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RHEOLOGICAL AND FUNCTIONAL PROPERTIES OF WHEAT AND GREEN GRAM COMPOSITE FLOURS

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ABSTRACT
In the present study composite flour blends of wheat (WF) and green gram flour (GGF) were prepared to investigate their proximate, functional, rheological and antioxidant properties. The composite flours with varied mass ratios (WF: GGF) were prepared in six variants, namely T1 (100:0), T2 (80:20), T3 (60:40), T4 (40:60), T5 (20:80) and T6 (0:100). Results showed that the level of GGF in the composite flour contributed to total flour protein, while carbohydrate, moisture, and fiber were found at high levels in WF enriched flour blends. Other properties such as ash, crude fat, and energy were similar across the blends. Furthermore, minerals (K, Ca, Mg, Fe, and Zn) in the composite flours were observed at high levels in the GGF enriched flours (T4-T6). The major functional properties (pH, aw, water and fat absorption capacities, foam capacity and stability, gelatinization temperature, least gelation capacity, swelling capacity and bulk density) were enhanced by a high proportion of GGF in the blend. On the other hand, the rheological performance of the blend gradually degraded with the GGF content. In addition, GGF improved the antioxidant properties (radical scavenging ability and metal chelating activity) of the flour blend, whereas WF only had minute antioxidant activity. Overall, the addition of GGF in the flour mixture with WF tended to provide potential health benefits and improve flour functional properties.

1. Introduction

Flour is a major ingredient in the majority of ready to eat snack foods, especially in bakery products. Nutritious flour can be made from a variety of pulses, legumes, nuts, root, and tubers. Bakery industries around the world use wheat flour as the predominant component in bakery products because of its viscoelastic properties when mixed with water that makes it uniquely fit for many food applications; in the bakery industries, it dominates over other cereal flours. Wheat gluten protein is mainly responsible for the special viscoelastic properties and strengthens the dough (Shewry et al., 2000; Song and Zheng, 2007). However, the wheat dough is considered nutritionally poor. Wheat flour contains low levels of protein and essential amino acids, such as lysine, tryptophan or methionine (Yadav et al., 2012). Additionally, the consumption of gluten can lead to celiac disease (CD), which is an autoimmune disorder from damage to the small intestine caused by gluten intake. Therefore, non-gluten and composite flours have been widely studied, to restrict the consumption of gluten and to avoid unpleasant disease symptoms in the consumers (Bourekoua et al., 2016).

Composite flour is a mixture of various flours usually acquired from different sources, such as roots, tubers, cereals, and legumes, and may or may not contain also wheat. These have been widely studied in recent times and are applied in the bakery industries. Additionally, the composite flours can have nutritional benefits than the individual flours lack. Although composite flours can be beneficial, the dough's rheological properties play a vital role in the final quality of bakery products. These properties can be affected or "optimized" by adjusting the composition of the flour blend (Oladunmoye et al., 2010). Rapid Visco Analyzer (RVA) is primarily used to analyze the rheological behavior of flour, as it relates to food applications. The suitability of an individual or composite flour for producing a cake, cookie, bread or snack products can be evaluated using the RVA (Itagi and Singh, 2012). Thailand is produced only small amounts of wheat flour, so the demand for bakery products is met by imports from nearby countries in Asia, mainly India. Therefore, composite flours provide opportunities to increase the use of domestic agricultural crops in flours for bakery products. Presently, rice flour and potato flour are commonly blended into the bakery products found in Thailand. Though there are plenty of healthy legumes produced throughout the country, their use in bakery products is very rare.

Among such legumes, green gram or mung bean is a staple legume produced widely in Asia. Flour made from green gram is starchy and a non-gluten fine-grained flour mostly used in South Asia, and in South-East Asia, it is used as a whole grain and/or starchy flour to produce local sweet desserts, such as Luuk Chuup, Med Kanun, and Tua Pap in Thailand. Green gram flour is, however, rarely used in bakery products in South-East Asia. Several studies have proven that green gram provides both good functional properties and human health benefits. A few studies have shown that the dough made from composite flours containing green gram can have excellent functional and rheological properties for bakery products (Chandra and Samsher, 2013; Chandra et al., 2015). However, most such scientific information concerns multi-flour composites with only a tiny portion of green gram. Therefore, the present study focused on the binary blends of wheat and green gram flours, over the whole range of mixture proportions, examining the rheological and functional properties that predict suitability for bakery products.

2. Materials and methods

2.1. Materials and flour blend preparation

The whole wheat grains and green gram legumes were purchased in a single batch from a local market in Muang, Surat Thani, and Thailand. They were sorted, cleaned (destoned) and stored separately in airtight containers, and kept in a dry and cool storage prior to use. The preparation of flour blends started by grinding the materials separately in an electric grain mill, and sieving (44 mesh) them. After that, components were weighed for mixing in desired proportions to the blends T1 (100:0), T2 (80:20), T3 (60:40), T4 (40:60), T5 (20:80) and T6 (0:100). The composite flours were checked with the following determinations.

2.2. Determinations

2.2.1. Proximate composition

The proximate analysis of protein, crude fat, moisture, ash, fiber, and gluten index in the composite flours was based on standard methods (AOAC, 2000). The results are reported as mass percentages (%). The carbohydrate contents of the flours were estimated by subtraction. Gross energy content (kcal) of each flour was measured using a ballistic bomb calorimeter. Mineral contents

(K, Ca, Mg, Fe and Zn) of the composite flour was measured using an inductively coupled plasma optical emission spectrophotometer (ICP-OES, Vista Pro, Australia).

2.2.2. Functional properties

Water activity (a_w) of the samples was measured using a water activity analyzer (Aqua lab, USA). pH of the composite flours was measured using a digital handheld pH meter (Clean pH30, 30 Series Tester, China). The viscosity of the flour was measured using the Brabender amylograph. Water (WAC) and fat absorption capacities (FAC) of the composite flours were measured following the method of Yadav et al. (2012). Swelling capacity (SC) was measured by the method of Okaka and Potter (1979). Bulk density (BD) was measured based on the method of Wang and Kinsella (1976). Foaming capacity (FC) and foam stability (FS) were measured based on the method of Narayana and Narasinga Rao (1982). Least gelation concentration (LGC) of the flours was determined based on the method of Coffmann and Garcia (1977). The emulsion capacity (EMC) and stability (EMS) of the composite flours were measured using the method of Yasumatsu et al. (1972).

2.2.3. Rheological properties

The rheological properties of composite flours were evaluated by the method of Julianti et al. (2015) using Rapid Visco Analyzer (RVA, Newport Scientific, Model RVA-4, Australia). A suspension of 3 g flour in 25 g of distilled water underwent controlled heating and cooling under constant shear, with the flour held at 50ºC for 1 min, heated from 50 to 95ºC at 6ºC/min and held at 95ºC for 5 min. During this measurement process, the following data were recorded: pasting temperature (P_{temp}), peak viscosity (PV), hot paste viscosity (HPV), breakdown viscosity (BPV), setback viscosity (SBV) and stability ratio (SR).

2.2.4. Extraction and antioxidant properties of extracts

A flour sample (10g) was mixed with 50 ml of acidified methanol solvent in an amber colored bottle under nitrogen. The sample mixture was mixed thoroughly and subjected to extraction. The extraction was continued in a temperature controlled water bath with an electrical shaker for 8 hr at 30 °C. Then, the extract was centrifuged (50 ml tube size at fixed rotor angle of 40°) at 7800 x g for 15 min, and the supernatant was collected and stored in dark, in a sealed container at -4°C, until use in further analysis.

The total chlorophyll content (TCC) in the composite flours was measured according to AOAC (2000). The results are expressed as mg chlorophyll/g. Total phenolic content (TPC) of the composite flour was determined according to the method of Singleton et al. (1999). The results are expressed as mg equivalents of Gallic acid/g (mg Eq GA/g). Total flavonoid content (TFC) in the samples was determined based on the method of Zhishen et al. (1999). The results are expressed as mg equivalents of Catechin/g (mg Eq CE/g). The capacities of the composite flours to scavenge DPPH (2, 2-diphenyl-1-picrylhydrazyl) radicals (DPPH-RSC) were measured by the method of Sánchez-Moreno et al. (1998). The results are expressed as percentages. The ferric reducing power (FRAP) of each flour was measured according to the method of Benzie and Strain (1996). The results are expressed as percentages. The metal chelating activities (MCA) of the flours were measured by the method in Aktumsek et al. (2013). The results are expressed as mg equivalents of EDTA/g (mg EDTA/g).

2.2.5. Statistical analysis

Data from the completely randomized experimental design are expressed as Mean ± SD (n=6). These data were subjected to one-way analysis of variance (ANOVA) followed by testing for Least Significant Differences (LSD) at 95% confidence level. The threshold $P \leq 0.05$ was required for statistical significance.

3. Results and discussions

3.1. Proximate composition

The proximate compositions of the WF and GGF blends are shown in Table 1. The protein contents ranged from 10.1 to 21.51%, with significant differences between blends. The pure component T6 (100%, GGF) flour had the highest protein content, while at the other extreme T1 (100%, WF) flour had the lowest. Carbohydrate content in the composite flour ranged from 8.12 to 10.12%, with T1 having the most (10.12%) carbohydrates while adding GGF tended to decrease the carbohydrate content. The moisture content of the blends had a similar trend as their carbohydrate content, with GGF decreasing the total moisture level. The moisture content ranged from 8.6% to 10.10%, with the highest level observed in T1 and the lowest in T6. The ash contents of the blends had significant differences, ranging from 0.97% to 3.12%. The highest level of ash was in T6 and the lowest in T1: GGF contributed to the ash content. The gluten content mostly came from the WF component of the blend, so GGF content decreased the gluten level as expected. The composite flours T4, T5, and T6 are suitable for the bakery products with low gluten profile. On the other hand, the crude fat (0.970-0.977%), total fiber (0.27-0.40%) and energy (359.22-395.25 kcal) in the flour blends did not vary significantly. The fiber content decreased with GGF content. The micronutrients or mineral in terms of metals (K, Ca, Mg, Fe, and Zn) were significantly affected by the blend ratio (Table 1). The data show that GGF enriched composite flours contained elevated levels of minerals relative to the WF; in particular, K, Ca and Mg, but also Fe and Zn.

3.2. Functional properties

The functional properties of WF and GGF blends are shown in Table 2. Overall, flour pH was found to be slightly acidic (6.15; T1) and increasing the percentage of GGF brought it towards neutral (6.71; T6). However, the pH did not significantly differ between the blends ($P>0.05$). Adeleke and Odedeji (2010) reported that the shelf life of flour could be prolonged by acidic pH. Water activity (a_w) decreased slightly from 0.639 to 0.598. The highest a_w was found in T1, and the lowest in T6: increasing GGF content decreased the water activity. However, the a_w variations were not significant ($P>0.05$). Water absorption capacity (WAC) and fat absorption capacity (FAC) showed that GGF had a stronger affinity to water while WF had a stronger affinity to fat. Itagi and Singh (2012) reported that WAC of composite flours mainly depends on the content of polar amino groups in proteins and polysaccharides. The changes in affinities to water and fat were significant ($P\leq0.05$). WAC ranged from 84 (T1) to 97% (T6) and, whereas FAC ranged from 101.72 (T6) to 124.22% (T1). Chandra and Samsher (2013) reported similar findings, in that WF absorbed more fat than GGF or other flours in that study. Emulsion capacity (EMC) and emulsion stability (EMS) exposed the better emulsion properties of WF relative to GGF. EMC ranged from 39.63 (T6) to 44.87% (T1) and, on the other hand, EMS ranged from 36.46 (T6) to 39.99% (T1). The differences in EMC and EMS were significant between T1 and the rest (T2 to T6). However, the EMC and EMS did not significantly vary within the latter group of cases. Emulsions play a crucial role in bakery products, in which proteins interact with fats, and this improves the quality and stability of the products (Sathe and Salunkhe, 1981). Although GGF had higher protein content than WF (Table 1), the latter had stronger emulsion properties. Kaushal et al. (2012) reported that emulsion properties are mainly influenced by protein solubility in the flours.

Table 1. Proximate analysis of the composite flours

Proximate analysis		**Flour Composite (% WF: GGF)**					
		T1	**T2**	**T3**	**T4**	**T5**	**T6**
		100 WF	**80 WF: 20 GGF**	**60 WF: 40 GGF**	**40 WF: 60 GGF**	**20 WF: 80 GGF**	**100 GGF**
Macro Nutrients	Protein (%)	10.10 ± 0.38^{f}	12.44 ± 0.29^{e}	15.06 ± 0.02^{d}	17.20 ± 0.01^{c}	19.40 ± 0.03^{b}	21.51 ± 0.28^{a}
	Crude fat (%)	0.970 ± 0.01^{a}	0.977 ± 0.00^{a}	0.977 ± 0.00^{a}	0.974 ± 0.00^{a}	0.973 ± 0.00^{a}	0.970 ± 0.00^{a}
	Carbohydrate (%)	10.12 ± 0.02^{a}	9.76 ± 0.02^{b}	9.44 ± 0.04^{b}	9.10 ± 0.02^{b}	8.70 ± 0.00^{c}	8.40 ± 0.03^{c}
	Moisture (%)	10.10 ± 0.03^{a}	9.70 ± 0.05^{b}	9.60 ± 0.09^{b}	9.06 ± 0.02^{b}	8.90 ± 0.11^{bc}	8.60 ± 0.13^{c}
	Ash (%)	0.57 ± 0.04^{d}	1.01 ± 0.05^{c}	1.5 ± 0.05^{c}	2.10 ± 0.09^{b}	2.50 ± 0.05^{b}	3.12 ± 0.04^{a}
	Fiber (%)	0.40 ± 0.05^{a}	0.31 ± 0.01^{b}	0.29 ± 0.33^{b}	0.28 ± 0.00^{b}	0.27 ± 0.00^{b}	0.27 ± 0.01^{b}
	Gluten Index (%)	89 ± 0.26^{a}	73 ± 1.04^{b}	51 ± 1.88^{c}	36 ± 0.61^{d}	17 ± 0.78^{e}	0 ± 0.00^{f}
	Energy (kcal)	359.22 ± 0.01^{a}	359.22 ± 0.13^{a}	359.23 ± 0.53^{a}	359.23 ± 0.13^{a}	359.24 ± 0.52^{a}	359.25 ± 0.48^{a}
Micro Nutrients	K (%)	0.18 ± 0.00^{e}	0.352 ± 0.01^{d}	0.524 ± 0.05^{c}	0.696 ± 0.00^{c}	0.868 ± 0.08^{b}	1.04 ± 0.00^{a}
	Ca (%)	0.17 ± 0.00^{a}	0.186 ± 0.00^{a}	0.202 ± 0.00^{a}	0.218 ± 0.00^{a}	0.234 ± 0.05^{a}	0.25 ± 0.00^{a}
	Mg (%)	0.06 ± 0.00^{c}	0.078 ± 0.02^{c}	0.106 ± 0.01^{b}	0.124 ± 0.00^{a}	0.138 ± 0.04^{a}	0.16 ± 0.01^{a}
	Fe (mg/kg)	26.79 ± 0.10^{f}	35.58 ± 0.50^{e}	44.38 ± 0.00^{d}	53.18 ± 0.12^{c}	61.98 ± 0.88^{b}	70.78 ± 0.88^{a}
	Zn (mg/kg)	12.72 ± 0.01^{c}	14.67 ± 0.01^{bc}	16.56 ± 0.70^{b}	18.48 ± 0.05^{ab}	20.4 ± 0.54^{ab}	22.33 ± 0.40^{a}

Note: The values are shown as mean ± standard deviation (n=6). Different superscripts indicate statistically significant differences within one row ($P \leq 0.05$).

Table 2. Functional properties of the composite flours

Functional Properties	Flour Composite (% WF: GGF)					
	T1	T2	T3	T4	T5	T6
	100 WF	80 WF: 20 GGF	60 WF: 40 GGF	40 WF: 60 GGF	20 WF: 80 GGF	100 GGF
pH	6.15±0.05^{a}	6.46±0.02^{a}	6.56±0.02^{a}	6.66±0.04^{a}	6.71±0.08^{a}	6.71±0.03^{a}
a_w	0.639±0.00^{a}	0.587±0.01^{a}	0.595±0.01^{a}	0.602±0.00^{a}	0.619±0.00^{a}	0.598±0.00^{a}
WAC (%)	84±1.73^{f}	86.6±1.11^{e}	89.2±3.66^{d}	91.8±3.08^{c}	94.4±5.13^{b}	97±1.14^{a}
FAC (%)	124.22±1.21^{a}	119.4±1.14^{b}	117.8±0.81^{c}	110.2±1.05^{d}	105.6±1.40^{e}	101.72±1.77^{f}
EMC (%)	44.87±1.54^{a}	43.57±0.84^{b}	42.00±0.88^{b}	41.88±0.51^{b}	40.10±0.14^{bc}	39.63±0.22^{bc}
EMS (%)	39.99±0.67^{a}	39.10±1.44^{a}	38.55±0.80^{b}	37.48±2.10^{b}	36.88±3.80^{bc}	36.46±1.30^{bc}
FS (%)	10.87±0.36^{f}	15.66±0.61^{e}	21±0.68^{d}	25.91±0.80^{c}	30.51±0.47^{b}	35.11±0.71^{a}
FC (%)	13±0.20^{f}	17.8±0.42^{e}	23.7±0.20^{d}	27.5±0.46^{c}	33.9±0.31^{b}	36.57±0.21^{a}
GT (ºC)	61.27±2.27^{a}	59.84±1.24^{b}	60.47±0.85^{b}	61.09±1.10^{a}	61.72±2.00^{a}	62.27±1.84^{a}
LGC (%)	10±0.78^{f}	11.2±0.51^{e}	12.4±0.91^{d}	13.8±0.13^{c}	15.2±0.41^{b}	16±0.12^{a}
SC (%)	18.60±0.85^{ab}	18.4±0.71^{ab}	19.16±0.22^{a}	19.44±0.57^{a}	19.72±1.12^{a}	20±0.48^{a}
BD (g/cm^3)	36.32±0.81^{c}	37.42±0.53^{b}	37.45±0.62^{b}	36.84±0.74^{c}	36.59±0.59^{c}	38.08±0.56^{a}

Note: The values are shown as mean ± standard deviation (n=6). Different superscripts indicate statistically significant differences within one row (P≤0.05).

Table 3. Rheological properties of the composite flours

Rheological properties	Flour Composite (% WF: GGF)					
	T1	T2	T3	T4	T5	T6
	100 WF	80 WF: 20 GGF	60 WF: 40 GGF	40 WF: 60 GGF	20 WF: 80 GGF	100 GGF
P_{temp}	83.6 ± 0.02^{a}	82.8 ± 2.10^{a}	80.9 ± 0.80^{b}	75.7 ± 0.40^{c}	75.1 ± 1.20^{c}	70.2 ± 0.50^{d}
PV (Cp)	1040 ± 50.50^{a}	934 ± 71.00^{b}	826 ± 18.20^{c}	722 ± 8.20^{d}	616 ± 12.70^{e}	510 ± 52.12^{f}
HPV (Cp)	793 ± 10.00^{a}	755 ± 8.50^{a}	717 ± 10.20^{a}	680 ± 13.00^{ab}	642.6 ± 5.50^{b}	605 ± 11.70^{c}
BDV (Cp)	295 ± 10.00^{a}	270 ± 11.50^{a}	268 ± 12.00^{a}	244 ± 10.00^{a}	240 ± 9.00^{a}	236 ± 10.00^{a}
SBV (Cp)	950 ± 12.00^{a}	840 ± 15.00^{b}	730 ± 11.00^{c}	620 ± 14.00^{d}	580 ± 10.00^{d}	450 ± 7.00^{e}
SR	1794 ± 12.00^{a}	1562 ± 11.00^{b}	1257 ± 12.00^{c}	1109 ± 11.00^{d}	1050 ± 14.00^{d}	879 ± 5.00^{e}

Note: The values are shown as mean ± standard deviation (n=6). Different superscripts indicate statistically significant differences within one row (P≤0.05).

Table 4. Antioxidant capacities of the composite flours

Antioxidant capacities	**Flour Composite (% WF: GGF)**					
	T1	**T2**	**T3**	**T4**	**T5**	**T6**
	100 WF	**80 WF: 20 GGF**	**60 WF: 40 GGF**	**40 WF: 60 GGF**	**20 WF: 80 GGF**	**100 GGF**
TCC (mg Chl/g)	0.160 ± 0.05^{e}	1.654 ± 0.03^{d}	2.720 ± 0.10^{c}	3.617 ± 0.01^{c}	4.293 ± 0.04^{b}	6.450 ± 0.32^{a}
TPC (mg GAE/g)	0.019 ± 0.00^{b}	0.020 ± 0.00^{ab}	0.020 ± 0.00^{ab}	0.021 ± 0.00^{a}	0.022 ± 0.00^{a}	0.024 ± 0.00^{a}
TFC (mg CAE/g)	0.023 ± 0.00^{a}	0.024 ± 0.00^{a}	0.024 ± 0.00^{a}	0.024 ± 0.00^{a}	0.024 ± 0.00^{a}	0.025 ± 0.00^{a}
DPPH-RSC (%)	44.58 ± 0.46^{f}	56.64 ± 0.05^{e}	62.39 ± 0.05^{d}	66.32 ± 0.05^{c}	71.10 ± 0.11^{b}	88.07 ± 0.60^{a}
FRAP (%)	54.69 ± 0.27^{e}	55.90 ± 0.17^{d}	56.71 ± 0.04^{d}	58.51 ± 1.22^{c}	60.59 ± 0.17^{b}	62.35 ± 0.53^{a}
MCA (mg EDTA/g)	2.20 ± 0.10^{e}	3.70 ± 0.20^{d}	4.20 ± 0.05^{d}	5.50 ± 0.01^{c}	6.90 ± 0.02^{b}	7.80 ± 0.30^{a}

Note: The values are shown as mean ± standard deviation (n=6).
Different superscripts indicate statistically significant differences within one row (P≤0.05).

Foam stability (FS) and foam capacity (FC) values ranged from 10.87 to 35.11% and from 13 to 36.57%. T1 flour had the least FS and FC among the flours in this study. The GGF increased FS and FC of the flour blends significantly ($P \leq 0.05$). Chandra and Samsher (2013) reported that the foaming properties of GGF were better than those of other flours they tested. Acuña (2012) found that the protein content in legume plants always induces high foaming abilities. Gelatinization temperature (GT) slightly increased with the GGF content, ranging from 59.84 to 62.27 ºC. The lowest GT was observed in T1 and the highest in T6. However, the differences in GT were not significant between the flours. Generally, GT of flour is increased by high contents of proteins and carbohydrates that might promote physical competition for water between protein gelation and carbohydrate gelatinization when the flour is heated. Least gelation capacity (LGC) was highest in the GGF containing flour blends, ranging from 10 to 16%. T1 had the least LGC, followed by T2 to T6. The differences in LGC between the composite flours were minimal but still statistically significant. High level of protein in the flour possibly increased the LGC. It can be seen that the T6 flour contained the most proteins. In addition, the gelation of flour is primarily guided by the balance between hydrophobic and repulsive electrostatic interactions by the proteins. The highest value of swelling capacity (SC) was observed for the T6 flour (GGF), whereas the flours rich in WF (T1, T2 & T3) had low values. However, the actual flour bends between these extremes did not differ much mutually ($P > 0.05$). SC ranged from 18.4 to 20%. The bulk density (BD) of T6 was high, while that of T1 was comparatively low. BD ranged from 36.32 to 38.08 g/cm^3, showing no significant effects from mixture proportions ($P \geq 0.05$). GGF rich composite flours had slightly increased BD values relative to other cases. The BD of flour is affected by density and particle size of the flour. High levels of BD enable further applications in food preparation (Akpata and Akubor, 1999; Karuna et al., 1996).

3.3. Rheological properties

Rheological properties of the composite flours are shown in Table 3. The results demonstrate that WF had higher values of the rheological characteristics (PV, HPV, BDV, SBV, SR, and P_{temp}) than GGF. Julianti et al. (2015) reported that normally composite flours show poorer rheological properties than wheat flour, represented by the case T1 in the current study. Increasing the GGF level in the composite flour diminished the rheological properties in a consistent gradual manner. PV is an indicator of starch water binding capacity and of the granules' peak swelling during cooking (Itagi and Singh, 2012; Julianti et al., 2015). PV of the composite flours ranged from 510 to 1040 Cp, with the highest value for the WF flour (T1) and for the GGF flour (T6). The size of starch granules plays a major role in determining the physicochemical properties, especially swelling power, paste clarity and water binding capacity (Singh et al., 2003). Additionally, the starch content in WF is higher than in GGF (we used flours, not purified starches); this could also decrease the PV of GGF containing composite flours. HPV of the composite flour ranged from 605 to 793 Cp, with the similar trend as found in PV. BDV ranged from 236 to 295 Cp, and the lowest BDV values were observed for the GGF enriched flour blends. However, the BDV values did not differ significantly ($P > 0.05$). SBV indicates retrogradation of starch, and it ranged from 450 to 950 Cp. T1 showed the highest SBV with the consistent trend across the blends. SR ranged from 879 to 1794 Cp, and the WF rich composite flours had the highest values with a consistent decrease by GGF content. Low SR indicates good stability against retrogradation after gelatinization of starch. The results indicate that GGF content in the composite flour is reduced retrogradation. P_{temp} is indicative of the minimum temperature required to cook the flour (Kaur and Singh, 2005), and it ranged between 70.2 and 83.6ºC.

Cases T1 and T2 had the highest P_{temp}, followed by the other composite flours. In particular, pure WF (T1) had the highest P_{temp}. This result is in agreement with the results of Wani et al. (2016). Kesarwani et al. (2016) reported that high protein content in the flour could thicken the walls around starch granules, and as a result could reduce the rheological properties. In the present study the GGF had high protein content (Table 1), and in addition the WF component had higher starch content: both aspects could induce higher viscosity values of the WF.

3.4. Antioxidant properties

The antioxidant properties of WF and GGF composites are shown in Table 4. TPC (0.0227 to 0.0246 mg/g) and TFC (0.0193 to 0.024 mg/g) varied insignificantly across the cases, although T1 had lower observed TPC and TFC than the other flours. Generally, the whole green gram pulses are rich sources of polyphenolics and have high antioxidant activities; however, the processing into flour may decrease the phytochemical and antioxidant abilities (Guo et al., 2012; Wei-Yu and Wang, 2015). Total chlorophyll (TC) of the composite flours increased with the GGF content, ranging from 0.015 to 6.448, with significant variation ($P \leq 0.05$). DPPH radical is a stable free radical that accepts electrons to form a stable diamagnetic molecule. The results showed that DPPH radical scavenging ability was enhanced with GGF content in the composite flours. It ranged from 44.58 to 88.07% ($P \leq 0.05$). Normally, antioxidant activity in plant originated materials is mainly contributed by the polyphenolics and vitamins. The TPC and TFC results exposed that the GGF had more activity than the WF. The activities may be influenced by amino acids that can interfere with the phytochemicals in the flour, improving the antioxidant capacity (Itagi and Singh, 2012). However, the ferric reducing power (FRAP) did not significantly differ against the tested composite flours, ranging from 54.69 to 62.35%. Although without statistical significance, these values slightly increased with the content of GGF. On the other hand, metal chelating activity (MCA) significantly differed between the blends. MCA is predominant as it decreases the transition metal concentration in the lipid peroxidation. The blends with GGF had a higher level of MCA than pure WF, and MCA ranged from 2.2 to 7.8 mg/g. Increased GGF content overall tended to increase the antioxidant properties. Bhattacharya and Malleshi (2012) reported that GGF with higher chlorophyll and carotenoid pigment contents possesses higher antioxidant activities. In addition, GGF also contains antioxidant enzymes such as superoxide dismutase, catalase, and peroxidase.

4. Conclusions

The combinations of cereal grain and legume flours can facilitate producing nutritionally rich and low gluten profile bakery products. In the present study, the results showed that blends of wheat flour (WF) and green gram flour (GGF) allowed significant control of the proximate, functional and antioxidant properties. However, the added GGF tended to reduce the pasting properties (RVA viscosities) of these composite flours. Overall, the flours with a high content of WF could be more suitable for softer bakery products, such as bread and cakes, due to high pasting viscosities, while those with dominant GGF fraction could be more appropriate for the harder bakery products such as cookies or crackers, due to the lower pasting properties. However, further studies are required to develop actual bakery products and test them, using such flour blends.

5. References

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