The Use of Gum Arabic from Acacia Tree (*Acacia senegal*), a Food Additive to Improve the Nutritional and Rheological Properties of Wheat Flour Dough

Yousif A. Elhassaneen[1], Yahya A. Abd Elhady[2] and Nehal H. Mohamed[1]

[1]Department of Nutrition and Food Science, Faculty of Home Economics, [2]Home Economics Division, Faculty of Specific Education (Ashmoun), Minoufiya University, Shebin El-Kom, Egypt
Yousif12@hotmail.com

Abstract: The aim of this study was to elucidate the influence of gum arabic (GA) from acacia tree on nutritional and rheological properties of wheat flour dough. The results showed that the addition of GA by 4% to wheat flour has induced non significant decreasing in its content from moisture, total protein, crude fat and carbohydrates, while crude fiber and ash content were significantly increased by the ratio of 572.13%, 20.31% in comparison with the control sample, respectively. Rheological properties revealed that the addition of GA to the dough decreased water absorption. However, development time and stability of the dough increased. Regarding the pH-farinograph, results shows that the values of the samples with the addition of GA were not affect significantly with the control sample. According to farinograph quality number (FQN), the improvement in quality of the doughs occurred only after the addition of 1.0 g.100g^{-1} GA, when the FQN value increased significantly in comparison with the control sample. Regarding extensograph measurements the addition of GA to the dough increased strength (Extensibility) and resistance to extension. In conclusion, GA from acacia tree is able to increase the fiber content of wheat flour, modify the rheological properties of its dough and thus improve the quality of the final bakery products. Like of these products will be in a high degree of importance from the nutritional and therapeutic point of views.
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1. Introduction

Gum arabic (GA) refers to dried exudates obtained from the stems and branches of *Acacia senegal* (L) or *Acacia seyal*. The exudate is a non-viscous liquid, rich in soluble fibers, and its emanation from the stems and branches usually occurs under stress conditions such as drought, poor soil fertility, and injury (Williams & Phillips, 2000). Such as reported by Phillips and Williams (1993), there are over 1000 species producing commercial Acacia gum which grow naturally in the semi-arid sub-Saharan regions of Africa. Although from the 1950s to the early 1990s, Sudan accounted for roughly 80% (60 kTn/year) of gum arabic production, today, that figure is under 50% (World Bank, 2007). New GA-producing countries such as Chad and Nigeria which produce mainly Acacia seyal are actively participating in the global production (Abdel Nour, 1999). Europe and U.S. are the most important GA markets importing 40 kTn/year, on average, while Japan, the largest Asian consumer, imports about 2 kTn/year. Structurally, gum arabic is a neutral or slightly acidic salt of a complex polysaccharide composed of galactose, arabinose, rhamnose, glucuronic acid, 4-*O*-methylglucuronic acid, calcium, magnesium, and potassium. The molecular weight has been reported to be 600,000 (Anderson and Dea, 1971). Gum arabic is distinguished from other gums by its high solubility in water; 50% solutions can be prepared, compared with maximum concentrations of 5% or less for most other gums (Furia, 1972).

The use of GA dates back to the year 2000 BC when the Egyptians used it as an called "Gum arabic" because was exported from Arabian ports (Abdul, 2002). Today, the properties and features of GA have been widely explored and developed and it is being used in a wide range of industrial sectors such as textiles, ceramics, lithography, cosmetics, pharmaceuticals and food. Regarding food industry, GA is approved for use as a food additive by the U. S. Food and Drug Administration and is on the list of substances "generally recognized as safe" (CFR, 1974). GA is used as a stabilizer, a flavor fixative, a thickener, an adhesive and/or an emulsifier agent (Verbeken *et al.,* 2003). The following products may contain GA at approximately the concentrations indicated: candy (28%); chewing gum (2.8%); imitation dairy products, frostings, fats and oils, and grain products (1%); sugar substitutes, fruit ices, nut products, and gelatin puddings (0.5% - 0.06%); baked goods, meat products, and alcoholic beverages (0.15% - 0.06%); instant coffee and tea (0.08% - 0.01%); nonalcoholic beverages (0.06% - 0.04%), processed fruit, frozen dairy products, and breakfast cereals (0.02% - 0.007%) (Life Sciences Research Office, 1973).

Additionally, many studies have confirmed the effective biological role of GA including reduction in plasma cholesterol level in animals and humans (Sharma, 1985 and Tiss *et al.,* 2001), anticarcinogenic effect (Nasir *et al.,* 2010) and antioxidant effect (Al-Majed *et al.,* 2002; Ali *et al.,* 2003; Trommer and Neubert, 2005 and Ali and AlMoundhri, 2006) with a protective role against hepatic and cardiac toxicities. In addition to that, it has been claimed that GA alleviates effects of chronic renal failure in humans (Matsumoto *et al.,* 2006; Ali *et al.,* 2008Glover *et al.,* 2009 and Ali *et al.,* 2010). Also, GA is indigestible to both humans and animals, not degraded in the intestine, but fermented in the colon to give short-chain fatty acids, leading to a large range of possible health benefits (Phillips and Philips, 2011). One of these benefits is its prebiotic effect (Phillips *et al.,* 2008). Calame *et al.,* (2008) reported that four week supplementation with Gum Arabic (10 g/day) led to significant increases in Bifidobacteria, Lactobacteria, and Bacteriodes indicating a prebiotic effect. Several epidemiological studies suggest that a high intake of dietary fiber, including GA (dietary fiber > 80%), is associated with beneficial effects on fat metabolism [Slavin, 2003 and Ali *et al.,* 2009]. It can serve to reduce obesity and therefore prevent associated complications in humans including coronary heart disease, stroke and diabetes (Lear *et al.,* 2003 and Hedley *et al.,* 2004). Therefore, there is substantial evidence that GA can play a positive health-related role in addition to its well-known properties as a food additive. In an attempt to open up a new horizon for the use of GA in an important nutritional and food technological applications, in this study, we will use of GA, a food additive to improve the nutritional and rheological properties of wheat flour dough subsequently improve the quality of the final bakery products.

2. Materials and methods

2.1 Materials

Gum Arabic (*Acacia senegal* L.) was obtained in three batches from the SAVANNA Companies Group (Processing Gums, Juices and Confectionery), Khartoum, Sudan. (Specification: appearance colour-off white, appearance form- powder, purity, 98.14± 0.65%).

Wheat flour**,** variety Giza 155 wheat (*Triticum vulgare*) was obtained from Shebin ElKom market, Menoufiya Governorate, Egypt during the 2012 harvesting period. The collected samples was transported to the laboratory and stored immediately on the refrigerator at 0 ^{0}C until using in preparation of flour.

All chemicals, buffers and solvents in analytical grade were purchased from El-Ghomhoria for Trading of Drug, Chemicals and Medical Instruments, El-Sawah, Cairo, Egypt.

2.2 Preparation of wheat flour:

The wheat kernels samples were go out the refrigerator and sieved to get rid of any foreign matters or dust. Kernels were then dried to below 10 % moisture content and were then adjusted to the moisture content required which was 14%. The quantity of water added to the quantity of grains to reach the level 14% moisture content was according to the formula mentioned by Ahmed et al., (1982) as follow:

$$X = 100 \times \frac{B - A}{100 - B}$$

Where: X, the quantity of water to be added to 100 grams of wheat; A, the initial moisture content and B, the moisture content required.

The kernels was milled by using of laboratory mill and sieved through 60 and 50 meshes screen to obtain wheat flour extraction rate 72.

2.3 Methods

2.3.1 Chemical properties

Moisture, protein (T.N. x 6.25, Micro-Kjeldahl method), Fat (Soxhelt appratus, petrolium ether solvent), crude fiber and ash contents were determined using the methods described in the A.O.A.C. (1994). Carbohydrates content was obtained by subtraction of contents of moisture, protein, total lipids, crude fiber and ash from 100.

2.3.2 pH-farinograph

pH was measured of the dough by means of a pH-meter (HANNA pH 210) at a temperature of 22 ±1 °C during the farinograph measurement. Within the farinograph measurement, pH was determined in the dough which consisted only of redistilled water and flour. In order to discover if the addition of particular hydrocolloids influenced the key values, the results were compared with the values of the control sample which did not contain any additives.

2.3.3 Rheological properties

Rheological properties of both wheat flour control sample and samples with additions of GA (*Acacia senegal*) were determined by using of farinograph and extensograph tests according to the methods of A.A.C.C. (1969) as the following: the individual measurements were performed in GA in four different additions. The amounts of the gum were selected according to their chemical structure and their effect on the rheological properties of dough. Higher amounts were used in the case of GA because the differences between the control sample and the addition of 1.0 g.100g^{-1} were not very significant.

Therefore the additions of 0.5 $g.100g^{-1}$, 1.0 $g.100g^{-1}$, 2.0 $g.100g^{-1}$and 4.0 g.kg−1 were used.

Farinograph measurement:

Farinograph test was carried out on a Brabender R Farinograph (BrabenderR GmbH & Co, Duisburg, Germany) to determine the water absorption, dough development time, dough stability and dough weakening of wheat flour control sample and samples with additions of GA according to the following procedure: A 300 grams of wheat flour were placed in the farinograph bowel and the burette filled with water at room temperature and set at zero adjustment. The machine was set at high speed and was run for one minute until zero minute line was reached. Water was added immediately to the side of the bowel from the burette nearly to the volume expected to be the right absorption of flour. When the dough was beginning to be form, sides of the bowel were scraped down. When the mixing curve leveled off at a value larger then 500 Brabender unit (B.U), more water was added and the bowel was covered with a glass plate tp prevent evaporation. Subsequent titration were needed to adjust the absorption curve at 500 B.U for final titration the total volume of water was added within 25 seconds after opening burette's stopcock. Absorption values were corrected to the nearest 0.1% and were calculated on 14% moisture basis by means of the following equation:

$$\text{Absorption } \% = (x + y - 300) /3$$

Where: x, ml of water required to produce curve with maximum consistency entered on 500 B.U. line and y, grams of flour equivalent to 300 grams 14% moisture basis.

Extensograph measurement:

Extensograph test was carried out on a Brabender R Extensograph (BrabenderR GmbH & Co, Duisburg, Germany) to determined the maximum resistance to extension extensibility and strength of the dough (energy) of wheat flour control sample and samples with additions of GA according to the following procedure: A normal run of a farinograph was made in order to estimate the water absorption capacity of the flour. The estimated water containing 6 grams of salt was added to 300 grams of flour to form dough having consistency of 500 B.U. The ingredients were then mixed for one minute and the mixing was stopped after 5 minutes of rest mixing was resumed and continued until the full development time of the farinograph. When mixing was completed dough of 150 grams was scaled off and was given 20 revolutions in the extensograph rounder. The dough ball was carefully centered on the shaping unit and rolled into a cylindrical test piece, which was then clamped in a lightly greased dough holder and stored in humified chamber for testing. After rest period of nearly 45 minutes from the shaping operation, the test sample was placed on the balance arm of the extensograph and pen was adjusted horizontally of zero line on chart. At exactly 45 minutes from the end of the shaping operation, the stretching hook was started. It was stopped when the test piece broke. Afterthat , the dough was removed from its holder, reshaped and allowed a rest period of 45 minutes, and then stretched again. By repeating this procedure, the dough was tested at 45 minutes, 90 minutes and 135 minutes total time. The following measurements were made on the extensograms, resistance to extension, extensibility and energy (area under curve, cm^2), to evaluate the results of the extensograph.

2.4 Statistical Analysis

Statistical analysis was performed with the Student *t*-test and MINITAB 12 computer program (Minitab Inc., State College, PA).

3. Results and discussion

3.1 The effect of GA on the proximate analysis and nutritional value of wheat flour

Data in table (1) indicated the proximate analysis of wheat flour control sample and samples with additions of GA. With the increasing addition of GA up to 4%, the value of moisture, total protein, crude fat and carbohydrates in the sample were not significant decreasing in comparison with the control sample. Crude fiber and ash contents were recorded the opposite direction the difference between the lowest addition (0.50 g. $100g^{-1}$ GA) and the control sample is significant for the crude fiber. The highest addition (4.0 g.100 kg^{-1}) of GA resulted in a difference of 572.13% and 20.31% for fiber and ash contents in comparison with the control sample. On the other side, nutritional properties of flour and its products may be altered as the result of such chemical composition alterations. These properties include the total energy (Kcal/100g), the daily requirement of adult man from energy (GDR/energy) and from protein (GDR/protein), percent satisfaction of the daily requirements of adult man in energy (P.S./energy) and protein (P.S./protein). With the increasing addition of GA up to 4%, the value of total energy, GDR/energy and GDR/protein in the sample were significant altering in comparison with the control sample. In general, the significant increasing in fiber content of wheat flour (more than five folds) subsequently its final bakery products will be in a high degree of importance from the nutritional point of view. Fiber resulting from the addition of GA is a soluble dietary fiber (SDF) with unique properties. There is preliminary evidence that SDF can increase fecal nitrogen excretion and lower serum concentrations of urea and other retained metabolites in chronic renal failure (CRF) patients (Bliss and Settle, 1991). The use of dietary fiber to increase fecal excretion of retained metabolites in CRF may be a beneficial adjunctive therapy (Bliss *et al.,* 1996). SDF help decrease the total cholesterol and the LDL-cholesterol which has a negative influence on coronal heart diseases. Twenty five grams of SDF from GA per day reduce the total cholesterol significantly and have therefore a positive influence on the prevention of coronal heart diseases (McLean-Ross *et al.,* 1983). It has a positive effect on the microbiological flora in the bowl, provides it with fermentable carbon and enables suitable conditions for probiotic bacteria by decreasing the pH due to the production of Short Chain Fatty Acids (Hill, 1983). Additionally, The absorption of minerals in the bowel is increased through SDF and the nitrogen metabolism is positively influenced by SDF (Wapnir *et al.,* 1996).

Table 1. Proximate analysis and nutritional value of wheat flour control sample and samples with additions of gum arabic (*Acacia senegal*)

Component	Control sample	Gum arabic ($g.100g^{-1}$)			
		0.5	1.0	2.0	4.0
Moisture (%)	14.03 [a***]	13.98 [a]	13.89 [a]	13.81 [a]	13.62 [a]
Total protein (%)	10.83 [a]	10.80 [a]	10.71 [a]	10.68 [a]	10.46 [a]
Crude fat (%)	1.22 [a]	1.22 [a]	1.21 [a]	1.18 [a]	1.16 [a]
Crude fiber (%)	0.61 [e]	1.14 [d]	1.62 [c]	2.69 [b]	4.10 [a]
Ash (%)	0.64 [b]	0.66 [b]	0.68 [b]	0.71 [a]	0.77 [a]
Carbohydrates (%)	72.67	72.31	71.95	71.22	69.77
Energy (Kcal/100g)	344.98 [a]	343.41 [a]	341.50 [a]	338.22 [a]	331.37 [b]
G.D.R. (g) *					
for protein (63 g)	581.72 [b]	583.33 [a]	588.24 [a]	589.89 [a]	602.29 [a]
for energy (2900 Kcal)	840.63 [b]	844.47 [b]	849.19 [b]	857.42 [a]	875.16 [a]
P.S./ 80 g (One loaf, %) **					
for protein (63g)	13.75 [a]	13.71 [a]	13.60 [a]	13.56 [a]	13.28 [a]
for energy (2900 Kcal)	9.52 [a]	9.47 [a]	9.42 [a]	9.33 [a]	9.14 [a]

* G.D.R. (g): Grams consumed to cover the recommended daily allowance of adult man according to RDA (1989).

** P.S./130 (%): Percent satisfaction of RDA of adult man when consuming 80 grams of product (equivalent to one loaf of white baladi bread).

*** Means in the same row with different letters are significantly different at $p < 0.05$.

3.2 The effect of GA on the Rheological properties of wheat flour

3.2.1 Farinograph measurements

The results of farinograph measurements (Table 2 and Figure 1) show the influence of GA on the qualitative properties of the wheat flour dough, which are important during its processing. The results reveal that the control dough sample (without the addition of GA) has a sginificant higher absorption than the samples of dough with the additions of GA and also that with the increasing amount of GA the absorption is gradually decreasing. Such as reported by Nasr, (1998) this decrease in the water absorption value under the control samples could be related to the decrease in the quantity of the protein (See table 1).

From the viewpoint of dough development time (mixing time, min), statistically significant difference was found between the control sample and the doughs with additions of GA (0.5-4.0 $g.100g^{-1}$) between the dough with the lowest addition (0.5 $g.100g^{-1}$1) and the dough with the additions of (1-4 $g.100g^{-1}$) and also between the dough with the addition of 1.0 $g.100g^{-1}$g and the doughs with the additions of (2-4 0.5-4.0 $g.100g^{-1}$) GA ($P < 0.05$). Is that means, in comparison with the control sample, the dough development time increased with the rising addition of GA. The increasing dough development time illustrates that the dough with the addition of GA a longer relaxation time (the dough is tougher). Our data are in agreement with that mentioned by Pecivova *et al.,* (2011) and not in agreement with that mentioned by Barcenas *et al.* (2009) who said that the addition of arabic gum decreased the elastic modulus at 25 °C. Such as mentioned by Khalil *et al.,* (1976) and Nasr (1998) the peak dough development time was affected and varied proportionally with the protein content of the flour and its quality. Consequently, the affecting on the peak dough development of wheat flour as the result of GA addition can comes through changes occurred in wheat flour protein quality.

Dough stability in minutes is the most important index for dough strength. Addition of GA to flour samples showed markedly longer stability periods than the control samples (without the addition of GA). This affect was significantly started with the addition of 1.0 $g.100g^{-1}$ for wheat flour and also that with the increasing amount of GA the dough stability is gradually increasing. This affect could be attributed to the effect of GA addition on the quality of protein flour in particular the binding force property. Regarding the pH-farinograph, results shows that the values of the samples with the addition of GA were not affect significantly with the control sample. Our results are in agreement with that observed by Pečivova *et al.,* (2011).

From the viewpoint of dough farinograph quality number (FQN), statistically significant difference was found between the control sample (without the addition of GA) and the doughs with additions of GA (1.0 -4.0 g.100g-1) ($P < 0.05$). It is meaning that an improvement in the quality of the doughs occurred after the addition of 1.0 $g.100g^{-1}$, when the FQN value significantly increased in comparison with the control sample. Such as mentioned by Pecivova *et al.,* (2011), FQN determines the quality of dough and thus influences the quality of the final bakery product. Therefore, in order to improve the quality of bakery products, higher additions of GA (more than 1 $g.100g^{-1}$) to dough are recommended.

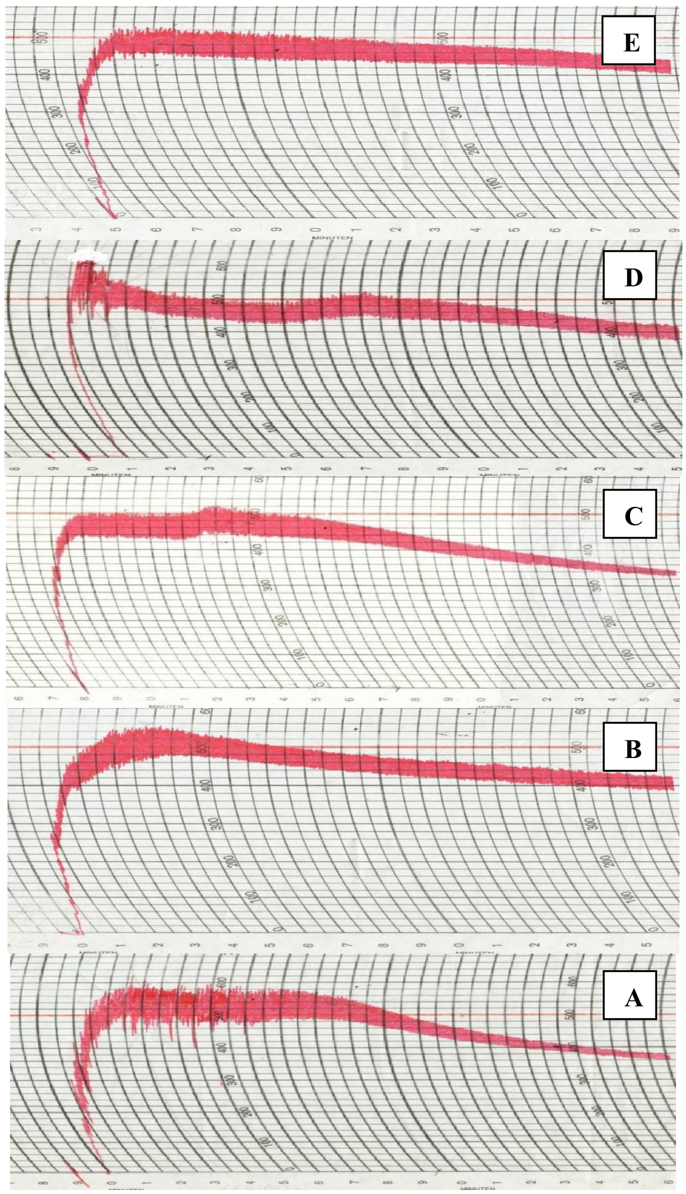

Figure 1. Farinograms of wheat flour control dough and dough's with additions of gum arabic [GA]
A: control dough B: 0.5 $g.100g^{-1}$ GA C: 1.0 $g.100g^{-1}$ GA
D: 2.0 $g.100g^{-1}$ GA E: 4.0 $g.100g^{-1}$ GA

Table 2. Farinograph results of wheat flour control dough and dough's with additions of gum arabic (*Acacia senegal*)

Parameters	Control sample	Gum arabic ($g.100g^{-1}$)			
		0.5	1.0	2.0	4.0
Water absorption (%)	59.1^{a*}	58.2^{a}	57.4^{b}	56.5^{b}	55.4^{b}
Dough development time (min)	2.3^{d}	4.1^{c}	5.9^{b}	7.2^{a}	6.8^{a}
Arrival time (min)	1.2^{b}	1.3^{b}	1.5^{a,b}	1.8^{a}	2.0^{a}
Stability (min)	6.4^{b,c}	6.0^{b,c}	8.1^{b}	11.9^{a}	12.8^{a}
pH- farinograph	6.07^{a}	6.03^{a}	6.06^{a}	6.07^{a}	6.04^{a}
Farinograph quality number (FQN)	152^{c}	150^{c}	158^{b}	160^{b}	166^{a}

* Means in the same row with different litters are significantly different at $p < 0.05$

3.2.2 Extensograph measurements

Data in table (3) and figure (2) show the extensograph results of wheat flour control dough and dough's with additions of GA. Dough strength (Extensibility) determined by the area under the curve and is proportional to energy needed to bring about rupture. The results reveal that the control dough sample (without the addition of GA) has a significant lower extensibility than the samples of dough with the additions of GA and also that with the increasing amount of GA the extensibility is gradually increasing. Dough resistance to extension in B.U. is the most important index for dough ability to retain gas. Addition of GA to flour samples showed markedly increasing resistance to extension than the control samples (without the addition of GA) and also that with the increasing amount of GA the resistance to extension is gradually increasing. The effect of GA on increasing the extensibility of the wheat flour may be due to the alteration of the viscosity (Kent-Jones and Amos, 1967) and forced the gluten net work (Abdel-Hamid *et al.,* 1986). Additionally, several reports suggest that GA has antioxidant activity (Al-Majed *et al.,* 2002, 2003) which could be easily prevented the oxidation process usually decreases dough extensibility (Khalil *et al.,* 1976). Also, GA have scavenging of free radical species including reactive oxygen species (ROS) (Aruoma, 1994). Oxygen from air oxidizes-SH groups forming disulfide linkage and thus, increases the cross linkage between the protein molecules responsible for the decreasing of the dough extensibility.

Table 3. Extensograph results of wheat flour control dough and dough's with additions of gum arabic (*Acacia senegal*)

Parameters	Control sample	Gum arabic ($g.100g^{-1}$)			
		0.5	1.0	2.0	4.0
Extensibility (mm)	180^{c*}	184^{b}	189^{b}	196^{a}	198^{a}
Relative resistance to extension (B.U.)	520^{c}	531^{b}	538^{b}	549^{a}	552^{a}
Proportional number	2.88^{a}	2.89^{a}	2.85^{a}	2.80^{b}	2.79^{b}
Energy (cm^2)	113^{c}	116^{b}	118^{b}	123^{a}	126^{a}

* Means in the same row with different litters are significantly different at $p < 0.05$

Conclusion

In conclusion, this study has been used of GA from acacia tree, a food additive to improve the nutritional and rheological properties of wheat flour dough subsequently improve the quality of the final bakery products. The addition of GA by 4% to wheat flour has induced significant decreasing in crude fiber and ash content by the ratio of 572.13%, 20.31% in comparison with the control sample, respectively. According to the rheological properties the improvement in quality of the wheat flour doughs occurred only after the addition of 1.0 g.100g−1 GA. Thus, GA from acacia tree is able to increase the fiber content of wheat flour, modify the rheological properties of its dough and thus improve the quality of the final bakery products. Like of these products will be in a high degree of importance from the nutritional and therapeutic point of views.

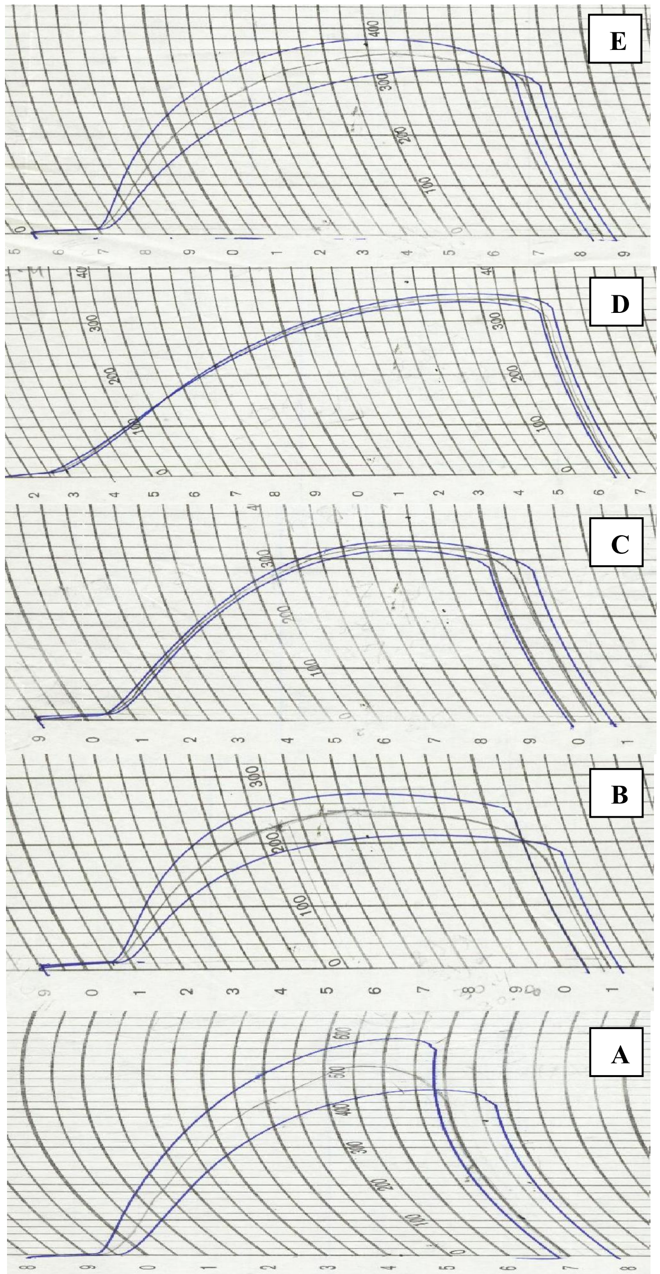

Figure 2. Extensograms of wheat flour control dough and dough's with additions of gum arabic [GA]
A: control dough B: $0.5\ g.100g^{-1}$ GA C: $1.0\ g.100g^{-1}$ GA
D: $2.0\ g.100g^{-1}$ GA E: $4.0\ g.100g^{-1}$ GA

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Corresponding author:
Prof. Dr. Yousif Elhassaneen
Department of Nutrition and Food Science, Faculty of Home Economics, Minoufiya University, Shebin El-kom, Egypt
Tel/Fax: + 2048 222 7638
P.O. Box: 32511
Email: yousif12@hotmail.com

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