Rheological Properties of Wheat Flour (*Triticum aestivum L.*) Doughs as Affected by Inclusion of Decorticated Pigeon pea (*Cajanus cajan* L.) Flour and Protein Isolate

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Abstract

The objective of this study was to investigate the rheological properties of wheat flour (*Triticum aestivum L.*) doughs affected by the incorporation of decorticated pigeon pea (*Cajanus cajan* L.) flour (DPPF) and pigeon pea protein isolate (PPPI) aiming the production of bakery products. Ratios of DPPF (0, 5, 10, 15, 20 and 25%) and PPPI (adjusted to raise the protein levels to 15, 20 and 25%) incorporated in two types of wheat flours (extraction rate 72%); for bread (BrWF) and biscuit (BsWF). Farinograph, Extensograph and Fermentograph of wheat and composite flour doughs were studied. The Farinograms showed that the water absorption values for the composite BrWF/DPPF and BsWF/DPPF were found to range from 65.1 to 65.9 % and 61.6 to 63.7%; dough development time from 4.0 to 5.0 min. and 4.0 to 4.4 min. dough stability from 2.4 to 4.0 and from 2.3 to 4.1 min. for DPPF different ratios compared to the controls (BrWF & BsWF) values 65.3% 7.0 and 8.5 min.; 63.7% 6.7 and 10.1min., respectively. On the other hand, addition of PPPI resulted in an increase in water absorption for BrWF and BsWF which were found to be ranged from 66.3 to 74.8% and 66.7 to 71.0%; dough development time from 7.5 to 12.8min. and 4.5 to 7.3 min; dough stability from 2.6 to 8.6 min. and 1.7 to 5.8 min, respectively. The Extensograms showed that the dough strength, extensibility and dough resistant to extension were decreased with the increasing levels of DPPF for the two types of wheat flour (BrWF and BsWF). The Fermentograms showed that the time taken to produce CO_2 through the first and the second hours of fermentation for controls were found to be 45 and 40 min. for BrWF and 52 and 43 min for BsWF. Different ratios of DPPF and PPPI obtained values ranged from 43 to 58 min. and 35 to 44 min. for the blends with BrWF and 48 to 60 min. and 36 to 53 min. for the blends with BsWF.

Keywords: Biscuit wheat flour, Bread wheat flour, Composite flour, Decorticated pigeon pea, Extensograph, Farinograph, Fermentograph.

1. Introduction

Bakery products are considered an important source of nutrients i.e. energy, protein, minerals and vitamins in the Middle East especially in the Arab countries. Most bakeries products can easily be enriched and fortified with low cost nutrients to meet specific needs of the target groups of the population (Indrani *et al*., 2007).

Food legumes are those species of the plant family *Leguminoseae* have a very specific place from the nutritive point of view and play an important role in the nourishment of world population. Legumes, particularly dry pulses, are cheaper source of proteins when compared to animal proteins. Clinically, pulses were reported to reduce the levels of cholesterol and glucose in blood as stated by Soni *et al*. (1982).

Among food legumes, pigeon pea (*Cajanus cajan* L.), also called red gram, and locally in Sudan known as Lobia addassy, is commonly grown and consumed in tropical and subtropical regions in the world. Pigeon pea is a valuable source of low-cost vegetable protein, minerals and vitamins and occupies a very important place in human nutrition.

Legumes are used in bread and cookies for protein enrichment. In Sudan, processing of pigeon pea i.e. decortication and utilization in baked foods and confectionary is not common. There is a lack of information in the addition of pigeon pea flour and protein isolate and their utilization in different bakery products.

Fortification of bakery products and bakers confectionery with different legumes, i.e. bread and toast bread, cookies, snack foods, biscuits and infant foods were reported by several authors, i.e., Hefnawy *et al*. (2012); Noor *et al*. (2012); Yamsaengsung *et al*. (2012), Chanchal *et al*. (2013); Hassan *et al*. (2013) and Baljeet *et al*. (2014).

Rheological information is valuable in product development as stated by Turabi *et al*. (2008). Rheological properties of doughs can be used as quality indicators for cereal products (Asghar *et al*., 2009). This fact has contributed to use rheological testing for following the changes in dough systems and mechanical properties. Bloksma and Bushuk (1988) stated that the characteristics of dough depend on the type of flour, quality and quantity of protein, ingredients used and mixing conditions. Hoseney and Rogers (1993) reported that wheat flour dough is able to retain gas, which is essential for production of baked products with a light texture.

Determination of the rheological properties of dough is a part of the quality assessment of the flour. Instruments designed for this purpose have been reviewed by Shuey (1975) and Bloksma and Bushuk (1988). Extensibility of doughs is enhanced by the presence of many un-branched, long-chain glutenin molecules and must be maintained long enough under baking conditions to permit sufficient oven rise as reported by Bloksma (1990a) and Bloksma and Bushuk (1988). Kieffer (2003) mentioned that the resistance is positively related to baked volume. The full bread making potential of dough is attained only at the optimum point of dough development time (DDT) as stated by Faubion and Hoseney (1990). Beyond the point of optimum mixing, resistance to extension no longer increased and the dough starts to breakdown as reported by Spies (1990). Bloksma (1990b) mentioned that a long dough development time of flour is considered an indication of good baking performance.

Farinographic measurements also showed that substitution of 30 % pea flour increased DDT about 21.1 % for blend compared to wheat dough. Similar results were reported by Bahnassey and Khan (1986), Shahzadi *et al*. (2005), Eissa *et al*. (2007) and Abou-Zaid *et al*. (2011). The increase in DDT resulting from pea addition could have been due to the differences in the physico-chemical properties between the constituents of the pea and those of the wheat flours, as reported by Mohammed *et al*. (2012). Dough stability (DS), which indicates the dough strength, decreased when the legume proteins i.e. faba bean, cowpea and broad bean flours were added to wheat dough as stated by Fenn *et al*. (2010), Abou-Zaid *et al*. (2011) and Giménez *et al*. (2012).

2. Materials and Methods

2.1 Materials

Two types of Australian wheat flour *Triticum aestivum L.* (Extraction rate 72 %); hard wheat flour for bread (BrWF) and soft wheat flour for biscuit (BsWF) were used. The wheat flours {small packs (1 kg)} were purchased from a Flour Mill agent in Khartoum North, Sudan. The wheat flour types were removed from the packs, homogenized separately in a homogenizer standard (No. YY 0219 China -1995), then packed each and tied in polyethylene bags and stored in a freezer (-20°C) until needed. Pigeon pea (*Cajanus cajan* L.), brown colored seeds, were purchased from Omdurman local market.

2.2 Methods

2.2.1 Preparation of decorticated pigeon pea flour (DPPF)

Pigeon pea grains were cleaned from impurities and shrunken seeds and then decorticated into its dicotyledons (dhal/splits), according to the method described by Hassan and Bureng (1996) and then milled in a pulverizer mill to a mesh size 80-100 mm.

2.2.2 Preparations of pigeon pea protein isolate (PPPI)

Pigeon pea protein isolate (PPPI) was prepared from the decorticated pigeon pea flour (DPPF) according to the method described by Mustafa *et al*. (1986).

2.2.3 Preparation of composite flour blends

Decorticated pigeon pea flour (DPPF) and pigeon pea protein isolate (PPPI) were added separately to BrWF and BsWF. The percentages of DPPF added to the two types of wheat flours were 0, 5, 10, 15, 20 and 25%. On the other hand, PPPI was blended with bread and biscuit wheat flours to increase the protein levels to 15, 20 and 25%.

2.3 Rheological properties of wheat flour and different blends

Farinograms characteristics of wheat flour and composite flour blends were determined using Farinograph-E (Brabender GmbH & Co. KG, Duisburg, Germany), according to the standard method of the AACC No. 54-21 (2000). The parameters determined were water absorption (WA %), dough development time (DDT), dough stability (DS) and time to breakdown. Extensograms characteristics were determined using the Brabender

Extensograph according to the standard method of the AACC No. 54-10 (2000). Fermentograph for measuring the gas production; Carbon dioxide (CO_2), of fermented dough was determined according to the Manual of Brabender Fermentograph.

3. Results and Discussion

3.1 Farinograms of doughs prepared from bread wheat flour and composite flour blends

The Farinograph behavior of doughs made from BrWF and the various composite flour blends is presented in Table 1 and shown in Figures (1 to 9). Water absorption (WA) value for BrWF was found to be 65.3%; this value increased to 65.9% for substitution of 5% decorticated pigeon pea flour (DPPF) and to 65.7% for both substitution with 10 and 15% of DPPF. The water absorption then decreased till it reached the lowest value (65.1%) for 75% BrWF/25% DPPF. Higher values of WA of composite flour could be attributed to the higher water absorption capacity and increasing levels of protein content caused by pigeon pea flour addition. These findings agreed with the results obtained by Sulieman (2005) who had supplemented wheat flour with chickpea flour and similar trends of WA increment were observed. Also Kohajdová *et al.* (2013) studied the incorporation of pea flour into fine wheat flour and reported an increase in WA. This also agreed with that stated by Sadowska *et al*. (2003), Eissa *et al*. (2007), Pasha *et al*. (2011), Des Marchais *et al*. (2011) and Mohamed *et al*. (2012). Increasing of WA has been attributed to the ability of proteins to absorb high quantity of water, thus limiting the water availability for the development of the gluten network when compete with wheat proteins (Des Marchais *et al*., 2011). Other components such as sugars and fibre may also affect WA of blend flours (Kamaljit *et al*., 2010; Abou-Zaid *et al*., 2011).

On the other hand, the water absorption of BrWF increased with increasing levels of pigeon pea protein isolate (PPPI). The values of 66.3, 71.6 and 74.8% were obtained for the levels of protein (15, 20 and 25%) in the blends, respectively. Incorporation of PPPI resulted in higher values of WA than DPPF. Mustafa *et al*. (1986) and Sulieman (2005) reported similar results.

Dough development time (DDT) and dough stability (DS) for BrWF were found to be 7.0 and 8.5 min., respectively. The composite flour gave values for DDT ranged from 4.0 to 5.0 min. and for DS from 2.4 to 4.0 for the blends with DPPF. However, dough development time for PPPI increased steadily to 7.7min. for 15% protein level, 12.8 min for 20% protein and to 7.5 min for 25% protein compared to the control (7.0 min). This followed the general trends claimed by Anaka and Tipples (1979) who reported that DDT increased in flours with high protein content. The dough stability time of BrWF value (8.5 min) tended to decrease with the substitution of DPPF although PPPI in blend (15% protein) gave the highest DS (8.6 min). In general, the increasing of DDT and reduction in DS could be explained by the interactions between non-wheat proteins, fibres and gluten leading to a delay in the hydration and development of gluten in the presence of these ingredients (Dhinda *et al.*, 2011).

The degree of softening of the doughs increased sharply from 28 FU for BrWF to 115 FU for both substitutions of 20 and 25% of DPPF. Addition of PPPI to BrWF also resulted in an increase in the degree of softening from 14 FU to 38 FU for 15 and 25% protein level, respectively (Table 1).

The Farinograph quality number values decreased gradually from 101 min for BrWF (control) to 53 min. for the substitution of 75% BrWF/25% DPPF. Substitution of PPPI in BrWF resulted in a decrease from 151 to 147 and 96 min. for protein levels (15, 20 and

25%), respectively. Compared to the control, the addition of pigeon pea proteins impacted the dough stability, dough mixing and dough weakening times (Table 1).

3.2 Farinograms of doughs prepared from biscuit wheat flour and composite flour blends

The Farinogram behavior of doughs made from biscuit wheat flour (BsWF) and the various composite flour blends is presented in Table 2 and shown in figures (10 to 18). Water absorption value for BsWF (control) was found to be 63.7%. Replacing BsWF with DPPF in the ratios of 5 and 10% gave similar values of water absorption (63.7%) as control. The lowest value of water absorption (61.6%) was noticed at the highest substitution of biscuit wheat flour (75% BsWF/25% DPPF).

On the contrary the water absorption of BsWF, when blended with varying amount of PPPI, increased gradually and gave highest values of 66.7, 69.5 and 71.0% for 15, 20 and 25% protein levels for the blends, respectively; compared with BsWF (control) value 63.7%.

Dough development time (DDT) of BsWF (control) was found to be 6.7 min. A negative increase was observed in dough development time of BsWF with the increasing levels of DPPF; the values decreased gradually from 4.4 min for 95 BsWF/5 DPPF to 4.0 min for75% BsWF/25% DPPF.

On the other hand, incorporation of PPPI in BsWF affected the dough development time and gave the highest value of 7.3 min for protein level of 20% and the lowest value of 4.5 min. obtained for 15% protein level.

The dough stability (DS) of 10.1 min. for BsWF tended to decrease with the increasing levels of DPPF and PPPI. The dough stability value for DPPF substitution decreased from 4.1 to 2.3 min. and for PPPI from 5.8 to 1.7 min. The degree of softening increased sharply from 21 FU for BsWF to 173 FU for 75 BsWF/25 DPPF. Lower values were obtained when PPPI was incorporated in the blends; 47, 58 and 69 FU for protein levels of 20, 15 and 25%, respectively.

Higher value (118 min.) of Farinograph quality number (FQN) was obtained for BsWF. DPPF incorporation resulted in decrease of FQN, and a lower value (55 min.) was obtained for 75% BsWF/25% DPPF; and the values of FQN for PPPI were found to be 76, 80 and 90 min. for 15, 25 and 20% protein levels, respectively.

3.3 Extensograms of doughs prepared from bread & biscuit wheat flours and composite flour blends

The Extensogram characteristics of doughs prepared from bread wheat flour (BrWF) and biscuit wheat flour (BsWF) in different blends; with decorticated pigeon pea flour (DPPF) are shown in Tables 3 and 4. The Extensogram measures the extensibility (E), the energy (cm^2), the resistance (EU) and the resistance to extension (R/E) ratio, of the doughs for wheat and different composite flours at 45, 90 and 135 min. The stretching properties of the dough, in particular the resistance to stretching and extensibility characterize the flour quality and consequently, the baking and the processing properties of corresponding dough. From the results obtained; the energy of the dough (dough strength), the dough extensibility and dough resistance to extension were found to be decreased with increasing replacement of the two types of wheat flour (bread and biscuit). This in general agreed with the findings of Jone (1991). It was clear that the strength of bread flour was superior to bscuit flour on all different measures of Extensograph.

Table 1: Farinograms characteristics of bread wheat flour containing DPPF and PPPI

Flour Blends*	Water Absorption (%)	Dough Development Time (min)	Dough Stability (min)	Degree of Softening FU	FQN(min)
100% BrWF (control)	65.3	7.0	8.5	28	101
95%BrWF + 5% DPPF	65.9	5.0	4.0	55	69
90%BrWF+10%DPPF	65.7	4.8	3.1	93	64
85% BrWF+ 15% DPPF	65.7	4.2	3.0	97	61
80% BrWF+ 20% DPPF	65.6	4.0	2.5	115	57
75% BrWF+ 25%DPPF	65.1	4.0	2.4	115	53
BrWF+ PPPI (15% protein)	66.3	7.7	8.6	14	151
BrWF+ PPPI(20% protein)	71.6	12.8	5.5	25	147
BrWF+ PPPI(25% protein)	74.8	7.5	2.6	38	96

BrWF: Bread wheat flour, DPPF: Decorticated pigeon pea flour, PPPI: Pigeon pea protein isolate, FQN: Farinograph quality number

Table 2: Farinograms characteristics of biscuit wheat flour containing DPPF and PPPI

Flour Blends*	Water Absorption (%)	Dough Development Time (min.)	Dough Stability (min.)	Degree of Softening (FU)	FQN.(min)
100% BsWF (control)	63.7	6.7	10.1	21	118
95%BsWF+ 5% DPPF	63.7	4.4	4.1	53	65
90%BsWF + 10% DPPF	63.7	4.4	3.6	71	64
85%BsWF+15% DPPF	63.0	4.2	3.2	88	59
80%BsWF + 20% DPPF	62.7	4.0	2.3	114	55
75%BsWF+25% DPPF	61.6	4.0	2.3	173	55
BsWF+ PPPI (15%protein)	66.7	4.5	5.8	58	76
BsWF+ PPPI (20%protein)	69.5	7.3	1.9	47	90
BsWF+ PPPI (25% protein)	71	6.8	1.7	69	80

BsWF: Biscuit wheat flour, DPPF: Decorticated pigeon pea flour, PPPI: Pigeon pea protein isolate

FQN: Farinograph quality number

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Table 3: Extensograms characteristics of bread wheat flour as affected by incorporation of DPPF

Flour Blends*	Energy (m^2)			Resistance (EU)			Extensibility (mm)			R/E		
	45	90	135	45	90	135	45	90	135	45	90	135
100% BrWF	84	101	80	225	291	240	179	174	160	1.9	2.5	2.4
95% BrWF+5%DPPF	74	81	87	172	188	228	201	197	183	1.3	1.5	1.9
90% BrWF+10% DPPF	49	57	57	130	144	156	196	200	187	0.8	1.0	1.1
85% BrWF+15%DPPF	37	44	43	98	108	108	207	217	125	0.5	0.6	0.6
80% BrWF+20%DPPF	26	24	23	77	70	64	203	201	203	0.4	0.4	0.3

BrWF: Bread wheat flour; DPPF: Decorticated pigeon pea flour; R/E: Resistance to extension

Table 4: Extensograms characteristics of biscuit wheat flour as affected by incorporation of DPPF

Flour Blends	Energy (m^2)			Resistance (EU)			Extensibility (mm)			R/E		
	45	90	135	45	90	135	45	90	135	45	90	135
100% BsWF	112	119	106	248	328	334	194	175	157	2.2	3.0	3.4
95% BsWF+5%DPPF	60	66	80	143	168	204	197	186	191	1.1	1.4	1.6
90% BsWF+10% DPPF	38	49	50	88	122	130	216	202	198	0.5	0.8	0.9
85% BsWF+15% DPPF	30	32	34	94	86	85	194	204	212	0.5	0.5	0.5
80% BsWF+20% DPPF	12	15	18	44	50	56	171	188	200	0.4	0.3	0.3

BsWF: Biscuit wheat flour; DPPF: Decorticated pigeon pea flour; R/E: Resistance to extension

3.4 Fermentograms feature of doughs prepared from bread & biscuit wheat flours and composite flour blends

The production of carbon dioxide (CO_2) of fermented doughs prepared from bread and biscuit wheat flours and composite blends, during two hours, are presented in Tables 5 and 6. The objective of fermentation is to bring the dough to an optimum condition for baking. During fermentation, the yeast converts the fermentable sugars into carbon dioxide and ethanol. Not enough fermentable sugars are present in the flour to maintain gas production until baking. The action of amylases on available starch is to supplement and form fermentable sugars during fermentation. The activities of the yeast, beside the influence of the ingredients were determined by the time taken by the yeast to evolve carbon dioxide (by using the Fermentograph).

The effect of decorticated pigeon pea flour (DPPF) and pigeon pea protein isolate (PPPI) on wheat flour doughs, to produce carbon dioxide by yeast showed that; the two types of wheat flour exhibited noticeable differences in the time taken to produce CO_2 through the first and second hours of fermentation. Although the CO_2 production of the two types of wheat flours (bread and biscuit) was close; the time taken for wheat bread (45 min) and the different blends range was (43 to 58 min) were lower than the time taken for biscuit flour (52 min) with its blends range (48 to 60). The second hour of fermentation showed reduction in the time taken to produce CO_2 than the first hour (Tables 5 and 6).

The activity results of yeast obtained in this study were in agreement with that reported by Bronn (1983) who grouped the yeast according to their gas generation. Yeast need less than 60 minutes for dough rising are of good quality. Yeast that need (60-100 minutes), are moderate and yeast that need over 100 minutes are of poor quality. Makoto *et al*. (1992) reported that the time needed to produce a full balloon (1000 cc) of the Fermentograph is recorded as an indicator of the activity of the yeast strain.

Shorter time (minutes) indicates high activity while increase in time (minutes) indicates slacken yeast activity.

Table 5: Fermentograms feature of doughs prepared from bread wheat flour and composite flour blends

Flour Blends*	First hour of fermentation		Second hour of fermentation	
	Vol. of CO_2	Time taken (min.)	Vol. of CO_2	Time taken (min.)
100% BrWF (control)	964	45	944	40
95% BrWF + 5% DPPF	885	48	880	40
90% BrWF+ 10% DPPF	980	48	964	55
85% BrWF+ 15% DPPF	960	43	960	35
80% BrWF+ 20% DPPF	940	48	920	36
75% BrWF+ 25% DPPF	940	46	920	36
BrWF+ PPPI(15%protein)	ND	-	ND	-
BrWF+ PPPI(20%protein)	1000	58	970	44
BrWF+ PPPI(25%protein)	ND	-	ND	-

BrWF: Bread wheat flour, DPPF: Decorticated pigeon pea flour, PPPI: Pigeon pea protein isolate

ND: Not Determined

Table 6: Fermentograms feature of doughs prepared from biscuit wheat flour and composite flour blends

Flour Blends*	First hour of fermentation		Second hour of fermentation	
	Vol. of CO_2	Time taken (min.)	Vol. of CO_2	Time taken (min.)
100% BsWF (control)	960	52	950	43
95% BsWF + 5% DPPF	890	50	880	37
90% BsWF+ 10% DPPF	990	50	960	48
85% BsWF+ 15% DPPF	920	56	920	48
80% BsWF+ 20% DPPF	940	48	940	36
75% BsWF+ 25% DPPF	940	60	920	45
BsWF+ PPPI(15% protein)	ND	-	ND	-
BsWF+ PPPI(20% protein)	890	58	880	53
BsWF+ PPPI(25% protein)	**975**	60	ND	-

BsWF: Biscuit wheat flour; DPPF: Decorticated pigeon pea flour; PPPI: Pigeon pea protein isolate.

CONCLUSION

From the results obtained it could be concluded that the decorticated pigeon pea flour and pigeon pea protein isolate substitution affected and improved the rheological properties of composite flour doughs and have a beneficial effect as improving agents and functional ingredients in processing of bakery products.

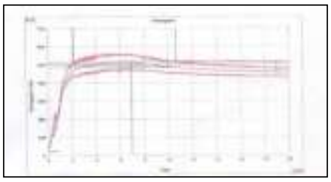

Fig 1: Farinogram of dough prepared from100 % bread wheat flour

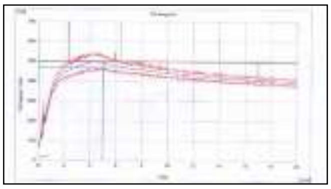

Fig 2: Farinogram of dough prepared from a blend of 95%BrWF and 5%DPPF

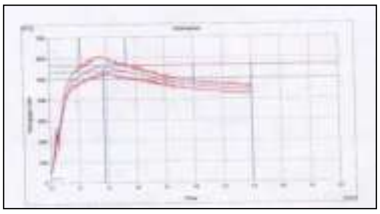

Fig 3: Farinogram of dough prepared From 90 % BrWF and 10%DPPF

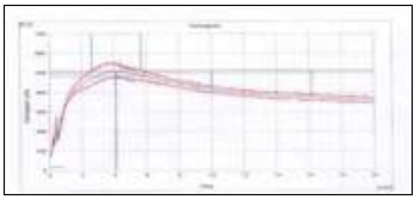

Fig 4: Farinogram of dough prepared 85 % BrWF and 15%DPPF

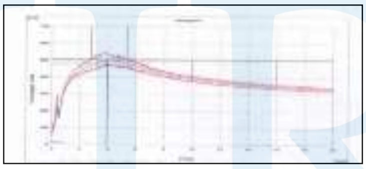

Fig 5: Farinogram of dough prepared From 80 % BrWF and 20% DPPF

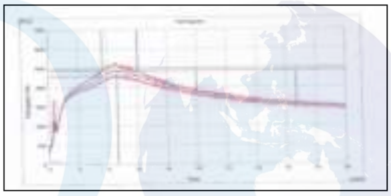

Fig 6: Farinogram of dough prepared from75 -% BrWF and 25% DPPF

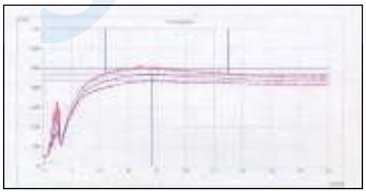

Fig 7: Farinogram of dough prepared from a blend of BrWF and PPPI (15 % protein)

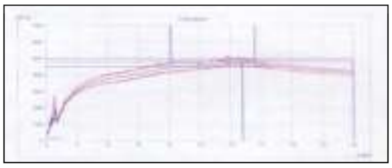

Fig 8: Farinogram of dough prepared from a blend of BrWF and PPPI (20% protein)

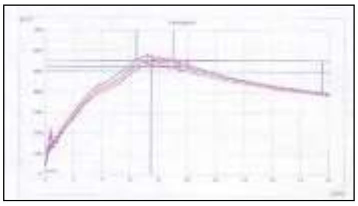

Fig 9: Farinogram of dough prepared from a blend of BrWF and PPPI (25 % protein)

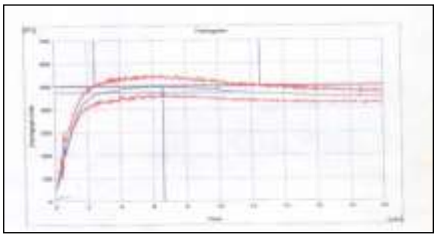

Fig 10: Farinogram of dough prepared from 100 % biscuit wheat flour

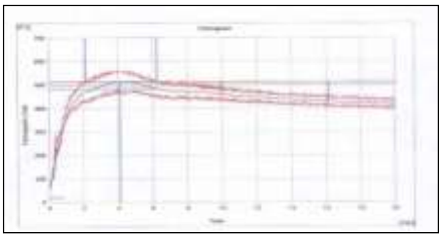

Fig 11: Farinogram of dough prepared from a blend of 95% BsWF and 5% DPPF

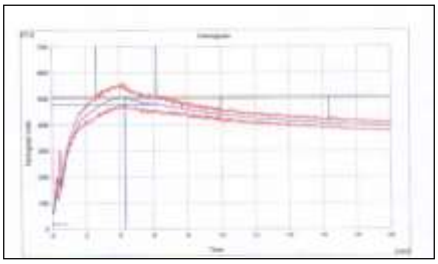

Fig 12: Farinogram of dough prepared from a blend of 90% BsWF and 10% DPPF

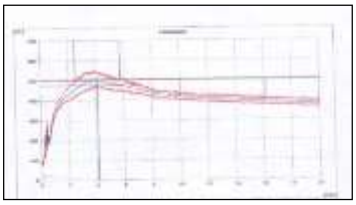

Fig 13: Farinogram of dough prepared from a blend of 85% BsWF and 15% DPPF

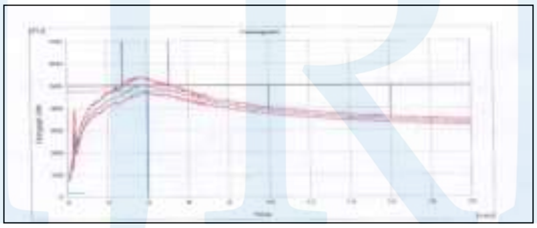

Fig 14: Farinogram of dough prepared from a blend of 80% % BsWF and 20% DPPF

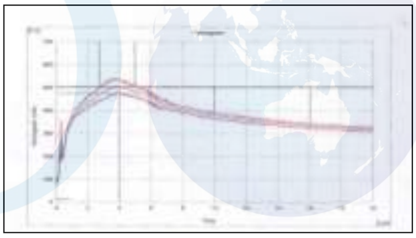

Fig 15: Farinogram of dough prepared from a blend of 75% BsWF and 25% DPPF

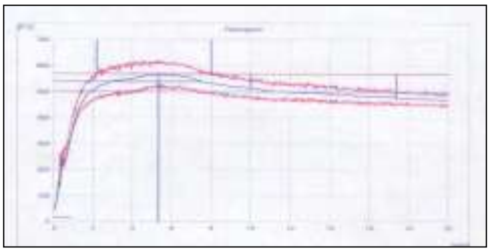

Fig 16: Farinogram of dough prepared from a blend of BsWF and PPPI (protein 15%)

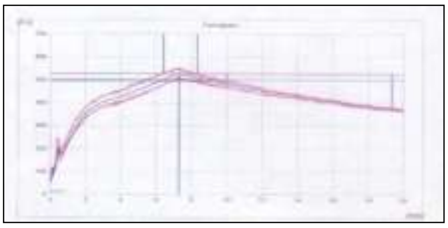

Fig 17: Farinogram of dough prepared from a blend of BsWF and PPPI (protein 20%)

Fig 18: Farinogram of dough prepared from a blend of BsWF and PPPI (protein 25%)

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