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FUNCTIONAL, RHEOLOGICAL PROPERTIES AND PROTEIN DIGESTIBILITY (IN VITRO) OF WHEAT DOUGH SUPPLEMENTED WITH SOME LEGUMES FLOUR

BY

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ABSTRACT

This study was conducted to evaluate the effect of legumes flour added at levels of 5%, 10% and 15% to wheat flour on its properties. The legumes flour chosen for this study was chickpeas, lentil, and sweet lupine flours. Legumes flour has relatively high in vitro protein digestibility. The in vitro protein digestibilities were 79.02±1.87%, 80±18 % and 82.60±2.35% for chickpea, lentil and sweet lupine, respectively. While, the lowest in vitro protein digestibility was observed in wheat flour, since it was 70.15±2.31%. It was found that legumes flour showed highly water and oil absorption capacity. All samples had slightly higher water absorption than those of the control, and a marked increase was observed when lupine flour was used. Moreover, results indicated that legumes flour could be used for food products. The legumes flour showed markedly good foaming capacity. Rheological properties of the dough containing legumes flour showed variable data by using Farinograph and Extensograph. It was found that wheat flour was the strongest among the samples, since it had the lowest dough weakening of 40 B.U., while this value increased when any of the legumes flour was added.

Key Words: functional properties, legumes flour-lentil - chickpea-sweet lupine-wheat flour – rheological properties –Farinograph test- Extensograph test.

INTRODUCTION

The fact that man has to look for new sources of proteins for the future has been well established. Several legumes (flour, protein concentrate and isolate) have been studied and some of them was proposed as protein alternatives for human consumption. Among these, soybean is the most utilized vegetable protein resource. In addition to the nutritional aspects, proteins should exhibit certain functional properties for their incorporation into foods. Plant proteins successfully utilized in food should exhibit desirable characteristics such as water and oil absorption, emulsification and foaming ability. Legumes are intended as additives in products for improving functional properties (Boneldi and Zayas,1995) .The present study was carried out to study some legumes flour in terms of proximate chemical composition, in vitro protein digestibility, functional and rheological properties. Water holding capacity is an important functional property for food, where the portion should imbibe water without dissolving. Hydration properties, water absorption, binding, swelling, and viscosity are known to influence the characteristics of a food system.

MATERIALS AND METHODS

Materials:

Hard wheat flour (72 %extraction) was obtained from the Flour Land Mills CO., 6 October City, Egypt. Chickpea seeds (*Cicer arietinum*) of variety Giza 25, Lentil seeds (*Lens escolantum.*) and Sweet lupine seeds (*Lupinus albus*) were obtained from the Legumes Res. Dept., Field Crops Res. Inst., Agric Res .Cent., Giza, Egypt.

Methods:

Chemical composition:

The seed of legumes were cleaned, milled by Brabender laboratory mill and sieved through 60 mesh sieves to get legumes flour. Moisture, crude protein, ether extract, crude fiber, and ash were determined according to the methods described in (A.O.A.C, 2007). Nitrogen free extract (NFE) was calculated by difference as follow:

Nitrogen free extract =100-(protein % + fat % + ash % + fiber %).

Protein digestibility (in vitro):

In vitro protein digestibility was assessed by employing pepsin and pancreatin as described by Santosh and Chauhan, (1986). The nitrogen content of the sample and supernatant after digestion were determined by the micro Kjeledahl method. The procedure of the protein digestibility was carried out as follow:

An accurate weight (1.5 g) of sample was mixed with 1.5 mg pepsin and 15 ml hydrochloric acid solution (0.1N). The mixture was incubated for 3 hr at 37 C° then, a mixture of 7.5 ml sodium hydroxide solution (0.2 N) and 4mg pancreatin in 7.5 ml phosphate buffer (PH 8) was added. The mixture was incubated again for 25 hr at 37 C° about 10 ml of trichloroacetic acid (10%) was added and the centrifugation was carried out at 2000 rpm for 30 min. The protein content of the clear supernatant was determined.

$$\text{The protein digestibility} = \frac{\text{Digested protein in supernatant}}{\text{Protein content of sample}} \times 100$$

Water holding capacity (WHC):

WHC was determined using Childs and Adajain, (1976) method, by mixing 1g sample with an excess of deionized water. The mixture was shaken for one min and allowed to stand for 30 min prior to being centrifuged at 3000 rpm for 15 min. The supernatant was decanted and the pellets were weighed. The difference in weigh between the wet pellets and the flour were defined as WHC.

Oil holding capacity (OHC):

Oil holding capacity was determined similarly to WHC expect that a commercial vegetable corn oil was used instead of water (Childs and Adajain, 1976).

Foam capacity:

The method of Aruna and Parakash, (1993) was used. Flour sample of 2 gm and 100 ml distilled water were mixed in blender. The suspension was stirred for 5 min at 1600 rpm and the contents along with foam were poured into a 250 ml graduated measuring cylinder. The percentage increase in volume after 30 second recorded as foam capacity according to the following formula.

$$\text{\% Volume increase (Foam Capacity)} = \frac{\text{Total volume (ml)} - \text{Initial volume (ml)}}{\text{Initial volume (ml)}} \times 100$$

Rheological Properties:

Farinograph Test:

The Farinograph test was carried out according to the method described in the (A.A.C.C., 1990).

Extensograph Test:

Extensograph test was carried out according to the method described in the (A.A.C.C., 1990)

Statistical analysis:

The data obtained from chemical composition, and the biological examinations were statistically analyzed according to (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

Chemical composition of wheat flour, and legumes flour:

Moisture, crude fat, crude protein, ash, fiber and nitrogen free extract of wheat flour (72% extraction) and legumes flour were determined. The results are presented in Table (1). Moisture, crude fat, crude protein, ash, fiber, and carbohydrate of wheat flour (72%) were 13.20, 1.02, 11.53, 0.56, 0.26, and 86.63% respectively. The results indicated that sweet lupine had the highest protein content 36.80±1.65 and the lowest protein content was observed in case of wheat flour (11.53±0.34). The results are in agreement with the values reported by Abd El-Hamid (2002), Cai *et al.* (2002), Hussein (2002), Reyes-Moreno *et al.* (2004) Kaur and Singh (2005), Sharara (2005), Iqbal *et al.* (2006) and Martinez- Villaluenga *et al.* (2006).

In vitro protein digestibility

In vitro protein digestibility of wheat flour and legumes flour samples was determined. The potential nutritional value of legumes seeds is limited by a number of factors, structural features of some of their protein fractions and the presence of anti-nutrients such as phytic acid and tannins may affect protein digestion.

Table (1): Chemical composition of wheat and legumes flours (on dry weight bases)

Parameter %	Wheat (72%)	Chickpea	lentil	Sweet lupine
Moisture	13.20 ±0.23	8.02±0.26	10.33±0.33	8.50±0.32
Crude protein	11.53±0.34	21.20±1.1	26.72±0.89	36.80±1.65
Crude Fat	1.02±0.18	4.35±0.33	1.88±0.08	10.78±0.36
Ash	0.56±0.07	3.10±0.25	2.20±0.37	3.14±0.21
Crude Fiber	0.26±0.09	4.66±0.43	3.59±0.13	6.88±0.28
NFE**	86.63±1.2	66.69±1.34	65.61±1.59	42.40±1.8

** By difference

Results presented in Table (2) indicated that there were slight differences between the three studied legumes flour. The in vitro protein digestibility of sweet lupine flour was slightly higher than that of the chickpea, and lentil flours. Whereas, in vitro protein digestibility value of sweet lupine flour was (82.60 %). However, chickpea flour had a slightly lower in vitro protein digestibility value than lentil, and sweet lupine flour. Whereas, in vitro protein digestibility values of chickpea and lentil flours were 79.02, and 80.18%, respectively. In vitro protein digestibility of wheat flour was found to be much lower than the three tested legumes flour and this assure the benefit of using such additives. The results are in agreement with those found by El-Bagoury *et al.* (1999) and Khatoon and Prakash, (2004)

Table (2): In vitro protein digestibility of wheat flour and legumes flour

Materials	Protein digestibility (%)
Wheat flour (72%extraction)	70.15±2.31
Chickpeas flour	79.02±1.87
Lentil flour	80.18±1.55
Sweet lupine flour	82.60±2.35

Functional properties

Water and oil absorption capacity

As is shown from results in Table (3), the sweet lupine flour had the highest water absorption capacity (1.36 g/g), followed by lentil flour (1.33 g/g), then chickpea flour (1.21 g/g). Such results may be due to the differences in the fat, crude fiber, and protein content between these legumes flour. The presence of fat reduces protein from water diffusion and the availability of Polar amino acids, which contain the primary sites for the interaction of protein with imbibed water. In addition, crude fibers have many desirable properties, including, high water holding capacity. These results are in agreement with Huyghe, (1997), Abd El-Baki, (1999), and Abd El-Hamid, (2002).

The legumes flour had the same trend for oil absorption capacity (which noticed in water absorption capacity). The oil absorption capacity of the sweet lupine flour was the highest, followed by lentil flour and chickpea flour 1.69±0.69, 1.64±0.56, and 1.63±0.93 (g/g), respectively. As shown in Table (3) this may be due to the difference in the protein contents of these materials and to the changes in protein non-polar sites on the surface of protein subunits. These sites are responsible of binding the hydrocarbon chains of oil. More hydrophobic proteins show superior binding of lipids, implying that non-polar amino acid side chains bind the paraffin chains of fats. Based on this suggestion, sweet lupine flour, which showed higher oil absorption capacity, had more available non-polar side chains in its protein molecules than other legumes flours. These results are in agreement with Kaur and Singh, (2005) and Sharara, (2005).

Table (3): Functional properties of legumes flour

Legumes flour	Water Absorption capacity (gm/gm)	Oil absorption capacity (gm/gm)	Foam Vol. After Whipping (ml)
Chickpea flour	1.21±0.84	1.63±0.93	131±3.40
Lentil flour	1.33±0.96	1.64±0.56	133±4.23
Sweet lupine flour	1.36±0.97	1.69±0.69	135±3.53

Foam capacity:

As seen in Fig. (1) and Table (3) the sweet lupine flour had better foaming capacity than lentil and chickpea flour 135±3.53, 133±4.23, and 131±3.40 (ml), respectively. These differences may be due to the variation in the protein and oil content of these legumes flour. Generally, the presence of oil negatively affected the protein solubility. In most foam, the soluble protein forms the thin foam films or exists as lamellas between adjacent bubbles. In addition, the increase in concentration of foam enhances greater protein–protein interaction, which increases viscosity and facilitates formation of a multi-layer cohesive protein film at the interface. Therefore, the coalescences of bubbles are offered resistance by this film formation. In addition, the increase in concentration could lead to formation of thicker films, which limits the effect of drainage of protein from films. Adebowale and Lawal, (2003).

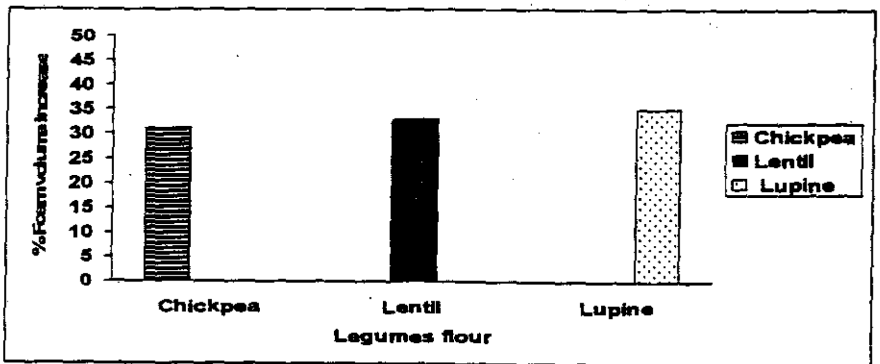

Fig. (1): % Foam volume increase of legumes flour.

Rheological properties of wheat flour, legumes flours and their blends:
Farinograph properties:

Supplementation of wheat flour with different level of legume flours (5%, 10%, and 15%) caused different effects on the Farinograms of the produced blends. The results in Table (4) showed that dough made from 100% wheat flour

(72 % extraction) had 60.5% water absorption, supplementing wheat flour with legumes flour caused an increase in water absorption of all the blends. Generally, blends substituted with different levels of sweet lupine flour absorbed more water than those supplemented with the same levels of chickpea or lentil flours.

Table (4): Effect of legumes flours on farinograph parameters

Samples	Water absorption (%)	Mixing time (min)	Stability time (min)	Degree of weakening (B U)
100 % wheat flour (72 %extraction)	60.5	2.5	1.5	40
Chickpea 5%	61.5	2.0	1.0	50
10%	62.0	2.5	1.0	60
15%	63.5	2.5	1.0	120
Lentil 5%	61.0	2.5	1.5	40
10%	61.5	2.5	2.0	60
15%	63.0	3.00	2.0	70
Sweet Lupine 5%	62.0	2.5	1.0	60
10%	63.5	3.0	3.0	90
15%	64.5	3.0	2.0	120

The results showed that sweet lupine flour protein had higher water holding capacity than the different tested legumes flour. The increase in water absorption was probably a result of the higher protein content of the blends causing greater hydration capacity. Same results were obtained by Bahgaat, (2000), and Abd El-Hamid. (2002).

On the other hand, blends containing different levels of legumes flour showed higher dough development time (mixing time) than control (100% wheat flour) with the exception for chickpea flour 5%.The highest increase in mixing time was observed when lupine flour was incorporated with wheat flour. The increase in mixing time is due to differences in the physical and chemical properties of the legumes flour protein. In addition, the increase in mixing time may be due to differences in particle size of the legumes flour and wheat flour Hegazy and Faheid (1991) and Rasmay *et al.* (2000).

Dough stability is the most important index for dough strength. Dough stability had been attributed to protein poor in sulfhydryll groups, which normally caused a softening, or degradation action of the dough. Consequently, the replacement ratio of wheat flour with chickpea flour may decrease the dough stability.

In general, it could be concluded that the low dough stability of the chickpea blends might be due to the higher fiber content, which destroyed the gluten matrix. On contrary dough mixture, containing lentil and lupine flour had a higher stability time than control. The increase in dough stability could be attributed to the increase in protein level, which could render the dough more stable. Same results obtained by Hegazy and Faheid (1991) and Rasmay *et al.* (2000).

Different legume blends had higher values of degree of weakening than wheat flour. As could be seen from Table (3) the degree of weakening of control dough was 40 B.U. and it increased to 120 B.U. for those contained 15% of chickpea and lupine flour. These results are agreement with those of Hassan, (1998), Bahgaat, (2000) and Abd El-Hamid (2002)

Extensograph properties:

The Extensograph is used for determining the extension of the dough prepared by mixing the wheat flour with gradient levels of chickpea, lentil, and sweet lupine flour. The resistance to extension, extensibility, proportional number and energy (the total area under the curve) were calculated. These results were calculated after 135 min. of rest period and appeared in Table 5.

Table (5): Effect of wheat and legumes flours on extensograph parameters:

Samples	Extensibility (ml)	Resistance of Extension (BU)	Proportional number	Energy (cm^2)
100% wheat flour (72 %extraction)	105	950	9.04	96.5
Chickpea 5%	90	860	9.56	87.2
10%	105	790	7.52	83.0
15%	125	700	5.6	88.6
Lentil 5%	105	850	8.09	88.9
10%	110	720	6.55	84.7
15%	120	595	4.96	76.6
Sweet Lupine 5%	125	880	7.04	113.1
10%	130	830	6.38	108.6
15%	135	530	3.93	85.8

From results in Table (5), it could be noticed that dough extensibility showed a rather pronounced increase as the amount of sweet lupine flour increased. It was 105, 125, 130 and 135 (ml) for dough prepared from wheat flour mixed with 0, 5%, 10% and 15% sweet lupine flour respectively. On the other hand, substitution of wheat flour with different level of chickpea and lentil flour (5%, 10%, and 15%) caused same or little increase for extensibility in comparison with control (100% wheat flour72%extraction) with the only exception in the case of using chickpea flour 5%.

The highest increase in extensibility was observed when wheat flour was incorporated with 15 % chickpea and lentil flours. The resistance of the dough to extension was decreased as the amount of legumes flour increased. The resistance to extension of control dough was 950 BU decreased to 530 BU for those contained 15% sweet lupine flour.

Addition of 5% sweet lupine flour displayed higher maximum resistance to extension .The proportional number showed a pronounced decrease as the level of legumes flour increased with the exception for chickpea flour 5%. The proportional number of control dough was 9.04 and it decreased to 3.93 for sample contained 15% sweet lupine flour. Addition of 5% chickpea flour displayed higher maximum proportional number 9.56 than did other legumes flour and control sample.

Most of the extensograms assure the direction of dough weakening due to addition of legumes flours and this could be explained to the less forming of gluten network, but in case of 5% additives, this matter was very limit.

From the results it could be concluded that there is a possibility for using 5% legumes flour to improve the protein digestibility and without a marked effect on the rehological properties of the supplemented wheat flour.

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دراسات على الخواص الوظيفية والريولوجية والقابلية للهضم لدقيق القمح المدعم بدقيق بعض البقوليات

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أجريت هذه الدراسة بهدف معرفة مدى تأثير استبدال دقيق القمح (إستخراج ٧٢ %) بدقيق بعض البقوليات (الحمص – الترمس- العدس) على التركيب الكيميائى وكذلك الخواص الوظيفية والريولوجية لدقيق القمح ولقد أظهرت النتائج أن دقيق القمح المستخدم يحتوى على ١٣,٢٠%، ١١,٥٣ %، ١,٠٢ %، ٠,٥٦ %، ٠,٢٦ %، ٨٦,٦٣ % من الرطوبة والبروتين والدهن والرماد والألياف والكربوهيدرات على

التوالى. وجد أيضا ان دقيق البقوليات يحتوى على نسبه عالية من البروتين تراوحت بين ٢١,٢٠ % الى ٣٦,٨٠ % أما نسبة الدهن فى دقيق البقوليات فكانت ١,٨٨ % و٤,٣٥% و١٠,٧٨ % لكل من العدس والحمص والترمس .تراوحت نسبة الرماد فى دقيق البقوليات بين ٢,٢٠ % و ٣,١٤ %.تراوح محتوى الألياف الخام فى دقيق البقوليات بين ٣,٥٩ % و٦,٨٨ %.

أظهر دقيق البقوليات ارتفاعا فى القدرة على امتصاص الماء والدهن مما يزيد من إمكانية استخدامهما فى العديد من المنتجات الغذائية مثل منتجات المخابز واللحوم. ولقد وجد أن دقيق البقوليات له قدرة كبيرة على تكوين الرغوة، عند قياس الخواص الريولوجية للعجينة المحتوية على دقيق البقوليات باستخدام جهازى الفارينوجراف والإكستنسوجراف وجد أن إضافة دقيق البقوليات أدت إلى زيادة إمتصاص الدقيق للماء بنسب متفاوتة بين العينات التى تم دراستها ووجد أن دقيق القمح هوالأقوى بين العينات. وأظهرت نتائج الإكستنسوجراف أيضا اتجاه العجينة إلى الضعف من خلال انخفاض المرونة وكذلك الرقم النسبى.، ويمكن التوصية باستخدام نسبة إضافه من دقيق البقوليات فى حدود ٥% دون تأثير سلبى واضح على الخصائص الريولوجيه وفى نفس الوقت الإستفادة مما تحققه هذه بالإضافة الى تحسين فى الخصائص الوظيفية وارتفاع متوقع فى قابلية البروتين للهضم.