UNIVERSITY GRANTS COMMISSION

PROFORMA FOR SUBMISSION OF INFORMATION AT MID-TERM GROUP REVIEW WORKSHOP

1.	**UGC Reference No and Date**	: 41-669/2012(SR), 23-07-2012
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5.	**Title of the Project**	: Characterization and utilization of banana flour in different products
6.	**Date of implementation**	: 01-07-2012
7.	**Tenure of the project**	: 3 years from 01-07-2012 to 31-12-2015
8.	**Grant Received**	:1st Installment: 8,70,000/- :2nd Installment: 2,48,000/-

9. Objectives of the project

1. T o study physicochemical and rheological properties of flour from different banana cultivars.
2. To evaluate the structure, thermal, pasting and retrogradation of starch from different banana cultivars
3. To study the effect of incorporation of banana flour in dough and baking properties of wheat flour.
4. To study the effect of incorporation of banana flour on the extrusion behaviour of corn and rice grits grits.

10. Methodology:

Materials

Five banana flour (BF) varieties namely *Musa Nendran (aab), Musa Poovan (aab), Musa Saba (abb), Musa Karpuravalli (abb), Musa Cavandish group* and to study the effect of BF on wheatflour, one weak wheat variety and one strong wheat variety were taken for present study.

(A) Banana Peel

(i) Total phenolic content (TPC)

TPC was determined according to the method given by Yu et al. (2002).

(ii) DPPH radical scavenging activity (AOA)

Antioxidant activity was measured by using method explained by Brand-Williams, Cuvelier, and Berset (1995).

(iii) Total flavonoid content (TFC)

TFC was determined by using method of Kim et al. (2003).

(B) Banana Flour

(i) Proximate composition

Proximate composition was determined using AAAC (2000) methods for moisture, ash and protein content.

(ii) Hunter Color

Color parameters (*L**, *a**, *b**) of extruded sample (before frying and after frying) as well as extrudates flour were carried out using an Ultra Scan VIS Hunter Color Lab (Hunter Associate laboratory Inc., Reston VA, U.S.A.). The values are measured in *L** indicating lightness to darkness, *a** indicating redness to greenness and *b** indicating blueness to yellowness. The reported values are mean of three replicates.

(iii) Total phenolic content (TPC)

TPC was determined as described earlier.

(iv) DPPH radical scavenging activity (AOA)

Antioxidant activity was measured by using method TPC was determined as described earlier.

(v) Total flavonoid content (TFC)

TFC was determined by using method as described earlier.

(vi) Pasting properties

The pasting properties of starches were evaluated using method Kaur et al (2013). Parameters recorded were pasting temperature; peak viscosity, final viscosity, breakdown viscosity, setback viscosity.

(vii) Dynamic Rheology

Dynamic rheology of the flour suspension (20%) was evaluated as given by Kaur et al 2013 G′peak, G″*peak*, G′final, G″*final* were measured.

(C) Banana flour-Wheat flour Blends

(i) Mixograph

Mixographs were recorded electronically using a 10g bowl (National Mfg. Co. Lincoln, NE, USA). For construction of mixograms, moisture content and protein content of the samples were determined according to AACC method (2000). Various parameters evaluated were peak time, peak height, peak width (MPW) and weakening slope (WS).

(ii) Dynamic Rheology

Dynamic rheology was measured using a Rheostress 6000 dynamic rheometer (Haake, ThermoScientific,Germany) as described by Kaur et al (2013). *G′* (elastic modulus), *G″* (viscous modulus) and *tan δ* (*G″/G′*) for dough samples were measured.

(iii) FTIR

Secondary structure of the dough samples were determined using FTIR spectroscopy. Spectra of dough was mixed in Mixograph (National Mfg. Co. Lincoln, NE, USA) were recorded on a Vertex 70 FTIR spectrometer (Bruker, Germany. Spectra of an empty cell were taken as background. Measurements were performed over wavenumbers ranging from 800 to 2000 cm-1 (fingerprint region) with 4 cm-1 resolution using OPUS software. All spectra were the averages of 200 scans.

The quantitative estimation of secondary structure in dough was determined from second-derivative spectra in the amide I region.

(D) Extrudates

Green/raw banana was procured from local market. They were harvested at a commercial stage and were not submitted to any maturation treatment or maturation chamber. The corn grit was procured from the BNF Mills (Batala). The corn grit was carefully stored in the sealed bags till further use.

(i) Sample preparation

Preparation of banana flour

Banana flour was prepared as discussed above.

Preparation of blends

The corn grit and banana flour prepared were mixed in the desired ratios i.e. 0%, 10%, 20% and 30%.

Extrusion cooking

The extrusion was performed on a co-rotating twin screw extruder (Clextral, BC 21, Firminy, France). The screw diameter, (L/D) ratio and die diameter of the extruder was 25 mm, 16 and 6 mm, respectively. The material is fed through a rotating screw hopper at a constant speed. The extrusion was carried out at 130, 150 and 180°C. The screw speed was kept at 300 rpm and 500 rpm. Cutter speed, feed rate (28 kg/h) was kept constant throughout the extrusion. When stable extrusion conditions were reached, the extrudates formed were carefully collected, air dried and sealed for further analysis.

Frying

The extrudates were fried at 160°C in refined groundnut oil for 5 minutes. The extrudates (before frying and after frying) collected were then ground to pass through 60 mesh number sieve (BIS). The ground samples were sealed in the zip lock bags and kept at 8°C till further analysis.

(ii) Extrudates characteristics

Hunter Color

Color parameters ($L*$, $a*$, $b*$) of extruded sample (before frying and after frying) as well as extrudates flour were carried out as discussed above.

Proximate composition

Proximate composition was determined using AAAC (2000) methods for ash; crude fat and crude protein.

Physical parameters

Expansion Ratio

Expansion ratio was determined as the diameter of extrudates divided by the diameter of the die exit (6 mm). Diameters at three different locations of an extrudates were measured and the expansion ratio was calculated by dividing the average diameter of the strand with the diameter of the die exit (6mm).

Bulk Density

The bulk density of the dried extrudates was calculated (Grenus et al, 1993). The reported values are the mean of three replicates.

Expansion after Frying

Expansion of the extrudates on frying was determined by the change in the sectional diameter. The diameter was measured with the help of a thread. The reported values were the mean of five replicates.

Water absorption index (WAI) and water solubility index (WSI)

WAI and WSI of the ground extrudates were determined by using method of Anderson et al. (1969).

Texture Analysis

Texture profile analysis (TPA) of fried extrudates was performed using a TA/XT texture analyzer (Stable Microsystems, Crawley, UK). The extrudates after frying was subjected to 75% compression with a probe (P/75) at a pretest and post speed of 1 mm/s. Flexural strength was determined. The reported values are the mean of the six replicate.

11. Work done so far

Objective 1: To study physicochemical and rheological properties of flour from different banana cultivars.

(A) Banana Peel

Total phenolic content of banana peel observed to be 9.93 mgGAE/g, antioxidant activity to be 88.98% and total flavanoid content to be 11.12 mgQE/g.

(B)Flour characteristics

(i) Hunter Color and composition

*L** ranged between 81.24 to 86.21 (Table 1). *Musa Cavendish* showed the lowest while *Musa Nendran* showed the highest. *a** ranged between 1.35 to 2.74. *Musa Nendran* showed the lowest while *Musa Karpurvalli* showed the highest. *b** ranged between 9.40 to 11.28. *Musa Saba* showed the lowest while *Musa Poovan* showed the highest.

Ash content ranged between 2.20 to 3.05%. *Musa Karpurvalli* showed the lowest while *Musa Nendran* showed the highest ash content (Table 1).

Protein content ranged between 2.66 to 4.43%. Musa Poovan showed the lowest while Musa Nendran showed the highest protein content (Table 1).

(ii) Total phenolic content (TPC)

BF ranged between 1.90 to 5.25 mgGAE/g. BF from *Musa Shrimanti* showed the lowest while *Musa Poovan* showed the highest (Table 2).

(iii) DPPH radical scavenging activity Antioxidant activity (AOA)

BF ranged between 19 to 95.76%. BF from *Musa Saba* showed the lowest while *Musa Shrimanti* showed the highest (Table 2).

(iv) Total flavonoid content (TFC)

BF ranged between 19 to 95.76%. BF from *Musa Saba* showed the lowest while *Musa Shrimanti* showed the highest (Table 2).

(v) Pasting properties

Pasting properties of BF from different varieties showed wide variations (Fig 1.). Peak viscosity, ranged between 3896 to 4933 cP. *Musa Poovan* showed the lowest while *Musa Cavendish* showed the highest peak viscosity. Breakdown viscosity ranged between 896 to 4933 cP. *Musa Poovan* showed the lowest while *Musa Cavendish* showed the highest peak viscosity. Final viscosity ranged between 4248 to 5704cP. *Musa Poovan* showed the lowest while *Musa Karpurvalli* showed the highest final viscosity. Pasting temperature ranged between 75 to 81.6°C. *Musa Cavendish* showed the lowest while *Musa Nendran* showed the highest pasting temperature.

(vi) Dynamic Rheology

G'peak ranged between 120 to 600 Pa (Table 3). *G"peak* ranged between 165 to 640 Pa. *G'final* ranged between 90 to 304 Pa. *G"final* ranged between 149 to 582 Pa. *Musa Cavendish* showed the lowest while *Musa Karpurvalli* showed the highest rheological properties.

Table 1: Color parameters and proximate composition of flours from different banana cultivars

Variety	L*	a*	b*	Ash content (%)	Protein content (%)
Musa Nendran	86.21	1.35	9.38	2.25	4.43
Musa Poovan	83.07	1.99	11.28	3.05	2.66
Musa Saba	84.64	1.81	9.40	2.45	3.82
Musa Karpurvalli	83.35	2.74	9.47	2.20	3.22
Musa Cavandish	81.24	1.79	9.85	2.90	3.18

Table 2: Phenolic content, Antioxidant activity and Flavanoid content of flours from different banana cultivars

Variety	Total phenolic content (mgGAE/g)	Antioxidant activity (%)	Total flavanoid content (mgQE/g)
Musa Nendran	1.90	95.76	3.30
Musa Poovan	5.25	30.44	1.10
Musa Saba	2.47	19.05	0.96
Musa Karpurvalli	3.26	17.64	1.36
Musa Cavandish	2.37	21.75	1.26

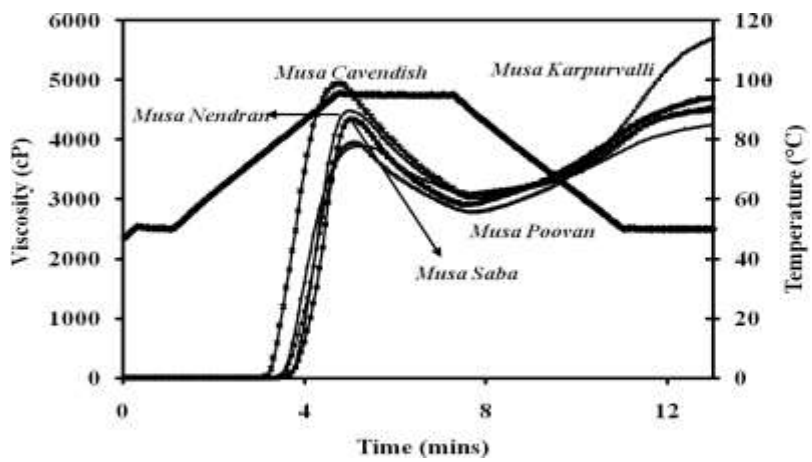


Fig. 1. Pasting profiles of Banana flour from different varieties

Table 3: Rheological properties of Banana flour from different varieties

Variety	G'_{peak} (Pa)	G''_{peak} (Pa)	G'_{final} (Pa)	G''_{final} (Pa)
Musa Nendran	238	419	195	409
Musa Poovan	242	413	139	346
Musa Saba	245	421	178	424
Musa Karpurvalli	600	640	304	582
Musa Cavandish	120	165	90	149

Objective 2: To study the effect of incorporation of banana flour in dough and baking properties of wheat flour.

(C) Banana flour-Wheat flour Blends

(i) Mixograph properties

Incorporation of BF in both the wheat varieties resulted in reduction in peak time. In case of weak flour, incorporation at 5% level, peak time ranged between 1.89 to 3.26 mins. *Musa Poovan, Musa Saba* showed the lowest while *Musa Karpurvalli* showed the highest. Peak height ranged between 57 to 64%. *Musa Nendran* showed the lowest while *Musa Cavendish* showed the highest. Peak width ranged between 21.76 to 41.55%. *Musa Nendran* showed the lowest while *Musa Poovan, Musa Saba* showed the highest. Weakening slope ranged between -2.09 to -7.75 %/min. *Musa Saba, Musa Karpurvalli* showed the lowest while *Musa Cavendish* showed the highest weakening slope. At 10% level, peak time ranged between 2.25 to 3.07 mins. *Musa Nendran* showed the lowest while *Musa Cavendish* showed the highest. Peak height ranged between 56 to 61%. *Musa Nendran* showed the lowest while *Musa Saba* showed the highest. Peak width ranged between 25.14 to 35.68%. *Musa Cavendish* showed the lowest while *Musa Nendran* showed the highest. Weakening slope ranged between -1.14 to -5.17 %/min. *Musa Karpurvalli* showed the lowest while *Musa Cavendish* showed the highest weakening slope. At 15% incorporation level, peak time ranged between 1.88 to 3.10 mins. *Musa Cavendish* showed the lowest while *Musa Nendran* showed the highest. Peak height ranged between 59 to 62%. *Musa Saba* showed the lowest while *Musa Karpurvalli* showed the highest. Peak width ranged between 22 to 47%. *Musa Nendran* showed the lowest while *Musa Cavendish* showed the highest. Weakening slope ranged between -1.83 to -6.61 %/min. *Musa Cavendish* showed the lowest while *Musa Nendran* showed the highest weakening slope.

In case of strong flour, incorporation at 5% level, peak time ranged between 3.88 to 4.42mins. *Musa Karpurvalli* showed the lowest while *Musa Poovan, Musa Saba* showed the highest. Peak height ranged between 59 to 62%. *Musa Karpurvalli* showed the lowest while *Musa Musa Poovan, Musa Nendran* showed the highest. Peak width ranged between 32.90 to 38.50 %. *Musa Karpurvalli* showed the lowest while *Musa Poovan* showed the lowest. At 10% level, peak time ranged between 3.71 to 4.76 mins. *Musa Saba* showed the lowest while *Musa Poovan* showed the highest. Peak height ranged between 57 to 61%. *Musa Saba* showed the lowest while *Musa Poovan* showed the highest. Peak width ranged between 35 to 42%. *Musa Poovan* showed the lowest while *Musa*

Cavendish showed the highest. Weakening slope ranged between -0.77 to -3.52 %/min. *Musa Cavendish* showed the lowest while *Musa Poovan* showed the highest weakening slope. At 15% incorporation level, peak time ranged between 4.10 to 4.94 mins. *Musa Poovan* showed the lowest while *Musa Cavendish* showed the highest. Peak height ranged between 39 to 59%. *Musa Nendran* showed the lowest while *Musa Saba* showed the highest. Peak width ranged between 37 to 59%. *Musa Cavendish* showed the lowest while *Musa Nendran* showed the highest. Weakening slope ranged between -2.49 to -4.15 %/min. *Musa Karpurvalli* showed the lowest while *Musa Nendran* showed the highest weakening slope. Effect of strong flour wheat on *Musa Cavendish* and *Musa Poovan* is shown in Fig. 2 and 3.

(ii) Dynamic Rheology

Incorporation of BF in both the wheat varieties resulted in increase in G' and G'' (Fig. 4 and 5). In case of weak flour, 5% level of incorporation, G' ranged between 17121 to 23287 Pa. *Musa Karpurvalli* showed the lowest while *Musa Poovan* showed the highest. G'' ranged between 5141 to 8966 Pa. *Musa Saba* showed the lowest while *Musa Poovan* showed the highest. *Tan* δ ranged between 0.39 to 0.41. *Musa Nendran, Musa Poovan* showed the lowest while *Musa Cavendish* showed the highest. At 10% level of incorporation, G' ranged between 17104 to 25801 Pa. *Musa Saba* showed the lowest while *Musa Nendran* showed the highest. G'' ranged between 6661 to 10032 Pa. *Musa Saba* showed the lowest while *Musa Poovan* showed the highest. *Tan* δ ranged between 0.37 to 0.39. *Musa Cavendish* showed the lowest while *Musa Poovan, Musa Saba* showed the highest. At 15% level of incorporation, G' ranged between 25845 to 50336 Pa. *Musa Nendran* showed the lowest while *Musa Cavendish* showed the highest. G'' ranged between 10040 to 16958 Pa. *Musa Saba* showed the lowest while *Musa Cavvendish* showed the highest. *Tan* δ ranged between 0.34 to 0.39. *Musa Cavendish* showed the lowest while *Musa Nendran* showed the highest.

In case of strong flour, 5% level of incorporation, G' ranged between 17175 to 48336 Pa. *Musa Saba* showed the lowest while *Musa Poovan* showed the highest. G'' ranged between 13757 to 23840 Pa. *Musa Cavendish* showed the lowest while *Musa Poovan* showed the highest. *Tan* δ ranged between 0.32 to 0.98. *Musa Cavendish* showed the lowest while *Musa Nendran* showed the highest. At 10% level of incorporation, G' ranged between 56356 to 78158 Pa. *Musa Poovan* showed the lowest while *Musa Cavendish* showed the highest. G'' ranged between 17516 to 26381 Pa. *Musa Saba* showed the lowest while *Musa Nendran* showed the highest. *Tan* δ ranged between 0.31 to 0.46. *Musa Saba* showed the lowest while *Musa Poovan,* showed the highest. At 15% level of incorporation, G' ranged between 61454 to 97473 Pa. *Musa Poovan* showed the lowest while *Musa Karpurvalli* showed the highest. G'' ranged between 26455 to 51392 Pa. *Musa Nendran* showed the lowest while *Musa Cavvendish* showed the highest. *Tan δ* ranged between 0.38 to 0.60. *Musa Karpurvalli* showed the lowest while *Musa Nendran*, *Musa Poovan* showed the highest. Effect of *Musa Cavendish* and *Musa Poovan* variety in strong and weak wheat flour is shown in Fig. 4 and 5.

(iii) FTIR Spectroscopy

Intermolecular β –sheets + antiparallel β sheets (1612-1632 cm^{-1}), α-helix (1650-1660 cm^{-1}) and β-turn+ β-sheets (1665-1670 cm^{-1}) were calculated from the area of the peaks obtained at different wave numbers (Fig.6 a and Fig.6 b). In case of weak flour, 5% level of incorporation, intermolecular β –sheets + antiparallel β sheets ranged between 16.20 to 18.75%. *Musa Karpurvalli* showed the lowest while *Musa Poovan* showed the highest. α-helix ranged between 46.51 to 49.26%. *Musa Saba* showed the lowest while *Musa Cavendish* showed the highest. β-turn+ β-sheets ranged between 34.22 to 34.79%. *Musa Poovan* showed the lowest while *Musa Saba* showed the highest. 10% level of incorporation, intermolecular β –sheets + antiparallel β sheets ranged between 16.07 to 18.94%. *Musa Cavendish* showed the lowest while *Musa Nendran* showed the highest. α-helix ranged between 47.39 to 50.04%. *Musa Saba* showed the lowest while *Musa Karpurvalli* showed the highest. β-turn+ β-sheets ranged between 33.15 to 35.11%. *Musa Karpurvalli* showed the lowest while *Musa Cavendish* showed the highest.

In case of Strong flour, 5% level of incorporation, intermolecular β –sheets + antiparallel β sheets ranged between 14.11 to 18.87%. *Musa Karpurvalli* showed the lowest while *Musa Nendran* showed the highest. α-helix ranged between 46.94 to 53.92%. *Musa Nendran* showed the lowest while *Musa Cavendish* showed the highest. β-turn+ β-sheets ranged between 30.35 to 35.23%. *Musa Cavendish* showed the lowest while *Musa Poovan* showed the highest. 10% level of incorporation, intermolecular β –sheets + antiparallel β sheets ranged between 14.52 to 17.83%. *Musa Cavendish* showed the lowest while *Musa Nendran* showed the highest. α-helix ranged between 46.88 to 54.52%. *Musa Cavendish* showed the lowest while *Musa Saba* showed the highest. β-turn+ β-sheets ranged between 29.09 to 35.11%. *Musa Karpurvalli* showed the lowest while *Musa Cavendish* showed the highest. Effect of incorporation of BF *Musa Cavendish* on weak wheat flour and strong wheat flour is shown in Fig. 6a and *Musa Poovan* on weak and strong wheat flour shown in Fig. 6b.

Musa Cavendish

Weak Flour **Strong Flour**

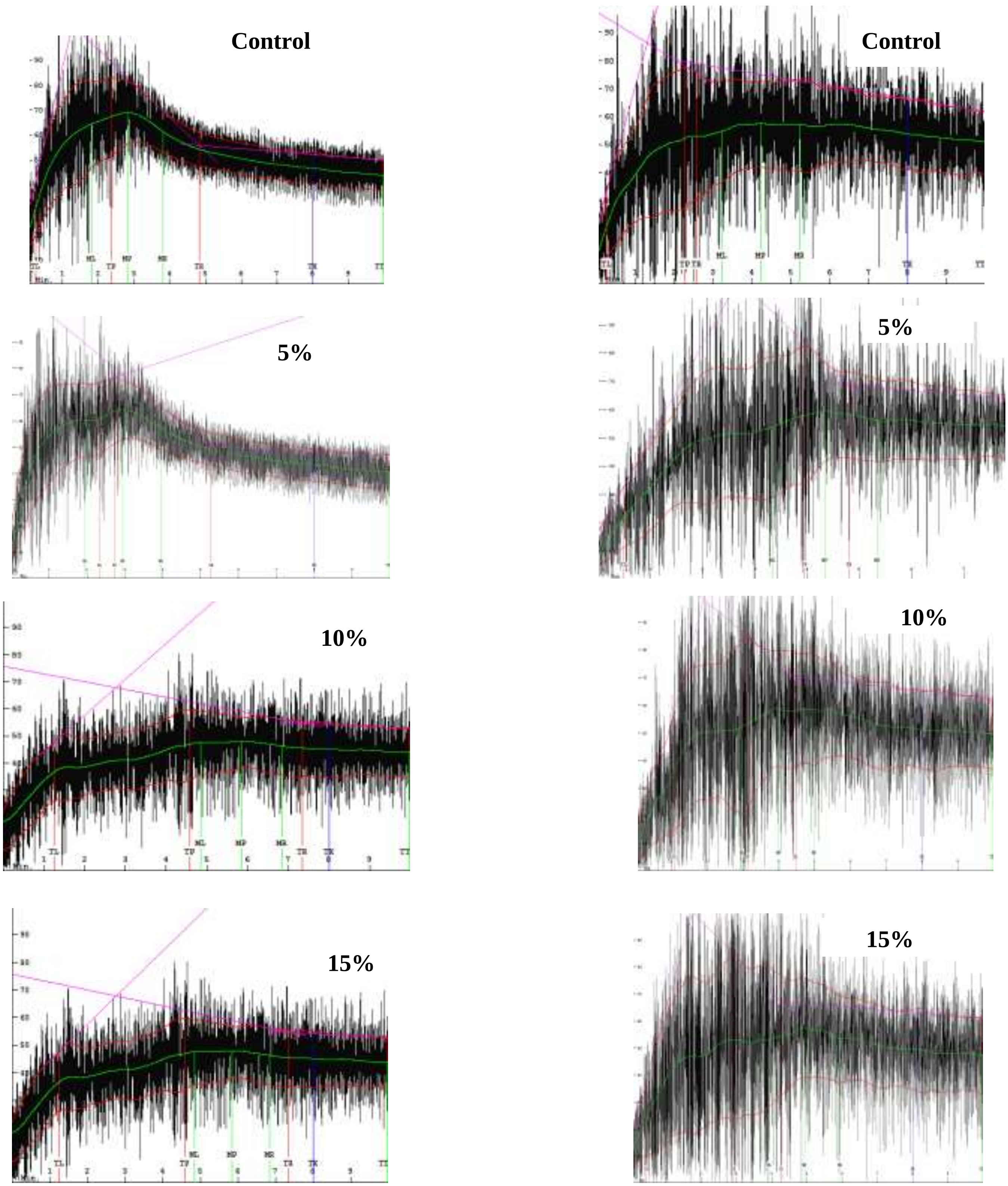


Fig. 2. Effect of BF (*Musa Cavendish)* incorporation on the mixographic properties of wheat flour

Musa Poovan

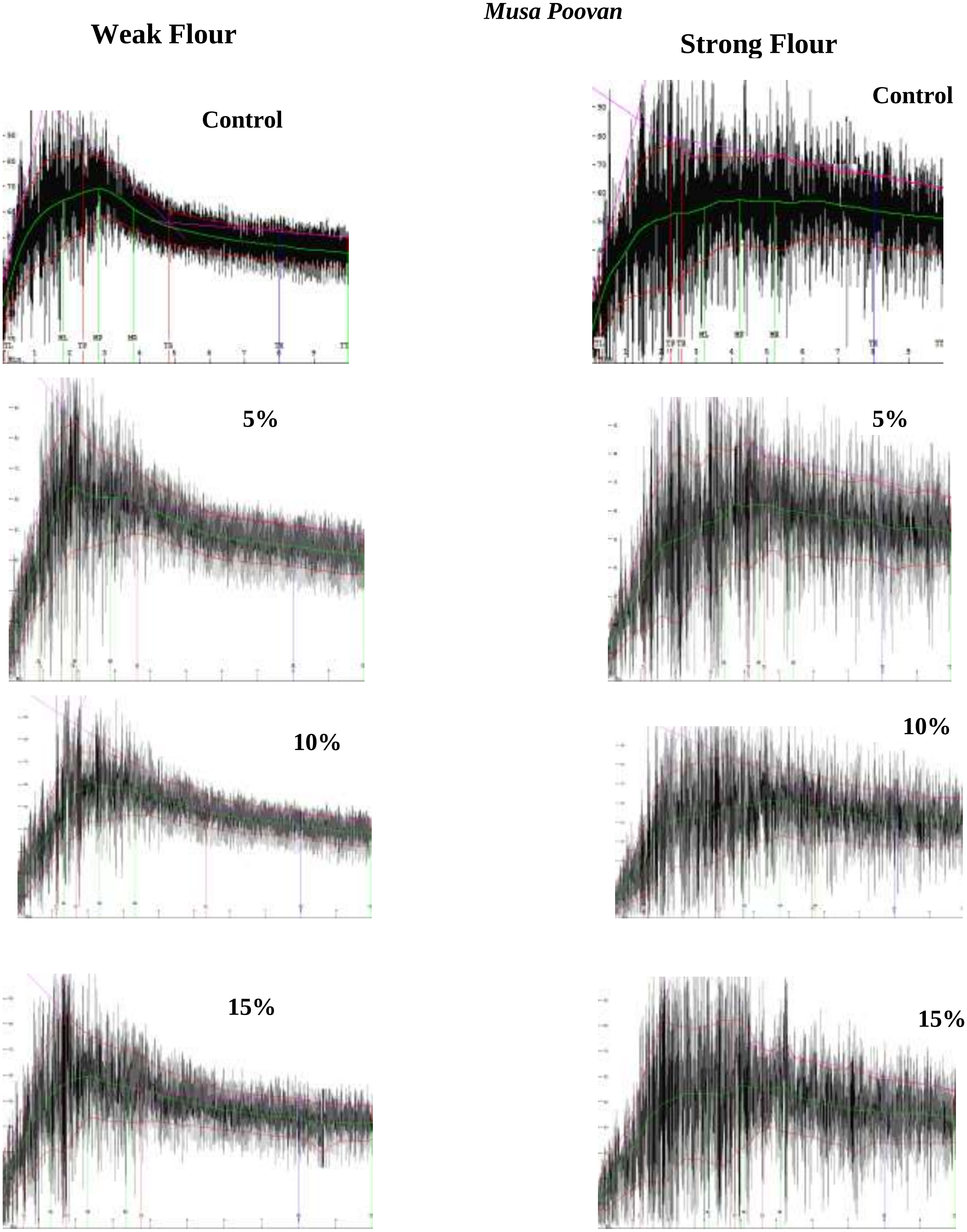
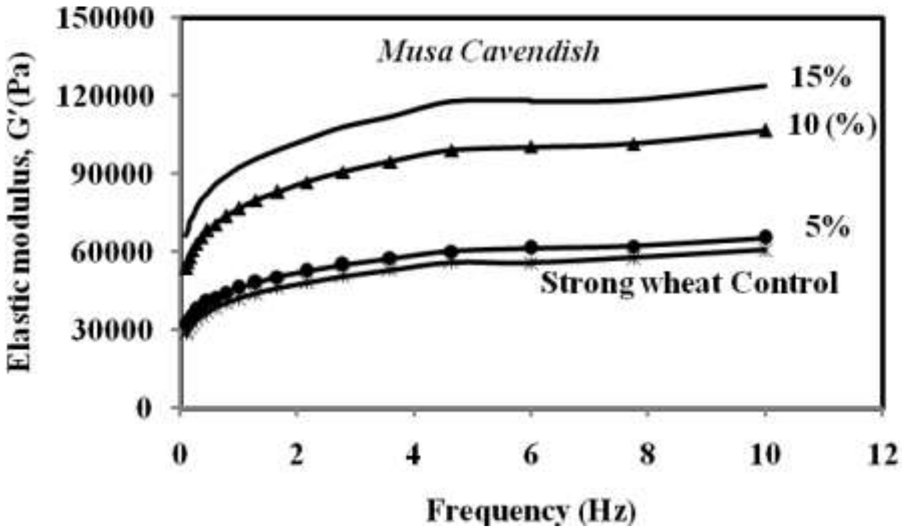


Fig. 3. Effect of BF (*Musa Poovan)* incorporation on the mixographic properties of wheat flour



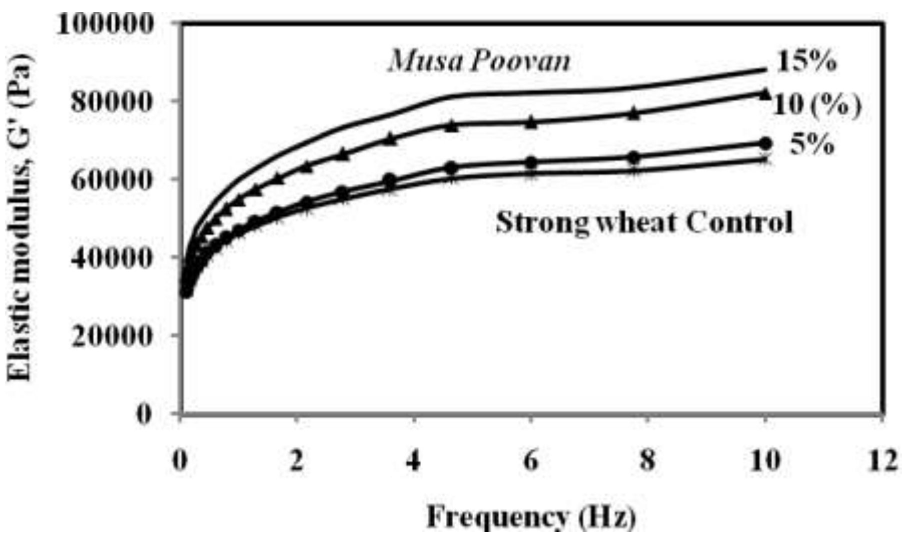


Fig. 4. Effect of incorporation of banana flour from *Musa Cavendish* and *Musa Poovan* variety into strong wheat flour

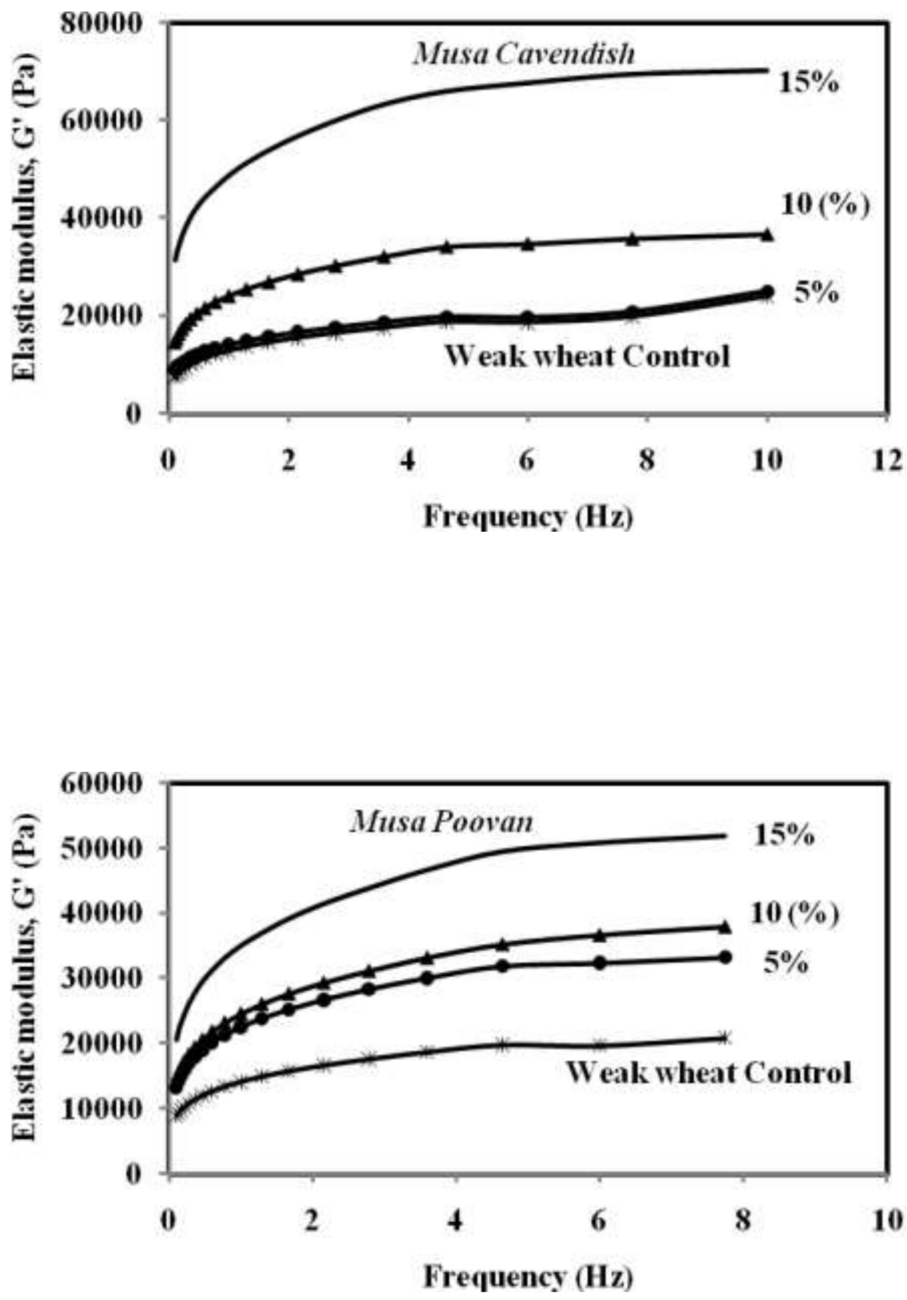


Fig. 5. Effect of incorporation of banana flour from *Musa Cavendish* and *Musa Poovan* variety into weak wheat flour

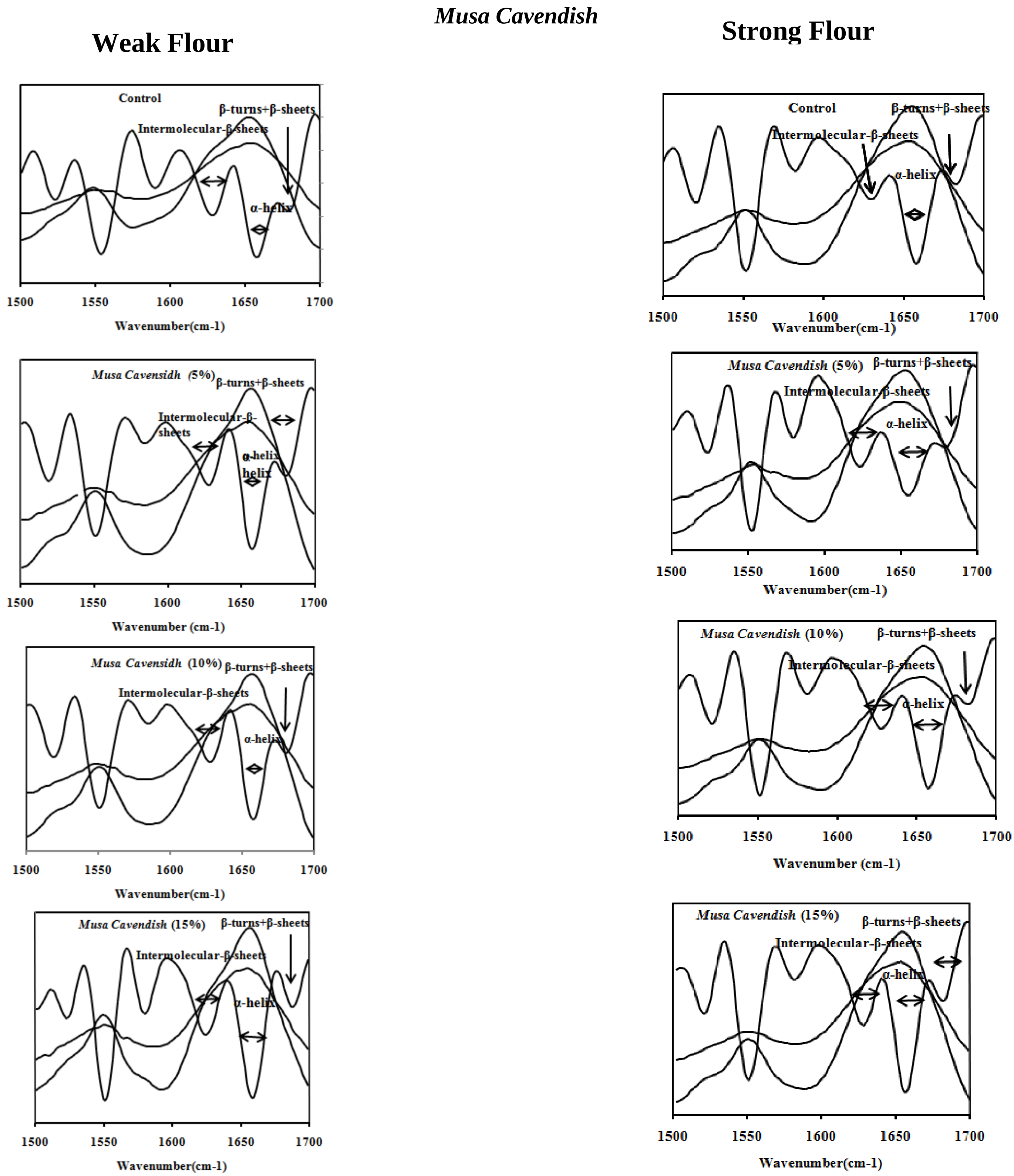


Fig. 6a. Effect of incorporation of banana flour from *Musa Cavendish* variety into weak and strong wheat flour on secondary structure of dough.

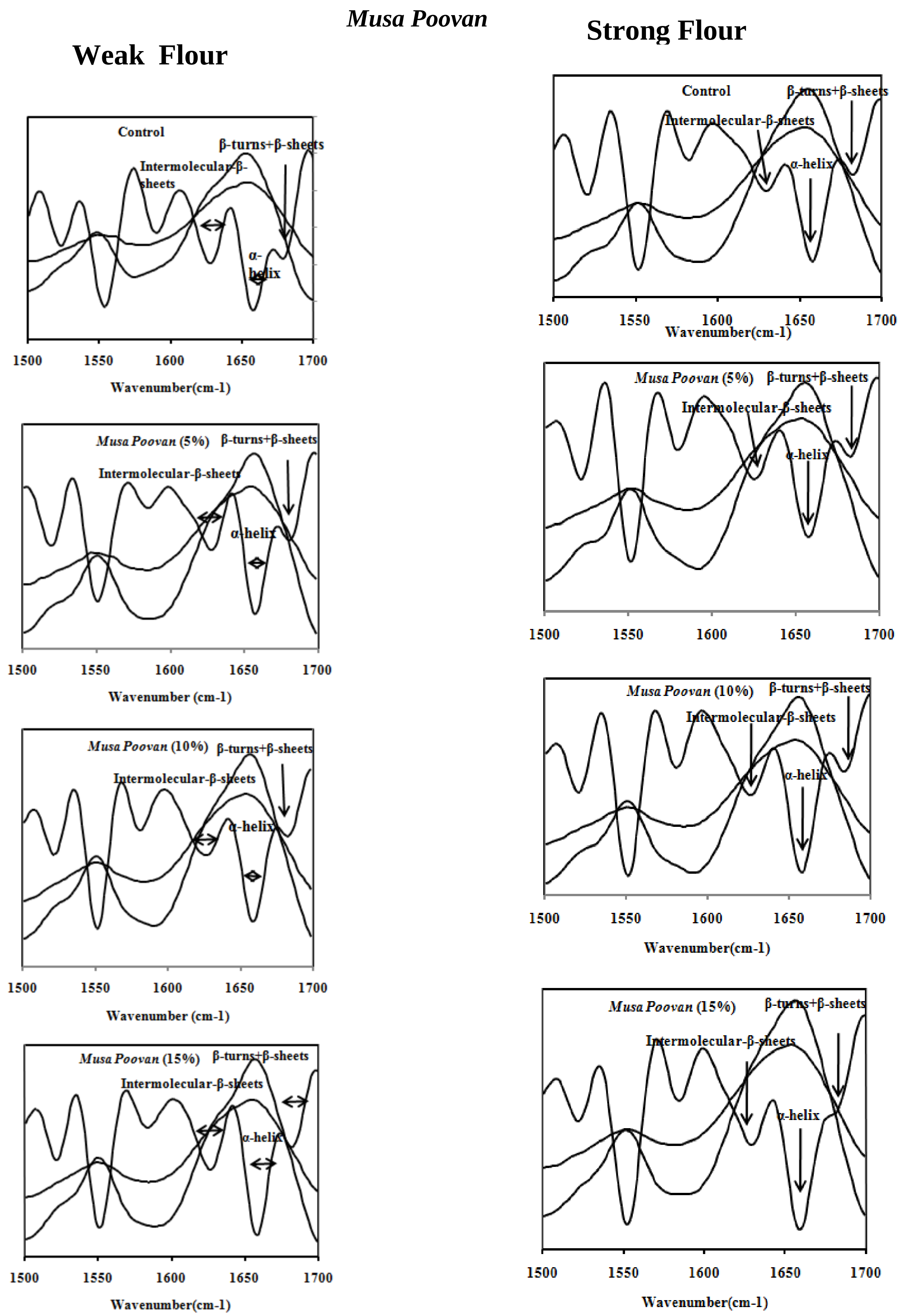


Fig. 6.b. Effect of incorporation of banana flour from *Musa Poovan* variety into weak and strong wheat flour on secondary structure of dough.

Objective 3: To study the effect of incorporation of banana flour on the extrusion behavior of corn and rice grits.

(a) Proximate composition of raw material

Green banana flour had ash, protein and fat content of 2.65%, 4.8%, 0.75% respectively.
L*, a*, b* were 76.19, 12.52, 38.44 for corn grit and 86.16, 0.43, 11.42 for green banana flour.
The ash, protein and fat content for the corn grit were 1.5%, 8.60%, 0.95% respectively.

(b) Raw Extrudates

(i) Hunter Color Parameters

The effect of different variables on color parameters of raw extrudates is illustrated in Table 4. L* value signifies lightness to darkness. Higher the L* value higher will be the lightness of the material. The banana flour had a highly significant effect on the L* value followed by the screw speed ($p \leq 0.005$). The L* value increased progressively with increase in the banana flour. The extrusion temperature also had a highly significant negative effect on the L* value of the raw extrudates ($p \leq 0.005$). The quadratic terms of the extrusion temperature also had a significant effect on L* value ($p \leq 0.05$). The interaction between screw speed and extrusion temperature significantly affected L* value ($p \leq 0.05$). Fig. 1, 2 shows the variation in the L* value with variations in banana flour, screw speed and extrusion temperature. a* value signifies redness to greenness. Higher a* value, higher is the redness in the product. The banana flour showed a highly significant effect on a* value ($p \leq 0.005$) followed by temperature of extrusion ($p \leq 0.005$). The interaction between screw speed and the extrusion temperature also had a significantly negative effect on a* value ($p \leq 0.05$). a* value decreased. progressively with increase in the banana flour and the temperature (Fig. 3).

b* value signifies yellowness to blueness. Higher the b* values, higher is the yellowness. The banana flour had a highly significant effect ($p \leq 0.005$) on the b* value for raw extrudates. With increase in the banana flour b* value decreased progressively.

(c) Fried Extrudates:

The effect of different variables on color parameters of fried extrudates is illustrated in Table 4. L* value in the fried extrudates was significantly affected by screw speed and banana flour ($p \leq 0.005$). The screw speed had a greater effect on the L* value as compared to the banana flour of the substitution. The L* value increased progressively with increase in the screw speed (Fig. 4). This might be due to the influence of the screw speed on the residence time. Higher the screw speed, lower is the residence time thus lower degradation of the pigments. The banana flour had a negative effect on the L* values in the fried extrudates.

Banana flour and the extrusion temperature had a highly significant effect on a* value of the fried extrudates ($p \leq 0.005$). The quadratic terms of banana flour and extrusion temperature also had negatively significant effect ($p \leq 0.05$). a* value decreased progressively with increase in the substitution and extrusion temperature (Fig. 5). The screw speed also had a significant effect on a* value ($p \leq 0.05$). The interaction banana flour and extrusion temperature had a negative significant effect while screw speed and extrusion temperature, had a positive significant effect on a* values ($p \leq 0.05$). The banana flour had a highly significant effect on b* value of fried extrudates ($p \leq 0.005$). The b* values decreased progressively with increase in the banana flour.

Table 4: Coefficient of regression for Dependent Variables of Corn and Green Banana flour extrusion

Terms	Raw Extrudates			Fried Extrudates		
	L*	a*	b*	L*	a*	b*
Constant	56.7117	5.08615	23.2831	54.4719	6.34031	21.8705
BF	2.0645**	-0.60475**	-3.7365**	-3.763**	-0.49725**	-5.4038**
SS	0.7308**	0.06042	-0.2267	0.7242**	-0.13875*	0.4462
Ext. temp.	-0.6950**	-0.38688**	0.5288	-0.4531	-0.52938**	-0.2375
BF × BF	0.0375	-0.14156	-0.8156	0.2869	-0.26156*	0.0553
Ext. temp. × Ext. temp.	0.7750**	-0.14063	-1.1938*	-0.8419	0.51938**	-0.1425
BF × SS	0.0305	-0.21275*	-0.271	0.5125	-0.02825	0.1273
BF × Ext. temp.	-0.2257	0.05138	-0.6315	-0.6131	-0.15787*	-0.816
SS × Ext. temp	0.3100*	-0.13313	-0.2188	-0.3294	0.15813*	-0.2388
R^2	95.8	88.3	87.2	93.4	94.0	93.2

*p≤0.05; **p≤0.005; BF = Banana Flour; SS = Screw Speed; Ext. temp. = Extrusion Temperature

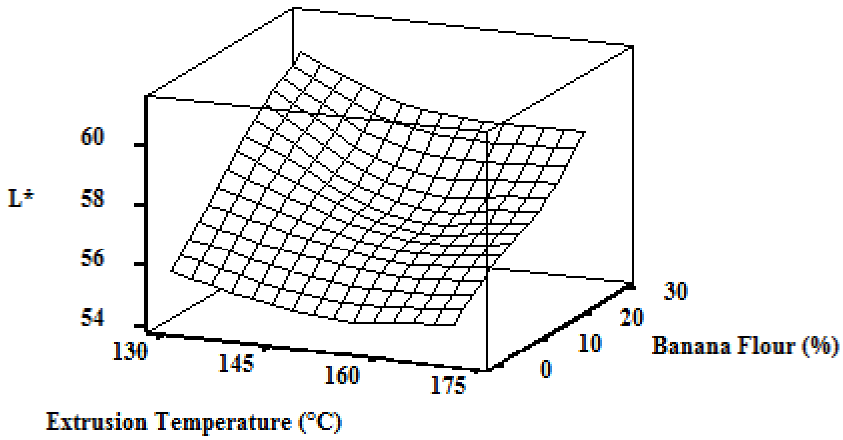


Fig. 1 Effect of Banana flour and Extrusion temperature on L* values of raw extrudates

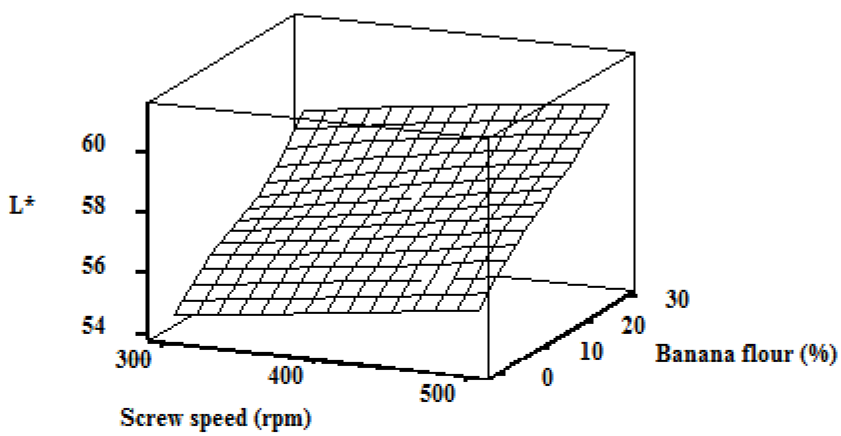


Fig 2. Effect on Banana flour and Screw speed on L* value of raw extrudates.

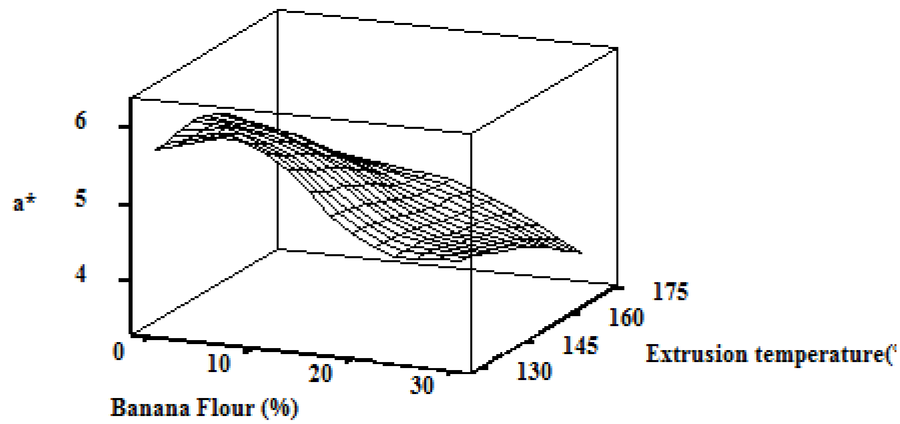


Fig. 3 Effect of banana flour and extrusion temperature on a* value of raw extrudates

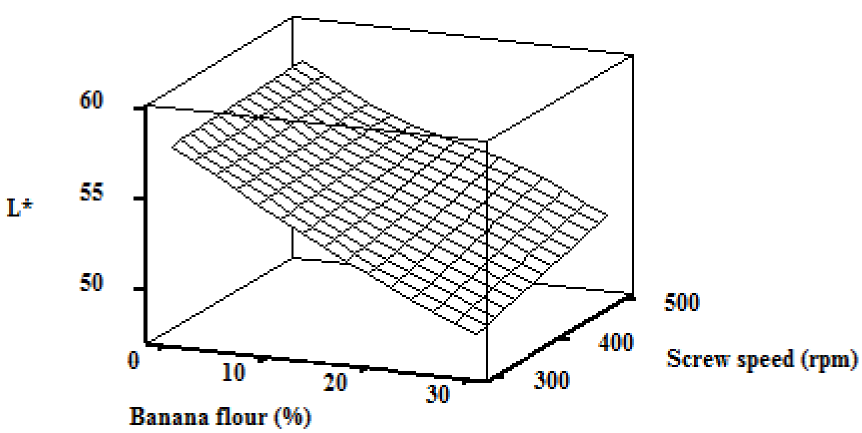


Fig. 4 Effect of Screw speed and Banana flour on L* value of fried extrudates.

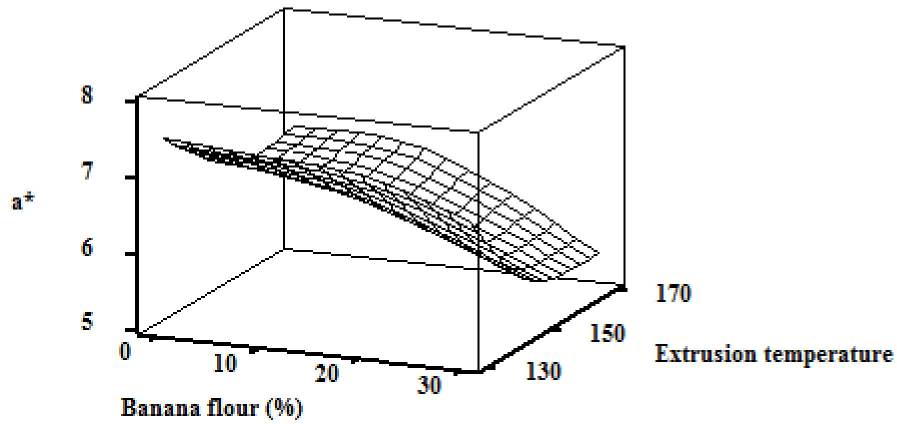


Fig. 5 Effect of Banana flour and Extrusion temperature on a* value of fried extrudates.

(A) Proximate composition of fried extrudates

(i) Ash content

The ash content is significantly affected by the banana flour ($p \leq 0.005$). The ash content increased progressively with increase in the banana flour. The increase in the ash content on increase in substitution of green banana flour (GBF) is due to the high potassium and magnesium content of banana flour (Chong & Noor Aziah, 2010) as well as other nutrients. Similar results were reported by Ovando-Martinez et al, (2009) on substitution of green banana flour in pasta.

(ii) Protein content

The banana flour had the highly significant effect ($p \leq 0.005$) on the protein content followed by extrusion temperature ($p \leq 0.05$). The protein content decreased progressively with an increase in the extrusion temperature. The interaction between banana flour and screw speed, screw speed and extrusion temperature banana flour had a negatively significant effect while interaction between banana flour and extrusion temperature had a positively significant effect on the protein content of the extrudates ($p \leq 0.05$). The decreased protein content might be due to poor protein content of green banana flour which leads to overall dilution of protein content in the extrudates. Similar results were reported by Ovando-Martinez et al, (2009) on substitution of green banana flour in pasta.

(iii) Crude Fat Content

The fat content was most significantly affected by banana flour followed by screw speed and extrusion temperature ($p \leq 0.005$). The quadratic terms of banana flour also had a highly significant negative effect on the fat content. Fat content increased progressively with the increase in either banana flour, screw speed or extrusion temperature. An increasing trend in the crude fat content might be attributed to the increase in the porosity (air cells) of the extrudates. During frying, the air inside these air cells is replaced by oil. The presence of fibers reduces the expansion and increase the porosity i.e. creates more pores (Steel et al, 2012). The interaction in banana flour and the screw speed also had a significant effect on the fat content ($p \leq 0.005$). This might also be attribute increase in the pressure inside the barrel on increasing the screw speed. When the material is extruded from the die, the sudden pressure drop leads to more porosity. Also High extrusion temperature during extrusion increases the porosity of the extrudates (Steel et al, 2012). The squared values of banana flour also showed a significant effect on fat content ($p \leq 0.005$).

(B) Physical Parameters

(i) Water Absorption Index

The regression model of WAI of the extrudates was significant and had sufficiently high R^2 values (Table 5). The screw speed and banana flour level showed highly significantly effect on WAI ($p \leq 0.005$). WAI increased progressively with screw speed however with increase in the banana flour WAI decreased (Fig. 6). The WAI increased till banana flour level was increased to 10% and on further increase caused a decrease. Irregular trends have also been reported by Lazou & Krokida, 2010. The interaction effects of banana Flour and screw speed had a significant effect on the WAI ($p \leq 0.05$). WAI depends on the availability of hydrophilic groups and on the gel formation capacity of the macromolecules (Gomez & Aguilera, 1983). It is a measure of damaged starch together with protein denaturation and new macromolecular complex formations. Although swelling is evidently a property of amylopectin (Tester & Morrison, 1990); and green banana starch has high amylopectin content (Zhang & Hamaker, 2012). The quadratic terms of banana flour also had a significant effect on the WAI ($p \leq 0.05$). Artz et al. (1990) also reported the decrease in the WAI value with an increase in fiber to starch ratio, as green banana is a rich source of dietary fibers. The formation of inter- and intra-molecular protein bonds with amylose and amylopectin leads to a low WAI value (Fernandez-Gutierrez et al, 2004).

(ii) Water Solubility Index

The regression models for WSI of extrudates as a function of banana flour level were significant and had a sufficiently high R^2 value (Table 7). The banana flour had the most pronounced effect on the WSI for extrudates ($p \leq 0.005$). WSI increased progressively with increase in the banana flour (Fig. 7). The squared terms of banana flour also had a significant effect on the WSI. The increase in the protein content enhances the cross linkages between denatured protein and starch, decreasing the solubility (Lazou & Krokida, 2010). But on the contrary a decrease in the protein content was observed. Screw speed and extrusion temperature also had significant effect on the WSI ($p \leq 0.05$). Increase in the WSI might be attributed to high starch content of green banana flour. The WSI is related to the quantity of soluble molecules, which is related to dextrinization. In other words, WSI can be used as an indicator for the degradation of molecular compounds and measures the degree of starch conversion during extrusion. The rise in extrusion temperature increases the severity of thermal treatment in the extruder, which consequently raises WSI (Lazou & Krokida, 2010). The interaction effect between screw speed and extrusion temperature also had a negatively significant effect on the WSI ($p \leq 0.05$).

Table 5:Coefficient of regression for Dependent Variables of Corn and Green Banana flour extrudates

Terms	WAI	WSI	Expansion Ratio
Constant	3.52458	35.2508	2.36042
BF	-0.35**	9.6805**	0.0805**
SS	0.14833**	-1.9108*	-0.01
Ext. temp.	0.05125	1.7856*	0.07625**
BF × BF	-0.16125*	3.8888*	0.02625
Ext. temp. × Ext. temp.	-0.06	-2.5169	-0.0525**
BF × SS	0.147*	0.067	0.0095
BF × Ext. temp.	-0.021	0.0986	0.4875**
SS × Ext. temp	0.04625	-2.0831*	0.0075
R^2	86.3	91.0	94.2

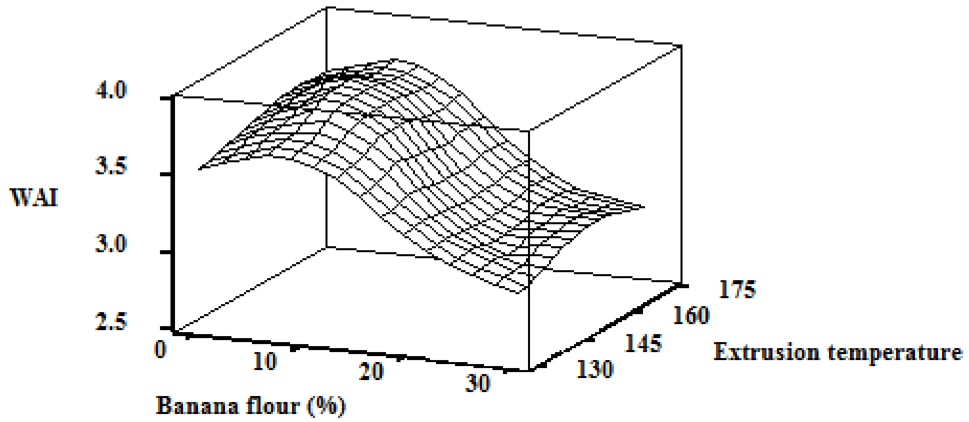


Fig. 6 Effect of Banana flour and Extrusion temperature on WAI

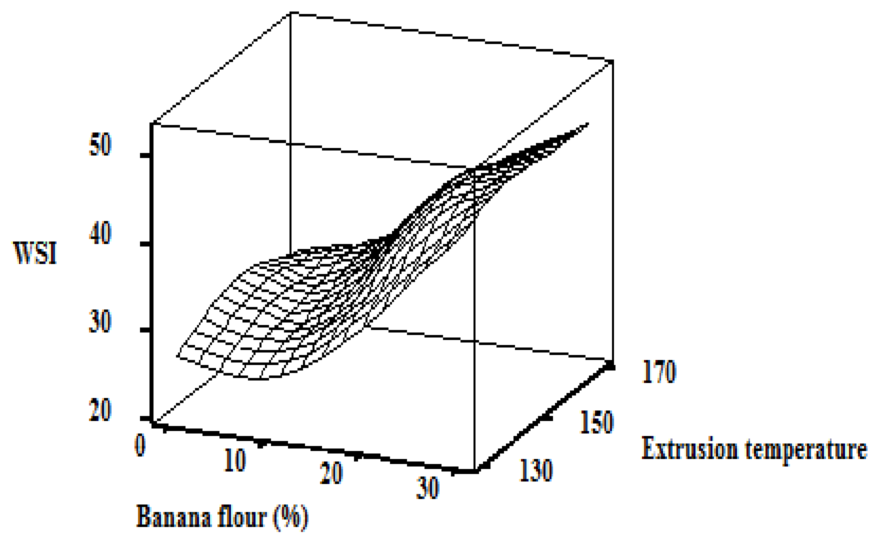


Fig. 7 Effect of Banana flour and Extrusion temperature on WSI

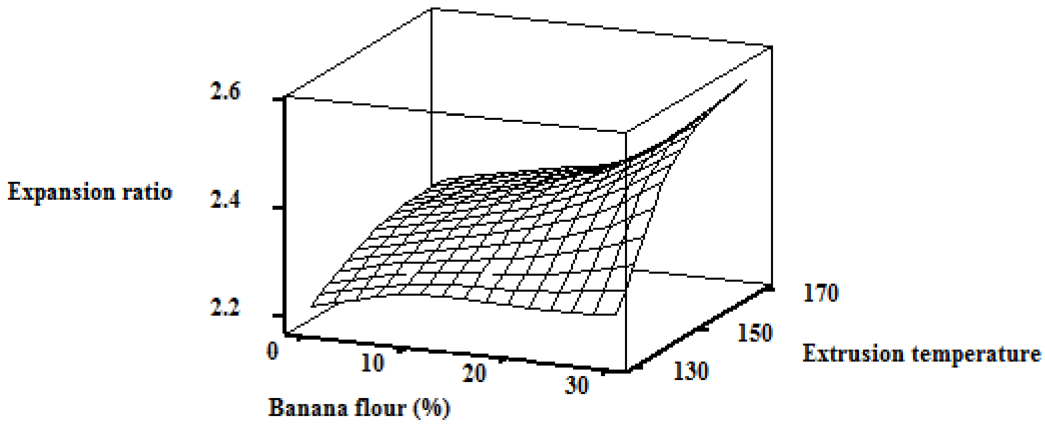


Fig. 8 Effect of Banana flour and Extrusion temperature on Expansion Ratio

Table 6: Coefficient of regression for Dependent Variables of Corn and Green Banana flour extrusion

Terms	Bulk Density	Expansion
Constant	100.115	1.0122
BF	-17.401**	-0.00268
SS	0.077	-0.00413*
Ext. temp.	-25.578**	-0.003
BF × BF	-8.381	0.00347
Ext. temp. × Ext. temp.	28.542**	-0.00437
BF × SS	-3.856	-0.00008
BF × Ext. temp.	0.732	0.003
SS × Ext. temp	-3.204	0.00263
R^2	88.2	53.0

$^*p \leq 0.05$; $^{**}p \leq 0.005$; BF = Banana Flour; SS = Screw Speed; Ext. temp. = Extrusion Temperature

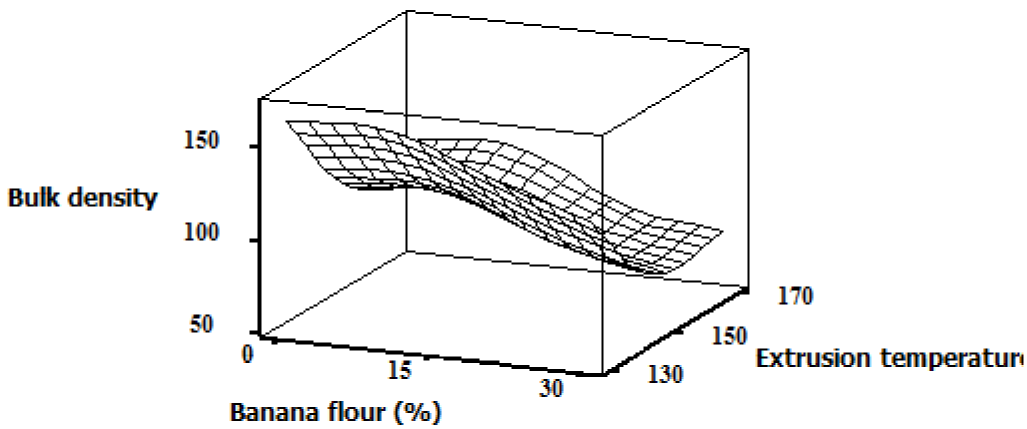


Fig. 9 Effect of Banana flour and Extrusion temperature on Bulk density

(iii) Expansion ratio

The effect of the different variables on the expansion ratio of the extrudates is illustrated in Table 5. The extrusion temperature had the most pronounced effect on the expansion ratio of the extrudates followed by banana flour ($p \leq 0.005$). The expansion ratio increased progressively with an increase in extrusion temperature (Fig. 8). The quadratic terms of banana flour level and interaction between extrusion temperature and banana flour also had a significant effect on the expansion ratio ($p \leq 0.005$). Several researchers have demonstrated that the expansion ratio of extruded cereals depends on the degree of starch gelatinization (Case et al, 1992; Chinnaswamy & Hanna, 1988). The increase in the expansion ratio with increase in level of banana flour might be attributed to increase in starch content on substitution of green banana flour. Onwulata et al. (2001) reported reduced expansion ratio with an increase in the protein content due to the decrease in the elasticity. However, the decrease in the protein content with increase in banana flour was observed.

(iv) Bulk density

The regression model for the bulk density was significant and had a sufficiently high R^2 value (Table 6). The banana flour level showed a highly significant effect on the bulk density ($p \leq 0.005$). The bulk density increased with decrease in banana flour level. The bulk density of the extrudates was significantly affected both in linear and quadratic terms by extrusion temperature ($p \leq 0.005$). With increase in extrusion temperature, the bulk density decreased (Fig. 9). The bulk density of the extrudates was related to the starch gelatinization. According to Mercier & Feillet,

(1975) and Case et al. (1992), as gelatinization increases, the volume of extrudates increases and bulk density decreases. A negative influence of extrusion temperature was obtained on bulk density of extrudates, which agrees with other investigations (Dogan & Karwe, 2003; Hagenimana et al, 2006)

(v) Expansion on frying

The coefficients for expansion of fried extrudates as a function of banana flour, extrusion temperature and screw speed are shown in Table 6. The screw speed had a significant negative effect in liner terms on the expansion of the extrudates on frying ($p \leq 0.05$). The expansion decreased progressively with an increase in the screw speed. The decrease in the expansion ratio might be attributed to the increase in the width or the radial expansion in the extrudates on frying which might lead to axial contraction.

(C) Textural properties

(i) Flexural Strength

The regression model of flexural strength of the extrudates was significant and had sufficiently high R^2 value (Table 7). The textural property of extrudate was determined by measuring the force required to break the extrudate (Singh et al, 1994). The higher the value of maximum peak force required in gram, which means the more force required to breakdown the sample, the higher the hardness of the sample to fracture (Li et al, 2005). The screw speed had the most prominent effect on the flexural strength ($p \leq 0.005$). The flexural strength increased progressively with increase in the screw speed (Fig. 11(a)). The extrusion temperature and banana flour level also had a significant effect on the flexural strength ($p \leq 0.05$) as illustrated in Fig. 11(b).

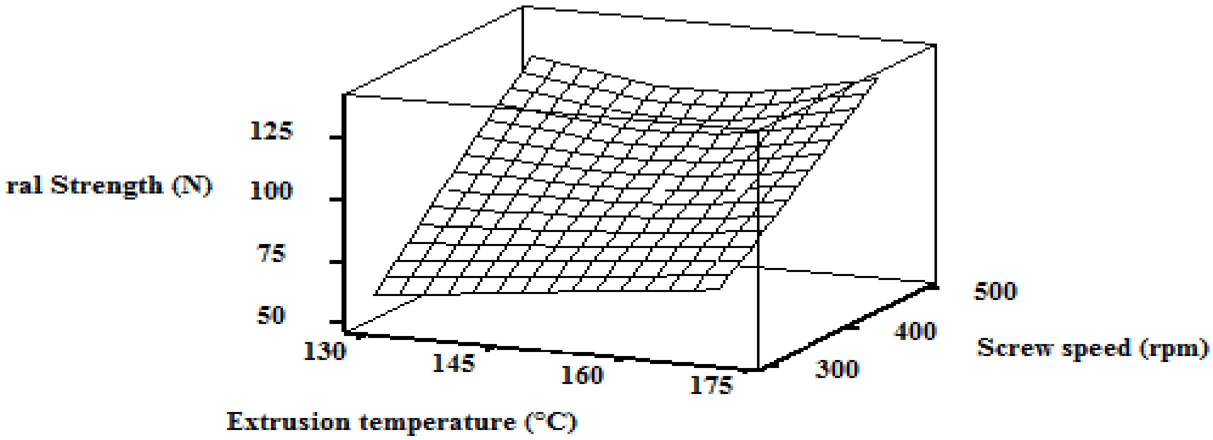


Fig. 11(a) Effect of Screw speed and Extrusion temperature on Flexural strength

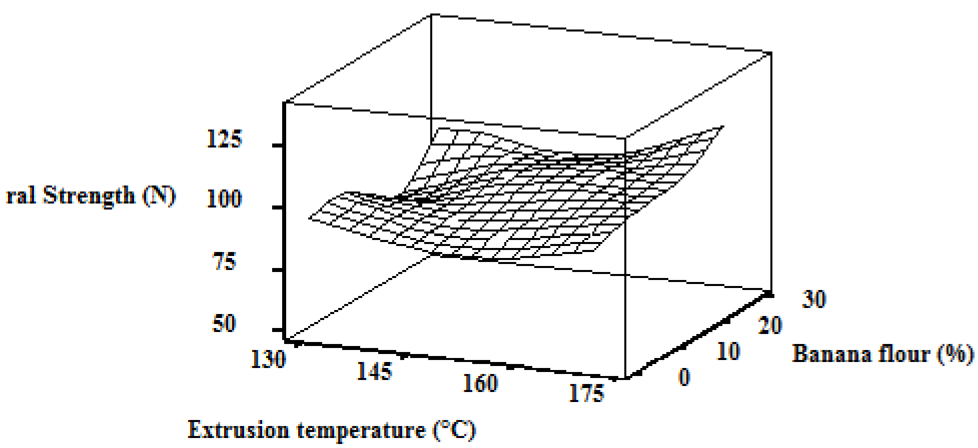


Fig. 11(b) Effect of Extrusion temperature and Banana flour on Flexural strength

Table 7: Coefficient of regression for Dependent Variables of Corn and Green Banana flour extrusion

Terms	Flexural Strength
Constant	91.51
BF	4.814*
SS	28.359**
Ext. temp.	4.591*
BF × BF	2.856
Ext. temp. × Ext. temp.	4.685
BF × SS	-2.836
BF × Ext. temp.	4.229
SS × Ext. temp	-2.879
R^2	95.3

***p≤0.05; **p≤0.005; BF = Banana Flour; SS = Screw Speed; Ext. temp. = Extrusion Temperature**

(II) Rice grit-banana flour extrudates

(a) Proximate composition of raw material

Green banana flour had ash, protein and fat content of 2.65%, 4.8%, 0.75% respectively.

(b) Raw Extrudates

(i) Hunter colour

The effect of banana flour, temperature and screw speed on Hunter color parameters of raw and fried rice extrudates is reported in Table 8. L* values indicates the lightness, a* values gives the degree of red-green colour, with the higher positive a* value indicating more red and b* value indicating the degree of blue to yellow colour, with the higher positive value b* value indicating more yellow.

In raw extrudates, banana flour and temperature showed most prominent effect in linear terms, on L* values of raw extrudates ($p \le 0.005$). The effect of banana flour was negative, and the effect of temperature was positive on the raw rice extrudates extrudates. The interaction effect of banana flour and screw speed showed negative and significant on the L* values of raw extrudates ($p \le 0.05$). L* values decreased with increase in the banana flour of extrudates (Fig.1). This decrease may be due to the light color of the banana flour which led to dilution in the color of the rice grit. The banana flour showed positive and most significant effect in linear terms, on a* values of rice extrudates ($p \le 0.005$). The temperature showed significant effect in quadratic terms on a* values of rice extrudates ($p \le 0.05$). The effect of temperature in quadratic terms was positive on rice extrudates. The a* values increase with increase in banana flour of the extrudates (Jamin & Flores, 1998). The banana flour and temperature were found to be the highly significant effect in linear terms on b* values of extrudates ($p \le 0.005$). The effect of both banana flour and temperature was positive on b* values of extrudates. The temperature showed positive and significant effect in quadratic terms on b* values of rice extrudates ($p \le 0.05$). The b* increased with increase in banana flour of rice extrudates (Fig. 2). The increase in b* may be attributed to the amount of carbohydrate and protein content due to their role in the development of non-enzymatic browning (Jamin & Flores, 1998).

In fried extrudates, banana flour was observed to be most prominent factor that affected the L* value of extrudates negatively in linear terms, on extrudates ($p \le 0.005$). Screw speed showed positive and prominent effect in linear terms on L* values of extrudates ($p \le 0.05$). L* values decreased with increase in the banana flour of extrudates (Fig. 3). The decrease in the L* values after frying may be due to the browning of the extrudates and replacement of the air inside the air cells by the oil. Banana flour showed positive and most significant effect in linear terms on a* values of rice extrudates ($p \le 0.005$). The banana flour showed negative and significant effect in quadratic terms on a* values of extrudates ($p \le 0.05$). The a* values increased with increase in banana flour of rice extrudates. Banana flour, screw speed and temperature showed most significant effect in linear terms, on b* values of extrudates ($p \le 0.005$). The temperature, screw speed and banana flour showed positive effect on b* values of extrudates. The interaction effect of banana flour and temperature, banana flour and screw speed, screw speed and temperature showed significant on b* values of raw rice extrudates. The interactions effect of banana flour and temperature, banana flour and screw speed had positive on b* values of rice extrudates. While the interaction of screw speed and temperature showed negative on b* values of the extrudates (Fig.4) .

Table 8: Coefficient of Regression Models for Dependent Variables of rice and green banana flour extrusion.

Terms	Raw Extrudates			Fried Extrudates		
	L*	a*	b*	L*	a*	b*
Constant	58.0563	1.23281	6.709	52.9707	2.65688	10.0588
Banana flour	-5.1670**	1.33275**	1.2328**	-5.6468**	1.81450**	1.0885**
Screw speed	-0.5983	-0.09542	-0.2104	1.3996*	0.06583	0.4567**
Temperature	3.7775**	0.07125	0.6825**	0.6219	-0.02687	0.4125**
BF×BF	-0.9787	-0.02531	0.2841	0.4622	-0.70313*	0.3263
Temp×temp	1.5262	0.34125*	0.6300*	-1.5219	0.39063	0.2763
BF×Screw speed	-1.8950*	-0.19525	0.1412	0.3933	-0.07000	0.4130**
BF×temp	0.4965	0.09600	0.1860	-1.5371	-10912	-0.6892**
Screw speed× temp	0.1762	-0.01000	-0.1963	0.3469	-0.13938	-0.3038*

***p≤0.05; **p≤0.005; BF = Banana Flour; SS = Screw Speed; Ext. temp. = Extrusion Temperature**

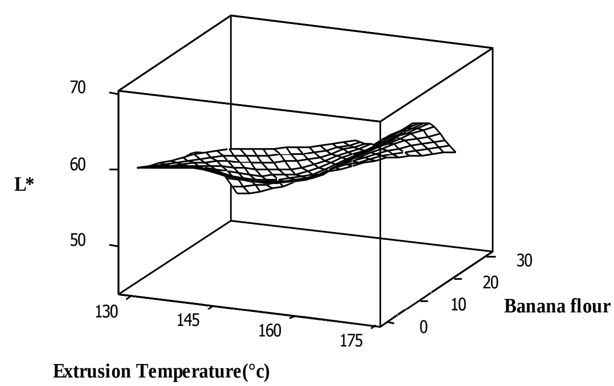


Fig.1 effect of banana flour and extrusion temperature on L* values of raw extrudates

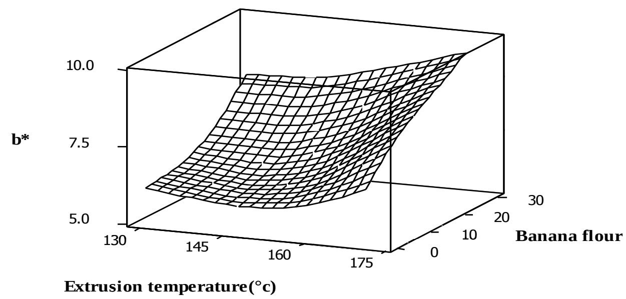


Fig.2 Effect on banana flour and extrusion temperature on b* values of raw extrudates.

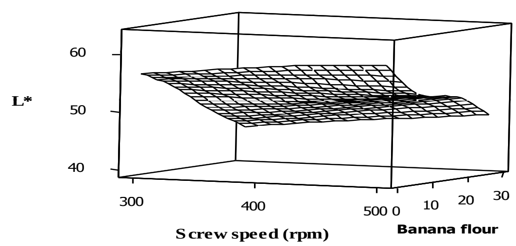
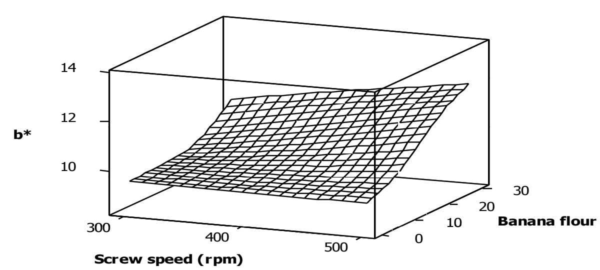


Fig.3.Effect of screw speed and banana flour on the L* values of fried extrudates



FFig.4. Effect of screw speed and banana flour on the b* values of fried extrudates

(A) Proximate composition of fried extrudates

(i) Ash content:

Banana flour had most significant and positive effect in linear terms, on the ash content of extrudates ($p \leq 0.005$).The interaction effect of screw speed and temperature showed significant negative on ash content of extrudates ($p \leq 0.005$). Increase in the ash content might be due to the high potassium content in green banana flour.(Chong & Noor Aziah, 2010). There was no significant effect of screw speed at barrel temperature on ash content of extrudates.

(ii) Protein content:

Banana flour showed most significant and negative effect in linear terms, on the protein content of extrudates ($p \leq 0.005$). Dilution of protein content in the extrudates might be due to poor protein content in green banana flour. There was no significant effect of screw speed, at barrel temperature on the protein content of rice extrudates.

(iii) Crude fat:

Banana flour showed positive and most significant effect in linear terms, on the fat of extrudates ($P \leq 0.005$). Temperature had positive and significant effect in linear terms and temperature in quadratic terms showed negative effect on crude fat of extrudates ($p \leq 0.05$). Increase in the crude fat content may be due to the increase in the air cells of the extrudates. Air cells were replaced by the oil after frying.

(B) Physical parameters

(i)Water absorption index (WAI):

The interaction effect of banana flour and temperature was positive and significant on water solubility index of extrudates as shown in Table 9 ($p \leq 0.05$). The WAI decrease with an increase in the banana flour level of extrudates. The decreasing trend might be due to high starch content in green banana flour and high amount of soluble polysaccharide released from the starch granules after addition of excess water (Badrie and Mellowes 1992).

(ii) Water solubility index:

The banana flour showed most prominent and positive factors in linear terms, on water solubility index of extrudates as shown in Table 9 ($p \leq 0.005$). Temperature showed positive and significant effect in linear terms on the water solubility index of extrudates ($p \leq 0.05$). The interaction effect of banana flour and screw speed was significant and positive on WSI of extrudates. Banana flour and temperature showed significant effect in quadratic terms. Temperature showed positive effect while the banana flour showed negative effect in quadratic terms on WAI of extrudates. The WSI increase with an increase in the banana flour of extrudates. The increasing trend in WSI might be due to thermal degradation of the proteins during extrusion. (Mercier et al., 1980).

(iii) Expansion ratio (length/breadth):

The banana flour and screw speed were found to be the most prominent factors in linear terms, on expansion ratio of rice extrudates as shown in Table 9 ($p \leq 0.005$). Banana flour showed positive effect while the screw speed showed negative effect (Fig. 6). The interaction of screw speed and temperature also was most significant and positive on extrudates. Temperature showed significant and negative effect in linear terms, on expansion ratio of extrudates ($p \leq 0.05$). Temperature showed positive and significant effect in quadratic terms. Expansion ratio decreased with increase in the banana flour of rice extrudates. (Pan et al., 1992).

(iv) Bulk Density

Banana flour and temperature showed negative and most significant effect in linear terms on, bulk density of rice extrudates as shown in Table 10 ($p \leq 0.005$). Screw speed in linear terms and temperature in quadratic term showed negative and significant effect on bulk density ($p \leq 0.05$). The interaction between banana flour and temperature, screw speed and temperature showed significant effect on bulk density of extrudates ($p \leq 0.05$). The interaction effect of banana flour and temperature was positive effect while the interaction between screw speed and temperature showed negative effect on the bulk density of extrudates. The bulk density decreased with an increase in the barrel temperature irrespective of screw speed (Fig. 7). The bulk density may decreased with increase in

Table 9: Coefficient of Regression Models for Dependent Variables of green banana flour extrusion

	WAI	WSI	Expansion ratio
Constant	3.59667	46.3439	2.33990
Banana flour	-0.19950	10.8058**	0.09325**
Screw speed	-0.04583	0.2688	-0.10125**
Temperature	0.19750	2.2063*	-0.05688*
BF×BF	0.24000	-5.9222*	0.02719
Temp × Temp	0.08125	3.8588*	0.09563*
BF × Screw speed	-0.18150	2.2992*	0.00625
BF × Temp	0.30375*	-0.4230	0.03562
Screw speed ×temp	-0.01000	0.6913	0.13687**

***p≤0.05; **p≤0.005; BF = Banana Flour; SS = Screw Speed;Ext. temp. = Extrusion Temperature**

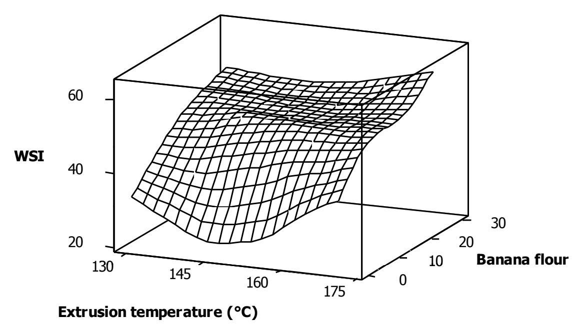


Fig.5. Effect of extrusion temperature and banana flour on WSI of extrudates

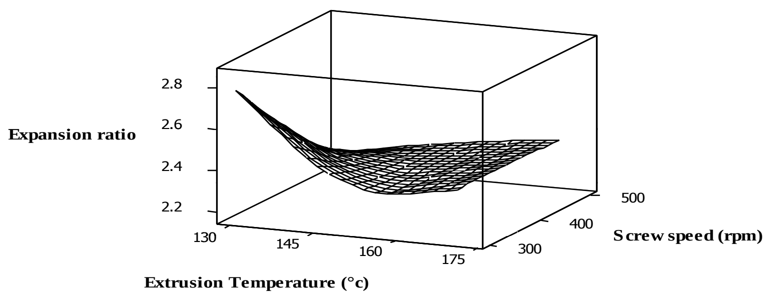


Fig.6. Effect of extrusion temperature and screw speed on expansion ratio of extrudates

with increase in gelatinization. The bulk density of the extrudates is affected by both screw speed and temperature of the barrel (Akpata & Akubor, 1999).

(v) Expansion on frying:

Screw speed and temperature showed most significant effect in linear terms, on expansion of fried extrudates ($p \leq 0.005$). Screw speed showed positive effect and temperature showed negative effect in linear terms, on fried rice extrudates. Expansion decrease with increase in banana flour of extrudates (Table 10). The decrease in the expansion ratio might be due to the increase in the width of extrudates on frying.

(C) Textural properties

(i) Flexural Strength

The regression model of flexural strength of the extrudates was significant and had sufficiently high R^2 value (Table 10). The textural property of extrudate was determined by measuring the force required to break the extrudate (Singh et al, 1994). The higher the value of maximum peak force required in gram, which means the more force required to breakdown the sample, the higher the hardness of the sample to fracture (Li et al, 2005).The screw speed had the most prominent effect on the flexural strength ($p \leq 0.005$). The flexural strength increased progressively with increase in the screw speed (Fig. 11(a)). The extrusion temperature and banana flour level also had a significant effect on the flexural strength ($p \leq 0.05$).

Table 10: Coefficient of Regression Models for Dependent Variables of green banana flour extrusion

Terms	Bulk density	Expansion	Texture
Constant	87.1790	1.01490	31.4507
Banana flour	-7.54657**	0.03225	1.7680
Screw speed	-2.0858*	0.06708**	0.4400**
Temperature	-11.2519**	-0.09562**	-1.1868
BF×BF	0.1256	0.00469	-0.0067
Temp×temp	-6.4519*	0.09438**	0.0067
BF×Screw speed	1.6425	0.00325	0.0020
BF×Temp	4.2304*	-0.02137	-0.0100
Screw speed× temp	-2.8856*	-0.09562**	-0.0017

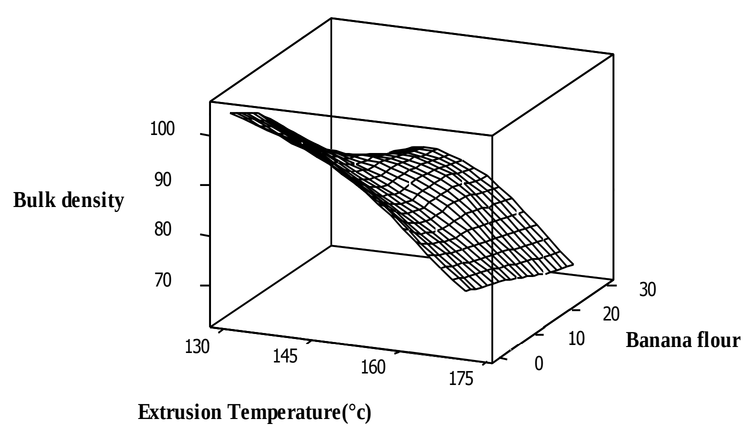
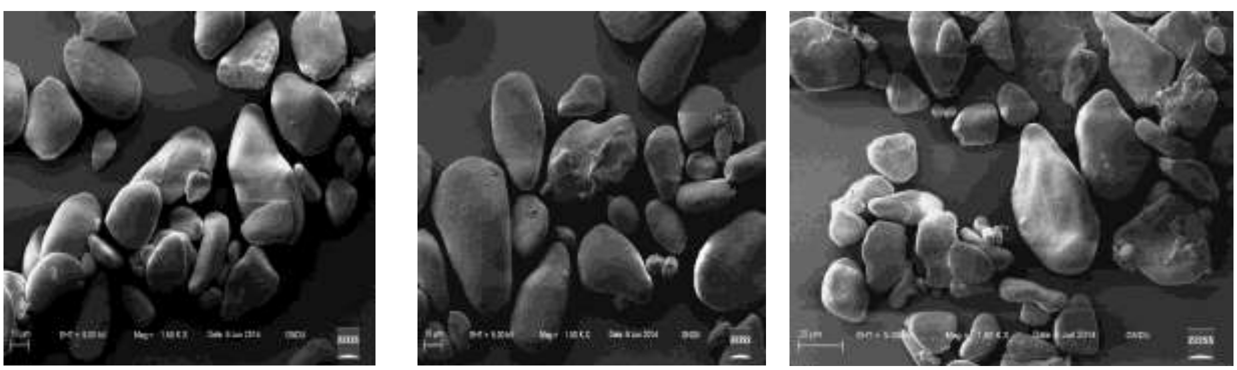


Fig.5. Effect of extrusion temperature and banana flour on bulk density of extrudates

Objective 4: To evaluate the structure, and retrogradation of starch from different banana cultivars.

Starches from different banana cultivars were evaluated for morphology (scanning electron microscopy), solubility, gel transmittance and synersis (retrogradation). The starches from different banana cultivars showed irregular shaped granules of varying sizes. Scanning electron micrographs revealed that starch from Robust had the largest proportion large granules whereas that from Saba had the largest proportion of small granules (Figure 1). The starch from Poovan showed the highest solubility (10.8%) followed by that from Robust (10.0%) and Saba (9.1%). The change in syneresis and transmittance of starch gels during storage at refrigeration temperatures indicates their retrogradation properties. Synersis increased with storage duration. Gel from Poovan showed the highest increase as its synersis increased from 65 to 90% against 70 to 88% for Robust and 70 to 90% for Saba. Percent transmittance of starch gels decreased with increase in storage duration. Starch gels showed transmittance of 0.47 to 0.67% at 0 h which decreased to values of 0.08 to 0.20% after storage at 96 h. The highest decrease in percent transmittance values was observed for Poovan (0.47 to 0.08%). The results showed that the starch from Poovan had the highest tendency to retrograde.



Poovan **Robust** **Saba**

Figure 1 Scanning electron micrographs revealing differences in granule morphology of starches from different banana cultivars

12. Work remains to be done

All proposed objectives have been completed.

13. Has the progress been according to the original plan of work and towards achieving objectives if not, state reasons: Yes it is according to the original plan of work

14. Whether project work was delayed. If yes, specify reasons: No

15. Please indicate the approximate time by which the project work is likely to be completed: N.A.

16. Please indicate the difficulties, if any, experience in implementing the project: No

17. Collaboration, if any (with Department, University, Industry etc.): NA

18. Ph. D Enrolled, if yes, details: N. A.

19. Details of the Publications resulting from the project work:

1. Effect of Banana flour, screw speed and temperature on extrusion behavior of corn extrudates. *Journal of Food Science and Technology*, 2015, 52, 4276-4285. (Impact Factor: 3.117)
2. Bioactive compounds in banana and their associated health benefits - a review. *Food Chemistry*, 2016, 206, 1-11(Impact Factor: 9.231)

20. Any other information which would help in evaluation of work done on the project: NA