.7896</td>
<td>29.3857</td>
<td>69.7415</td>
</tr>
</tbody>
</table>

Mean values with different superscripts along the same column are significantly different at p<0.05

Keys:
Ptemp = Pasting Temperature
PTime = Pasting Time
PV = Peak Viscosity
TV = Trough Viscosity
FV = Final Viscosity
BD = Break Viscosity
SB = Setback Viscosity
LSD0.05 = Least Significant Difference at 95% level of confidence

*0:100 = Control

temperature of 93.70°C followed by 25% CY blend, 50%, 75% and control with temperatures of 72.36°C, 66.41°C, 65.36°C and 65.19°C respectively, which are statistically equal (P<0.05). No significant difference (P<0.05) exists among the components of the TT factor, even though the highest mean value was exhibited by the flour of the raw sample (76.49°C), followed by roasted (73.11°C), boiled (70.76°C) and steamed (70.05°C). As the temperature at which the first detectable viscosity is measured (Adegunwa et al., 2011), such high initial gelatinization temperatures as witnessed in the achi-Cy flour (among BT factor), 100% CY flour blend (among the BR factor) and the Raw sample (among the TT factor) indicates that their starch granules resisted swelling (Shimelis et al., 2006). The pasting temperatures of these blends were higher than the values (61.41-61.80°C) of Ajatta et al. (2016). This, according to Uzomah and Odusanya (2011), can be attributed to the presence of strong binding forces within the interior of the starch granules. On the other hand, low pasting temperatures are reported to be associated with low paste stability, which is usually considered to be an undesirable property (Akinwade et al., 2007).

Peak Viscosity

The results of the Peak Viscosities of the various flour samples are shown in (Tables 3, 4 and 5). The peak viscosity is indicative of the viscous load likely to be encountered during mixing (Maziya-Dixon et al., 2004). The high peak viscosity causes the swelling index to increase. Low paste viscosity is an indicative of higher solubility as a result of starched gradation or dextrinization (Shittu et al., 2001). From the result, variations caused by the 3 factors (TT, BT and BR) are very significant (P<0.05). Among the components of the TT factor, flour of the Steamed sample gave the highest viscosity of 245.61 RVU, followed by that of the Raw sample (191.08 RVU), Boiled (101.80 RVU) and lastly, the Roasted sample (71.21 RVU). With respect to the BT factor, achi-Cy gave the highest Peak Viscosity of 272.85 RVU, followed by ofo-Cy (133.56RVU) and ukpo-Cy (50.86 RVU). Among the BR factor, flour of the Control sample gave the highest Peak Viscosity (244.39 RVU), followed by 25% CY (223.78 RVU), 50% CY (166.47 RVU), 75% CY (112.65 RVU) and lastly, 100% CY flour blend (14.83RVU). The peak viscosities of these blends were higher than the values (102.8-123.24 RVU) of Ajatta et al. (2016). Peak Viscosity, according to Pongsawarmanit et al. (2002), is considered to represent the equilibrium point between swelling and rupture of starch granules. It is closely associated with the degree of starch damage, and high starch damage results in high Peak Viscosity (Sanni et al., 2001). It is the maximum viscosity...
developed during the heating cycle of the sample blends. Moreso, as an indicative of the water binding capacity of starch and starch ability to swell freely before their physical breakdown, the flours of achi-Cy (among the BT factor), Steamed (among the TT factor) and the 0% CY flour blend (among the BR factor) are mostly favoured. Such relatively high viscosities are indicative that the starch of these flour samples may be suitable for products requiring high gel strength and elasticity (Ikegwu et al., 2010). This increase may be attributed to the high starch content of the cocoyam flour causing a high gelatinization and swelling index. In starches, high viscosity is desired for industrial applications in which a high thickening power at high temperatures is required (Ajatta et al., 2016).

**Trough viscosity**

Trough viscosity is the minimum viscosity value in the constant temperature phase of the RVA profile; and measures the ability of paste to withstand breakdown during cooling. It is an index of starch granule stability to heating (Ajatta et al., 2016). The results as shown in Tables 3, 4 and 5 revealed that variations caused by the three factors (TT, BT and BR) are quite significant (P<0.05). Among components of the TT factor, flour of the Steamed sample showed much stability (215.04 RVU) than the others. This was followed by the Raw sample (164.77 RVU), Boiled (81.57 RVU) and lastly, the Roasted sample (61.05 RVU). With respect to the components of the BT factor, achi-Cy showed much stability to heating with the viscosity of 234.25 RVU, followed by ofo-Cy (110.49 RVU) and ukpo-Cy (47.08 RVU). Regarding the BR factor, flour of the 25% CY flour blend showed greater stability (153.88 RVU), followed by the Control sample (191.48 RVU), 50% CY blend (155.00 RVU), 75% CY blend (98.34 RVU) and lastly, the 100% CY blend (13.08 RVU).

**Final Viscosity**

Final Viscosity indicates the ability of the food material to form a viscous paste or gel after cooking or cooling (Ikegwu et al., 2010). It is the ability of starch to form a viscous paste on cooling. It is the viscosity after holding during cooling. It is an index of starch granule stability to heating with the viscosity of 234.25 RVU, followed by ofo-Cy (110.49 RVU) and ukpo-Cy (47.08 RVU). Regarding the BR factor, flour of the 25% CY flour blend showed greater stability (153.88 RVU), followed by the Control sample (191.48 RVU), 50% CY blend (155.00 RVU), 75% CY blend (98.34 RVU) and lastly, the 100% CY blend (13.08 RVU).

**Setback viscosity**

Setback Viscosity is the phase of the pasting curve after cooling of the starch and this phase involves re-association, retrogradation or re-ordering of starch molecules. Setback value is the tendency of starch to associate and retrograde on cooling. Peroni et al. (2006) indicated that flours with low setback may have low values of amylose which have high molecular weight. The lower the retrogradation, the higher the setback value, during cooling of the products made from the flour (Ikegwu et al., 2010). High setback is associated with syneresis. Tables 3, 4 and 5 show that variations caused by the three factors (TT, BT and BR) are very significant (P<0.05). Among the components of the TT factor, the Raw sample exhibited the highest Setback Viscosity (192.15 RVU) which is statistically equal (P>0.05) to the Boiled sample (144.66 RVU) and the Steamed sample (140.07 RVU). Flour of the Roasted sample exhibited the lowest Setback Viscosity of 117.74 RVU even though it is statistically equivalent to the Boiled and Steamed samples. With respect to the BT factor, the achi-CY flour exhibited the highest mean value (202.26 RVU) which is significantly equivalent to the ofo-Cy blend (185.77 RVU). The ukpo-Cy flour blend, however, gave the lowest Setback value of 57.93 RVU. With respect to the BR factor, the control flour sample is significantly higher in Setback Viscosity than the other blending ratios. Having a viscosity of 282.25 RVU, it is followed by the 50% CY sample (170.43 RVU), and then 25% CY sample (153.88 RVU), 75% CY sample (123.92 RVU), and lastly, 100% CY sample (12.79 RVU). Setback viscosity is an index of the tendency of the cooked flour to harden on cooling due to amylose retrogradation. Mishra and Rai (2006) reported Setback Viscosity as a measure of the retrogradation phenomenon, which is closely related to the amylose content of the starch. According to Uzomah and Odusanya (2011), it indicates how starch molecules
behave after heating, cooking and cooling. In the light of this understanding therefore; the retrogradation tendency of the flour samples is as follows. For the BT factor, Achi-CY>Ofo-CY>Ukpo-CY. TT factor: Raw>Boiled>Steamed>Roasted. For the BR factor 0%CY>50%>25%>75%>100%CY.

Conclusion

The use and importance of selected thickening seeds and cocoyam in food formulation as thickening agents cannot be overemphasized. The result of this study has shown the possibility of blending flours of pre-treated indigenous seeds with cocoyam flour in varying ratios, and their possible effects on the pasting properties of flours from such blends. From the study, it was observed that heat treatments (Boiling, Steaming and Roasting of achi, ofo and ukpo) have significant effects on the pasting characteristics of the resultant flour blends of indigenous thickening seeds and cocoyam. The Steamed sample exhibited better pasting properties than the others. Regarding blend types, the study showed that the achi-Cy flour had better pasting properties. Among the blending Ratios, the Control sample showed better pasting characteristics.

Contribution to knowledge

Within the limits of this research work, the study has, no doubt, contributed immensely to knowledge, which is as follows:

(i) It has revealed and provided a scientific proof that heat treatments actually affect the pasting properties of indigenous thickening seeds.
(ii) It has provided a scientific proof that blending the flours of selected indigenous thickening seeds with cocoyam flour increases their thickening potentials. By this, the study has established/provided a guide for the choice of thickening agents that covers varying degrees of viscosity.
(iii) Another contribution to knowledge is the study's ability to establish standardization in the utilization of selected thickening agents with respect to the factors (TT, BT, and BR) that were studied.
(iv) Such knowledge, as revealed in this study, will, no doubt, promote the efficient utilization and application of the selected food thickeners even in the food industry.

Recommendations

This research, however, reveals that subjecting the selected indigenous thickening seeds to pre-heat treatments increases their pasting abilities, as well as blending their resultant flours with cocoyam flour in varying ratios. It is suggested, therefore, that heat treatments within the conditions of this study, especially, steaming improves pasting properties, should be given to achi, ofo and ukpo prior to use. The study also suggests the blends of achi-Cy had good pasting properties. Regarding the blending ratios of these thickeners with the cocoyam flour, the study suggests the Control had good pasting properties. There are many other root and tuber crops (particularly, other varieties of cocoyam) that can be used as thickeners in food to improve on the pasting ability of indigenous thickening seeds. Therefore, it is highly recommendable that further work be directed to investigate this experiment with another species of cocoyam (preferably, the Xanthosoma Sagittifolium – Tanna) to check whether remarkable improvements can be obtained in the characteristics of their resultant flour blends with achi, ofo and ukpo.

AUTHORS’ DECLARATION

We declare that this study is an original research by our research team and we agree to publish it in the journal.

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