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# Influence of Extrusion Condition and Defatted Soybean Inclusion on the Functional and Pasting Characteristics of African Breadfruit (Treculia Africana) Flour Blend

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**Abstract**
Influence of extrusion condition and defatted soybean inclusion on the functional and pasting characteristics of African breadfruit-Soybean-Corn flour blends was studied. The two blends were separately brought to 21% moisture content by water addition through material balance and extruded at $140^0$C barrel temperature, 140rpm screw speed in a single screw extruder fitted with 2mm die nozzle diameter. Functional properties such as bulk density, water absorption capacity, foam capacity and emulsion capacity increased from 0.61 to 0.75g/cm$^3$, 2.19 to 2.88$g_{water}/g_{sample}$, 9.66 to 12.33% and 13.53 to 16.79% respectively with extrusion condition and defatted soybean inclusion. However, gelation capacity was decreased with defatted soybean inclusion. Extrusion condition and defatted soybean inclusion significantly ($p<0.05$) reduced the peak viscosity, trough, final viscosity and setback values of the extrudates. Extrusion condition and defatted soybean inclusion did not influence pasting time and temperature of the extrudates. The decreased viscosity values of the extrudates are an indication of their potential in infant food formulation.

**Keywords:** African breadfruit, Soybean, Corn, Extrusion cooking, Functional and pasting properties.

## 1. Introduction

The African breadfruit (*Treculia africana*) is produced by a wild tropical ever green tree which has immense potential as a nutritional source for man. The tree grows wildly in the high rainforest zone of Nigeria and other African countries (Ajiwe *et al*., 1995). The crop constitutes a strategic reserve of essential food nutrients that are available at certain critical period of the year when common sources of other food nutrients are short in supply or out of season (Nwabueze, 2004). The seeds are traditionally consumed as porridge meal when cooked with other food ingredients or as a snack when roasted (Nwabueze *et al*., 2008).

Extrusion technology has been employed in developing a wide range of raw materials from cereal flour, starch granules, tubers and legumes into semi-cooked or completely cooked acceptable food products such as breakfast cereals, flakes, quick cooking pasta products, texturised vegetable protein and breakfast gruel (Iwe and Ngoddy, 1998; Iwe, 2001, Leszek, 2011).

Ariahu *et al*. (1999) reported that African breadfruit and soybean flour blend produced an acceptable weaning diet formula. Nwabueze *et al*. (2008) bridged the gap in terms of nutrient insufficiency by extruding blends of African breadfruit-soybean-corn mixtures thereby giving different extrudates characteristics controlled by extruder operating conditions and feed material variations.

Extrusion cooking significantly influences the functional and pasting characteristics of the extrudates. This could be desirable in certain food applications, particularly in instant breakfast cereal products. This is because the high temperature, shear rate, residence time experienced during extrusion cooking results in starch gelatinization, melting, or degradation which has a direct influence on the textural characteristics of the final product and by extension plays a role in the consumer acceptability of the product. The objectives of the study were to evaluate the functional and pasting properties of the raw flour blends and the influence of extrusion condition and defatted soybean inclusion on those prosperities.

## 2. Material and Methods

### 2.1 Source of raw materials

African breadfruit (*Treculia africana*) seeds were purchased from Umuahia main market, Abia State, Nigeria; Corn (16DT-Across Pool) variety was obtained at the International Institute for Tropical Agriculture (IITA) Kano substation; while Soybean (TGX 1740-1 MJ) seeds were obtained from the National Cereal Research Institute, Badegge, Niger State, Nigeria.

### *2.1.2 Preparation of raw Material*

African breadfruit seeds were washed in cold potable water and drained through a local perforated basket. The drained seeds were partially cooked in boiling water for 15min to facilitate the separation of the seed coats from the endosperm. Partially cooked seeds were drained and allowed to stand for 20min to further soften the seed coat and effect cooling. Softened seeds were then decoated in an adjustable disc attrition mill and the fruits were manually separated from the coat on a tray. Dehulled seeds were oven dried at $60^0$C for 17h and properly stored inside high density polyethene bag. Soy bean seeds were sorted and winnowed manually in air current. The seeds were soaked in potable water for 18h at room temperature in a stainless steel container. Soaked seeds were gently mashed in a mortar to loosen the seed coat and the coats were separated from the cotyledon via water floatation. The cotyledons were drained dried in an air convection oven at $60^0$C for 17h. Corn grains were sorted, dry-cleaned and stored in air-tight plastic container. The three processed seeds were stored under refrigeration prior to flour production.

### *2.1.3 Production of flour*

Dry cleaned breadfruit seeds were milled in a disc attrition mill (7hp, China) and the flour passed through a screen of 75µm pore size. The resulting flour was stored at room temperature ($28+2^0$C) in a high density polyethene bag. Decoated soybean seeds were milled in a disc attrition mill (7hp, China) and screened through a 75µm pore opening. The resulting flour was stored in high density polyethene bag. While for corn flour, the seeds were further dried in an air convection oven (Gallenkamp, England) at $60^0$C for 6h and pulverized in a disc attrition mill (7hp, China) and passed through a 75µm screen. The resulting flour was stored in an air tight plastic container and stored under refrigeration.

### *2.1.4 Defatting procedure*

Soybean flour was divided in to two portions. One portion was defatted from 17.60% to a known fat level 3.11%. This was done by soaking the flour in a food grade ethanol at 1:3 (flour:ethanol) ratio for 3h at room temperature ($28+2^0$C) and centrifuging at 4000rpm for 15min. The flour was separated from the supernatant and was spread under fan to reduce the concentration of ethanol in the sample. The defatted mass was then dried in an air convection oven (Gallenkamp, England) at $60^0$C for 24h to desolventize residual ethanol in the flour. It was then milled in a hammer mill to break flour clumps and stored in an air tight container before blending and subsequent extrusion. The other portion was used as undefatted/whole fat soybean flour in the blend.

### *2.1.5 Flour blending*

The undefatted soybean flour was used to formulate blend I while the defatted soybean flour was used to formulate blend II. The method reported by Nwabueze et al. (2008) was adopted for the formulation. The formulation was in ratio of 70:25:5 (African breadfruit-soybean-corn).

### *2.1.6 Sample preparation for extrusion*

The two flour blends were separately brought to 21% MC by water addition through material balance (Nwabueze and Iwe, 2010). The prepared samples were extruded at selected constant extrusion condition at screw speed of 140rpm and barrel temperature of $140^0$C in a Brabender laboratory single-screw extruder (Duisburg DCE 330, New Jersey USA).

## 2.2 Extruder preparation

The extruder had grooved barrel length to diameter (L/D) ratio of 20:1 fitted with 2mm die nozzle diameter operated at a constant screw speed (ss) of 140rpm and $140^0$C barrel temperature. A 4:1 compression ratio screw was employed (Nwabueze, 2007). The die nozzle diameter and length were 2mm and 40mm, respectively. Temperature settings were adjusted using thermostat, such that, feeding, compression, metering and die zone temperatures were 120, 150,170 and $150^0$C. The extruder was allowed to run to stabilization at a screw speed of 40rpm using corn flour before the experimental runs commenced. The feed was introduced gradually but continuously in to feed hopper equipped with an auxiliary anger screw at 300g/min and received at the die end as strands of pellets.

## 2.3 Extrusion cooking

The two portions for extrusion selected from blends I and II respectively were extruded at a screw speed (ss) of 140rpm and $140^0$C barrel temperature in a Brabender laboratory single-screw extruder (Duisburg DCE 330, New Jersey USA) fitted with 2mm die nozzle diameter.

## 2.4 Handling of extrudates

The emerging extrudates as pellets at the die nozzle were collected and spread under fan on the laboratory table at room temperature ($28+2^0$C) for 3h. The extrudates were later dried in an air convection oven (Gallenkamp, England) at $60^0$C for 10h. The resulting dried extrudates were packaged inside high density polyethene bags coded according to their runs. Few grammes needed for laboratory analysis were taken from each run and milled in a Brabender roller mill and sieved through a 75µm opening. The resulting extrudates flours were packaged inside coded high density polyethene bags and stored under room temperature (28+2$^0$C) until needed for analysis.

## 2.5 Determination of functional and pasting properties

The bulk density, water absorption, foam, emulsion and gelation capacities of flour blends and their extrudates were determined as described by the method of Okezie and Bello (1988). Pasting parameters were determined using a rapid visco analyzer (Newport Scientific Pty Ltd., Warrie-wood NSW 2102, Australia). About 2.5 g of sample was weighed into a previously dried empty canister; then 25 ml of distilled water was dispensed into the canister containing the sample. The suspension was thoroughly mixed and the canister was fitted into the rapid visco analyzer. Each suspension was kept at 50$^0$C for 1 min and then heated up to 95$^0$C at 12.2$^0$C /min and held for 2.5 min at 95$^0$C. It was then cooled to 50$^0$C at 11.8$^0$C /min and kept for 2 min at 50$^0$C. The expansion ratio (ER) was expressed as the mean diameter of the extrudates to that of the die orifice (Arts *et al*., 1990).

## 2.6 Statistical analysis

Data were analyzed by analysis of variance (Steel and Torrie, 1980). The mean values were separated by least significant difference (LSD) test at 5% probability level.

## 3.0 Discussion

The functional properties of raw flour blends and their extrudates are shown in Table 1. Extrusion condition and defatted soybean inclusion significantly ($p<0.05$) affected all the functional properties (ρB, WAC, FC, EC, GC) studied except the expansion ratio of the extrudates. Bulk density is a critical factor in handling and packaging requirements and shipping cost (Maga and Klim, 1989). The result for the bulk density showed that extrusion cooking significantly ($p<0.05$) increased the bulk densities of the extrudates by 0.05g/cm3 and 0.12g/cm$^3$ in blends I & II respectively. High increase in blend II extrudates can be attributed to defatted soybean inclusion which minimized protein-lipid, carbohydrate-lipid interaction during extrusion thereby increasing air space (porosity) giving extrudate high bulk density. Martinez-Serna and Lund (1987) reported that extrusion of corn-milk protein blends increased the bulk density and attributed it to the in ability of the walled cells to maintain their integrity as cells were expanded by steam. Extrusion cooking in general, leads to increase bulk density, increase water absorption capacity, increase water solubility index and expansion ratio of the extrudates (Mellower, 1992a and Filli et al., 2010). The water absorption capacity of the two flour blends were significantly ($p<0.05$) different from those of their extrudates and this signifies modifications in the physico-chemical profile of the raw material. Extrusion cooking as shown in this work significantly ($p<0.05$) increased the water absorption capacity from 2.19gwater/g$_{sample}$ in blend I to 2.30gwater/g$_{sample}$ in its extruded form; while an increment of 2.49gwater/g$_{sample}$ in blend II to 2.88gwater/g$_{sample}$ in its extruded form were recorded. Gomez and Aguilera (1983) explained that low water absorption capacity value for raw sample is an indication of intact starch granules in the raw flour. When intact starch flour granules are subjected to extrusion cooking starch are gelatinized, proteins are denatured and crude fibre swollen (Damardjati and Luh, 1987). Chauhan and Bains (1985) reported a 3-fold increase in water absorption capacity of extruded products over non extruded blends of different rice flour and defatted soybean. Increased water absorption capacity of blend II and its extrudates over the blend I and its extrudates could be attributed to the defatting process which lessened the formation of lipid complexes with proteins and carbohydrates. Extrusion cooking significantly increased the foam capacity of the extrudates by 0.69% and 0.60% in blends I & II extrudates. Forming capacity and stability depend on the surface active properties of the protein involved (Iwe, 2003). The ability of protein to be adsorbed rapidly at air-water interfaces during bubbling and undergo rapid transformation and rearrangements at the interface is a factor of forming of the food products (Adebowale et al., 2005). Therefore, the high foam capacity of extruded blends is an indication that the blends could be used in the preparation of food products that require high foaming properties. Extrusion cooking significantly ($p<0.05$) increased the emulsion capacity of the extrudates. Their values were increased by 0.75% and 0.30% in extruded blends I & II respectively. The emulsion capacity of flour depends on the area of stabilized oil droplets at interface which is a function of the oil content, protein concentration and the type of equipment used to produce the emulsion. This implied that, extrusion cooking significantly breaks up fat globules in food matrix which increased emulsion capacity of the product. Furthermore, low emulsion capacity in extruded blend II could be attributed to inclusion of defatted soybean flour in the blend. The gelation capacity of the flour blends and their respective extrudates were not significantly ($p>0.05$) affected by extrusion. This is an indication that the extrusion conditions applied as well as the blend ratio used gave the extrudates stable gelation. However, inclusion of defatted soybean gave extruded blend II reduced gelation capacity quantitatively. Extrusion cooking condition and defatted soybean inclusion did not significantly ($p>0.05$) affect extrudates expansion ration. However, blend II extrudates (1.59) had high value. The sudden reduction in pressure at the die causes moisture to flash off rapidly as steam, puffing the extrudates (Leszek, 2011).

The pasting characteristics of the raw flour blends and their extrudates are shown Table 2. Extrusion cooking condition and defatted soybean inclusion significantly ($p<0.05$) affected all the properties of raw flour blends and their extrudates measured except in their pasting times. Defatted soybean inclusion significantly reduced the peak viscosity, trough, break down, final viscosity and set back properties of the extrudates. But, pasting time and temperature were not significantly ($p>0.05$) affected. The peak viscosities of the extrudates were reduced compared with their respective flour blends. Extrusion cooking significantly ($p<0.05$) reduced peak viscosity by 10.58RVU and 25.48RVU in extruded blends I & II. This finding is in line with Belitz and Grosch (1999) who reported that starch extrudates are more dispersible, have better solubility with lower viscosity. Peak viscosity is the ability of the starch to swell freely before their physical break down. This implied that extrusion cooking altered the swelling capacity and by extension reduced ability of the extrudates to form gel which might be appropriate especially in infant feeding. Peak viscosity indicates the water binding capacity of starch. Viscosity generally depends on solubility and water holding capacity as well as the structure of components in a food system (Leszek, 2011). Extrusion can induce starch dextrinization resulting in reduction of viscosity in gruels and a concomitant increase in caloric and nutrient density (Jacson et al., 1981). Reduced viscosity recorded in this work could be of importance in children feeding. Pelembe et al. (2002) reported that, reduced viscosity of protein rich sorghum-cowpea extrudates could be very beneficial for infants feeding. Reduced viscosity of the extrudates significantly increased their pasting temperatures from $67.64^0$C in raw blend I to $73.23^0$C in its extrudates and from $66.95^0$C in raw blend II to $75.82^0$C in its extrudates. This can be attributed to gelatinized starch structures of the extrudates. Gelatinized granules would therefore need high temperature and longer time to activate the amylose content of degraded starch in order to gel due to low or non swelling nature of the degraded starch molecules. However, the pasting times of both the raw flour blends and their respective extrudates were not significantly ($p>0.05$) affected. The high gelatinization temperature is an index that, the granules of the extrudates have lost their optimal swelling ability and capacity. The pasting temperature is one of the pasting properties which provides an indication of the maximum temperature required for sample cooking, energy cost among other components (Shimelis et al., 2006). The trough which is the maximum viscosity value in the constant temperature phase of the RVA profile, measures the ability of paste to withstand break down during cooking. Extrusion cooking significantly reduced the values in the two extrudates from 120.86RVU in raw blend I to 115.85RVU in its extrudates and from 118.17RVU in raw blend II to 102.25RVU in its extrudates. Defatted soybean inclusion affected the trough value significantly which could be attributed to low heat conduction by the blend, increased shear rate over raw blend I. Extrusion cooking significantly ($p<0.05$) reduced the break down strength of the extrudates by 5.33RUV and 9.83RUV in blends I & II respectively. The high the break down viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking (Adebowale et al., 2005). By implication the raw flour blends are more susceptible to heat degradation than their extrudates. This suggests that the extrudates can be recooked without losing their intact shapes given by the choice of desired die size. The break down value further attests to Galvez and Resurreccion (1993) who reported that composite blends with cereals require that the starch granules swell sufficiently and remain intact and stable against sheering during the process. The setback values were significantly ($p<0.05$) reduced upon extrusion. Reductions by 23.17RVU and 22.33RVU in extruded blends I & II were recorded. The higher the set back value, the lower the retrogradation during cooling of the products made from the flour.

## 4.0 Conclusion

Extrusion cooking condition and defatted soybean inclusion significantly altered the physico-chemical structure of intact starch granules with resultant increase in bulk density, water absorption capacity, foam capacity, emulsion capacity and reduced gelation capacity. The extrudates had reduced viscosity compared with their raw flour samples which indicates their potentials in infant food formulations such as complementary foods where low viscosity is required. Pasting temperature of raw flour blends were significantly ($p<0.05$) higher than their respective extrudates while the pasting time of both the flour blends and their corresponding extrudates were not significantly ($p>0.05$) different.

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Table 1 Functional properties of raw blends and their extrudates

| | Blend I | | *Blend II | |
|---|---|---|---|---|
| Functional Properties | Raw | Extruded | Raw | Extruded |
| ρB (g/cm3) | 0.61$^{d}$ ± 0.61 | 0.66$^{b}$ ± 0.63 | 0.63$^{c}$ ± 0.63 | 0.75$^{a}$ ± 0.75 |
| WAC ($g_{water}/g_{sample}$) | 2.19$^{d}$ ± 0.04 | 2.30$^{c}$ ± 0.02 | 2.49$^{b}$ ± 0.02 | 2.88$^{a}$ ± 0.05 |
| FC (%) | 9.66$^{d}$ ± 0.13 | 10.35$^{c}$ ± 0.07 | 11.73$^{b}$ ± 0.12 | 12.33$^{a}$ ± 0.05 |
| EC (%) | 13.53$^{c}$ ± 0.09 | 14.28$^{b}$ ± 0.18 | 16.49$^{a}$ s± 0.30 | 16.79$^{a}$ ± 0.08 |
| GC (%) | 14.00$^{a}$ ± 2.00 | 13. 67$^{a}$ ± 1.53 | 10.00$^{b}$ ± 2.00 | 8.00$^{b}$ ± 2.00 |
| Expansion Ratio | - | 1.43$^{a}$ + 0.10 | - | 1.59$^{a}$ + 0.10 |

Values are means and standard deviations of three determinations. Values not followed by the same superscript in the same row are not significantly different ($p>0.05$). *with defatted soybean flour.
ρB = Bulk Density; WAC = Water Absorption Capacity; FC = Foam Capacity; EC = Emulsion Capacity; GC = Gelation Capacity.

Table 2 Pasting properties of raw flour blends and their extrudates

| | Blend I | | *Blend II | |
|---|---|---|---|---|
| Pasting Properties | Raw | Extrudate | Raw | Extrudates |
| Peak viscosity (RVU) | 145.33$^{a}$ ± 2.00 | 134.75$^{c}$ ± 1.00 | 139.57$^{b}$ ± 2.00 | 113.89$^{d}$ ± 3.00 |
| Trough (RVU) | 120.86$^{a}$ ± 2.00 | 115.83$^{b}$ ± 2.00 | 118.17$^{b}$ ± 1.53 | 102.25$^{c}$ ± 2.00 |
| Breakdown (RVU) | 24.25$^{a}$ ± 2.00 | 18.92$^{c}$ ± 1.00 | 21.41$^{b}$ ± 0.58 | 11.58$^{d}$ ± 1.00 |
| Final Viscosity (RVU) | 227.58$^{a}$ ± 2.00 | 199.33$^{c}$ ± 2.00 | 211.08$^{b}$ ± 1.00 | 172.42$^{d}$ ± 2.00 |
| Setback (RUV) | 106.67$^{a}$ ± 2.00 | 83.50$^{c}$ ± 1.00 | 92.57$^{b}$ ± 2.00 | 70.24$^{d}$ ± 2.00 |
| Pasting Time (Min.) | 5.94$^{a}$ ± 1.00 | 6.25$^{a}$ ± 1.00 | 6.16$^{a}$ ± 1.00 | 6.37$^{a}$ ± 2.00 |
| Pasting Temp (OC) | 67.64$^{b}$ ± 1.28 | 73.23$^{a}$ ± 1.00 | 66.95$^{b}$ ± 1.00 | 75.82$^{a}$ ± 3.00 |

Values are means and standard deviations of three determinations. Values not followed by the same superscript in the same row are significantly different ($p<0.05$).
*with defatted soybean flour.

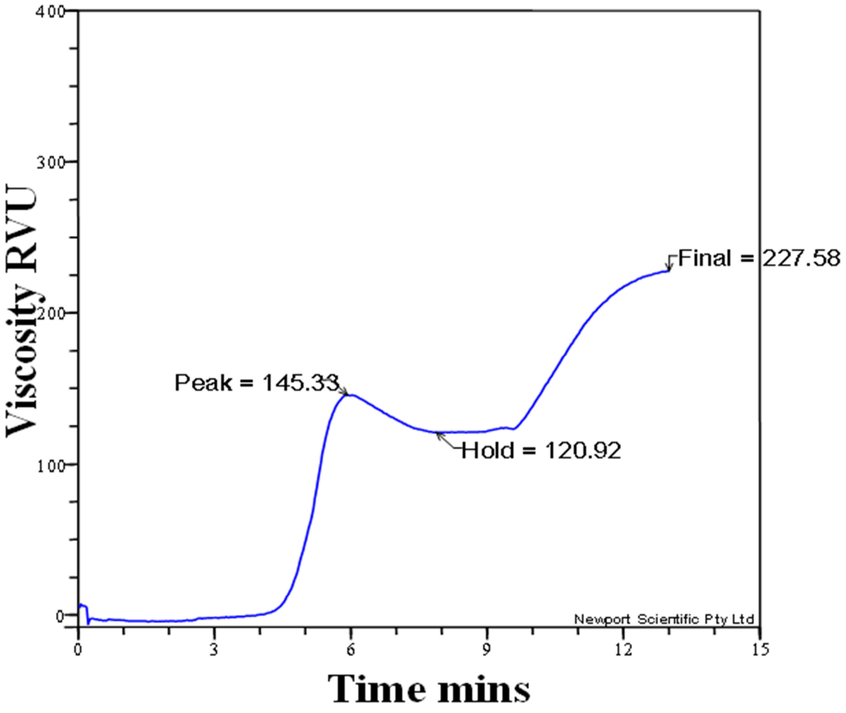

Fig. 1 Pasting characteristics of raw blend I

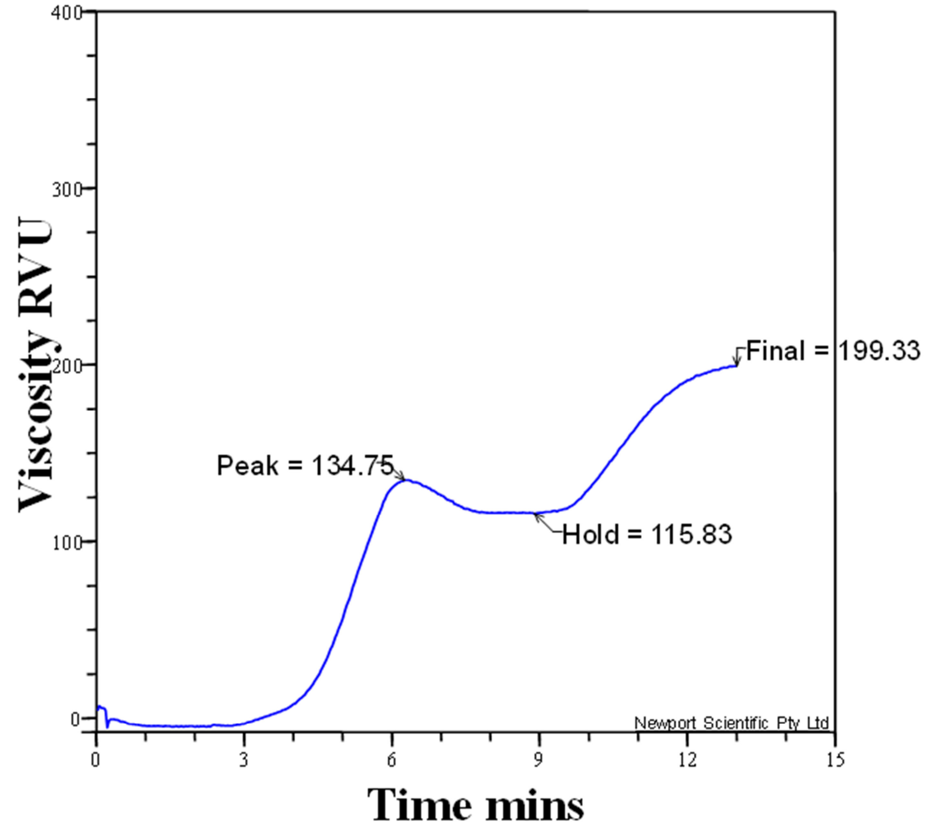

Fig. 2 Pasting characteristics of extruded blend I

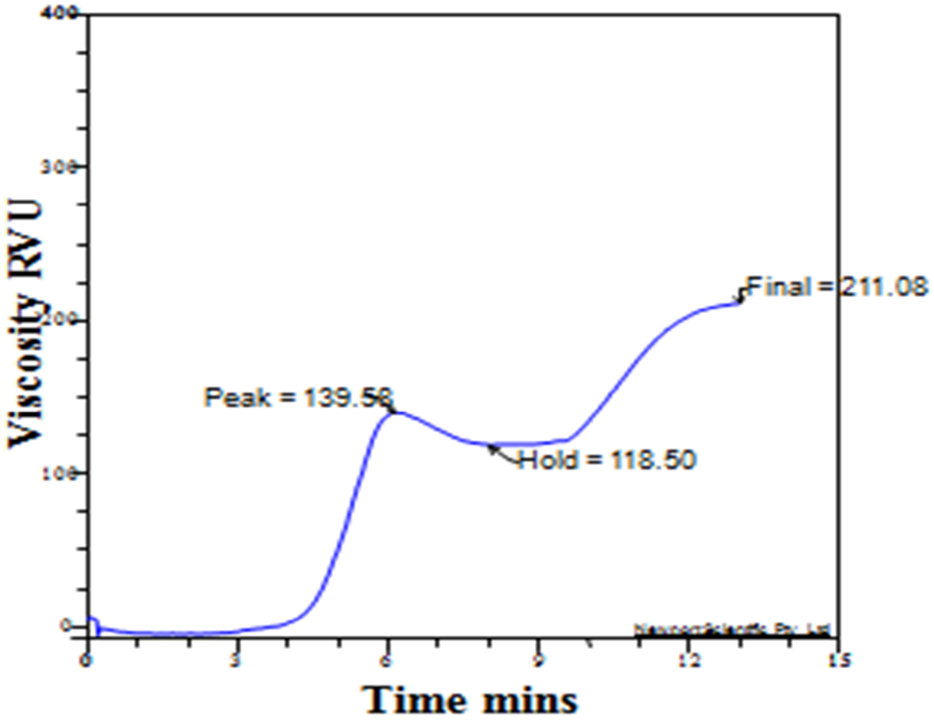

Fig. 3 Pasting characteristics of raw blend II

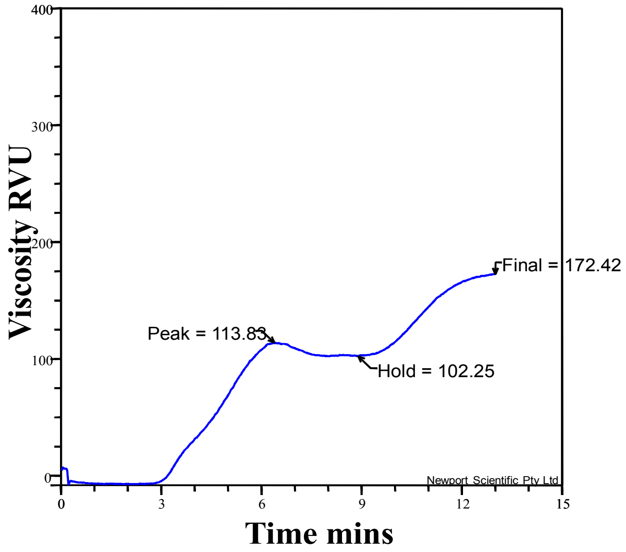

Fig. 4 Pasting characteristics of extruded blend II