NEW TRENDS FOR USING GUM ARABIC IN SOME FOOD PROCESSING AND THERAPEUTIC APPLICATIONS

by

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Abstract:

Food gap expresses an increase in consumption over the rate of production, which may lead the concerned country to import food from abroad. On the other hand, coinciding with the nutritional gap is the exacerbation of chemically synthesized therapies or drugs. Therefore, the present study was carried out in a trial to open up new horizons for the use of gum arabic (GA) in some food processing and therapeutic applications. For food processing application, mixing of wheat flour with Arabic gum at level 4% improved the properties of the dough (farinograph and extensograph parameters), which will reflect positively on the properties of the resulting bread. For therapeutic applications, intervention with GA at levels 2 to 4% are able to prevent or inhibit liver injuries induced by ubiquitous chemical toxin i.e. B(a)P. GA exhibit liver injuries inhibiting effects probably by improving the liver functions, modulating regulators of drug metabolizing enzymes (cytochrome P450) and glutathione fractions (Reduced, GSH,

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and oxidized, GSSG, glutathione) as well as inhibiting the lipid peroxidation parameter (malonaldehyde content, MDA) in liver cells. In conclusion, data of the present study recommended that GA by a concentration up to 4% (w/w) to be included in our daily dishes, beverages and pharmaceutical formulae.

Keywords: Chemical composition, farinograph, extensograph, benzo(a)pyrene, glutathione, cytochrome p450, malonaldehyde

Introduction

The food gap means the ratio between the rate of consumption of food and the rate of production of different foods in a country, so that the gap expresses an increase in consumption over the rate of production, which may lead the concerned country to import food from abroad (Al-Ajili 2012). Among the most common causes that exacerbate the problem of the food gap in various countries of the world, including Egypt, are population growth, low wage rates, the dominance of the consumption pattern, construction on agricultural land and its negative use, the decline in financial resources and expenditures on agricultural activity, the decrease in water resources, as well as the lack of the use of research strategies in the agricultural field leads to an increase in productive poverty (https://www.almrsal.com/post/1087150). In this regard, numerous studies indicated that the food gap in the Arab world, including Egypt, amounted to 128 billion dollars in 2015, and that it takes 30 years for Arab countries to bridge the food gap (Al Hammadi, 2013). On the other hand, coinciding with the nutritional gap is the exacerbation of chemically synthesized therapies or drugs. In order to overcome these problems, the

attention of scientists in all universities and academic research centers around the world are directed to searching for non-traditional foods and expanding the base of their use and benefit from them. On top of these sources is gum arabic (GA), which has been known for thousands of years for its nutritional value, as well as its richness in various groups of biologically active ingredients (Hegazy, 2014Elhassaneen et al., 2014 and 2018; Ahmed 2020). All of these factors and others open the way for more research studies to be conducted to expand the areas of its use as a promising material to be added to foods to produce functional foods, or to use it as a therapeutic material against many diseases that harm humans.

GA is an edible biopolymer obtained as exudates of mature trees of Acacia senegal and Acacia seyal which grow principally in the African region of Sahe in Sudan. Gum is essentially the secretion of several acacia (leguminous) trees. Acacia Gum species, of which there are up to seventeen, produce acacia gum of varying quality and quantity. 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 and Phillips, 2000). Such as reported by MSN (2008) there are close to 900 Acacia species capable of producing gum. Africa is the major site of the production of gum; this is the reason why it is also referred to as ‘Senegal Gum’. Interestingly, close to 80% of Gum Arabic is produced by the Acacia senegal (in Sudan). The remainder is produced either by the Acacia laeta or the Acacia seyal, with each species contributing 10% to the total supply of gum. Europe

countries and United States are the most important GA markets importing 40 kTn/year, on average, while Japan, the largest Asian consumer, imports about 2 kTn/year (Elhassaneen et al., 2014).

From the chemically point of view, GA 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 as well as the molecular weight has been reported to be 600,000 (Anderson and Dea, 1971; Hegazy, 2014). GA 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 chemical composition of GA is complex and consists of a group of macromolecules characterized by a high proportion of carbohydrates (~ 97%), which are predominantly composed of D-galactose and L-arabinose units and a low proportion of proteins (<3%) (Islam et al., 1997 and Mohamed, 2013; Ahmed, 2022).

The use of GA dates back to the year 2000 BC when the Egyptians used it as a 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 (Hegazy, 2014). Additionally, 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). In this direction, several

authors were fortified the flour with different levels of GA and produced high-dietary fiber bakery products (Mohamed, 2013; Elhassaneen et al., 2013 and 2014; Hegazy, 2014). Also, the addition of GA to the flour leads to enhance the rheological properties of the dough subsequently the quality of the manufactured breads. Also, GA is used as a stabilizer, a flavor fixative, a thickener, an adhesive and/or an emulsifier agent (Verbeken et al., 2003). Furthermore, the Life Sciences Research Office reported that different food product such as candy, chewing gums, fats and oils, sugar substitutes, nut products, gelatin puddings, baked products, meat products, beverages, coffee and tea, processed fruit, frozen dairy products, and breakfast cereals contains GA from 0.02 up to 28% (Life Sciences Research Office, 1973; Elhassaneen et al., 2014).

On the other side, the biological role of GA has been confirmed in the last three decades. Such role includes reduction in plasma cholesterol level (hypocholesterolemic), anticarcinogenic and antioxidant effects as well as protective role against hepatic and cardiac toxicities (Sharma, 1985; Tiss et al., 2001; Al-Majed et al., 2002; Trommer and Neubert, 2005; Ali and AlMoundhri, 2006; Nasir et al., 2010; Kotb, 2018; Ahmed, 2022). Also, it has been claimed that GA alleviates effects of chronic renal failure in humans (Glover et al., 2009; Ali et al., 2010; Domma et al., 2016; Elhassaneen et al., 2022). Furthermore, GA fermented in the colon of human to give short-chain fatty acids, leading to a large range of possible health benefits as prebiotic effect (Phillips et al., 2008; Phillips and Philips, 2011). Finally, 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; Ahmed, 2022).

All of above reasons and others proposed the widely used of GA around the world in folk medicine. It has been used internally for the treatment of inflammation of the intestinal mucosa, and externally to cover inflamed surfaces (Gamal el-din et al., 2003). Also, it used as a vehicle for drugs in experimental physiological and pharmacological experiments, and is assumed to be an ‘‘inert” substance. Furthermore, recent reports have claimed that GA possesses anti-oxidant, nephroprotectant, antiobese and other effects (Gamal el-din et al., 2003 : Ali et al., 2008; Ahmed, 2022: Dommah et al., 2016 and Elhassaneen et al., 2022). Clinically, it has been tried in patients with chronic renal failure, and it was claimed that it helps reduce urea and creatinine plasma concentrations and reduces the need for dialysis from 3 to 2 times per week (Suliman et al., 2000 and Abd El-Kafee, 2012). Therefore, the present study was carried out in a trial to open up new horizons for the use of GA in some food processing applications through fortify the wheat flour with GA in order to enhance its rheological properties subsequently improve the resulted bread. Also, the use of GA in some therapeutic applications through investigate the potential effects of GA intervention in

amelioration the liver disorders induced by benzo(a)pyrene in rats will be in the scope of this study.

Materials and Method

Materials

Gum Arabic (Acacia senegal L.) was obtained as a donation 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 (Triticum vulgare) was obtained from Benha City local markets, Qulubia Governorate, Egypt during the 2021 harvesting period. The collected samples was transported to the laboratory and stored immediately on the refrigerator at 0 0C until using in preparation of flour.

Chemicals: casein was obtained from Morgan Chemical Co., Cairo, Egypt. Benzo[a]pyrene [B(a)P], Glutathione (GSH) and malonaldehyde (MDA) were purchased from Egyptian agent of Sigma Chemical Co. (St. Louis, MO). All other chemicals (Except as otherwise stated) including minerals and vitamins mixtures for rat diets, reagents and solvents were of analytical grade were purchased from El-Ghomhorya Company for Trading Drug, Chemicals and Medical Instruments, Cairo, Egypt. Kits for biochemical determination were obtained from Biodiagnostic Co. Dokki, Giza, Egypt.

Methods

Preparation of wheat flour

The wheat kernels samples were go out the refrigerator, sieved, adjusted to the moisture content, milling and sieved

through 60 and 50 meshes screen to obtain wheat flour extraction rate 72 such as mentioned by Ahmed et al., (1982).

Determination of physco-chemical properties of wheat and GA

Moisture, protein (T.N. x 6.25, Micro-Kjeldahl method), Fat (Soxhelt appratus, petrolium ether solvent) and ash contents were determined using the methods described in the A.O.A.C. (1990). Total carbohydrates were obtained by subtraction of contents of moisture, total lipids, ash and protein from 100. pH of 1% aqueous solution of GA (w/v) was measured using a glass electrode pH-meter (HANNA pH 210). Specific rotation of GA samples was measured in a filtered 1% aqueous solution using a polarimeter (Bellingham and Stanley) equipped with a sodium lamp and a cell of 20 cm path length (Abu Baker, 1996). Relative viscosity of GA samples was measured in filtered 1% aqueous solution using U-shaped viscometer (AOAC, 1990).

Determination of nutritional value of wheat flour and GA composites

Total energy (Kcal/100 g) of wheat flour and GA composite samples was calculated according to Insel et al, (2002). Grams consumed (G.D.R. g) of food (wet weight basis) to cover the daily requirements of adult man (63 g) in protein was calculated using the RDA (1989) values. Grams consumed of food (wet weight basis) to cover the daily requirements of man in energy (G.D.R. g) were calculated using the RDA (Recommended dietary allowances, RDA) which are 2900 Kcal /day for man as given by RDA (1989).

Chemical and physical analysis of dough

Determination of moisture of the dough was done according to the ISO norm 712 (2009). Within the analysis, pH was measured by means of a pH-meter (HANNA pH 210) at a temperature of 23 ±2 °C during the farinograph measurement. Both wheat flour control sample and samples with additions of GA were determined by using of farinograph and extensograph tests according to the methods of A.A.C.C. (1969). The individual measurements were performed in GA in 4% addition. The amount of the gum were selected according to our previous studies (Mohammed, 2013; Elhassaneen et al., 2014 and 2022).

Biological Experiments

Animals

Animals used in this study, adult male albino rats (140±10 g per each) were obtained from Helwan Station, Ministry of Health and Population, Helwan, Cairo, Egypt.

Basal Diet

The basic diet (BD) prepared according to the formula as mentioned by AIN, (1993).

Experimental design

All biological experiments performed a complied with the rulings of the Institute of Laboratory Animal Resources, Commission on life Sciences, National Research Council (NRC, 1996). Rats (n=25 rats) were housed individually in wire cages in a room maintained at 25 ± 3 0C, relative humidity (53±4%), a 12-hr lighting cycle and kept under normal healthy conditions. All rats were fed on basal diet for

one-week before starting the experiment for acclimatization. After one week period, the rats were divided into two main groups, the first group (Group 1, 5 rats, as a negative or normal control group) still fed on BD and injected with the vehicle alone (5 ml/kg body weight) and the other main group (20 rats) was were challenged with an ip injection of B[a]P (100 mg/5 ml/kg body weight) dissolved in 0.9% NaCI solution containing 0.1% Tween 20 to induce liver impaired rats then classified into eight sub- groups as follow: Group (2): fed on BD only as a model or positive control and groups (3-5) fed on BD containing 2, 3, 4 g GA/100 g diet, respectively. GA concentrations were selected for experiments based on many of the results of our previous studies (Domma et al., 2016; Elhassaneen et al., 2014, 2018 and 2022). Each of the above groups was kept in a single cage for 28 days. Rats were weighted at the beginning of experimental then weekly and at the end of the experimental period.

Blood sampling

At the end of experiment period, after 12 hours fasting, rats were scarified under ether anesthetized and blood samples were collected using the abdominal aorta. Blood samples were received into clean dry centrifuge tubes and left to clot at 40C, then centrifuged for 10 minutes at 3000 rpm to separate the serum according to Drury and Wallington, (1980) and stored frozen into clean covet tubes at -20oC until biochemical analysis.

Hematological analysis

Liver functions

SGPT/ALT and SGOT/ AST activities were measured in serum using the modified kinetic method of Tietz et al., (1976) by using kit supplied by Biocon Company. Alkaline Phosphatase activity was determined using modified kinetic method of Vassault et al., (1999) by using kit supplied by Elitech Company.

Glutathione GSH fractions

GSH fractions was determined by HPLC according to the method of McFarris and Reed (1987).

Malonaldialdehyde content (MDA)

Lipid peroxide levels measured as malondialdehyde in liver tissue were determined by as thiobarbituric acid reactive substances (TBARS) as described by Buege and Aust, (1978).

Drug Metabolizing Enzymes (Cytochrome P-450)

Cytochrome P-450 was measured by the carbon monoxide difference spectrophotometry of dithionite-reduced samples by using the method of Omura and Sato (1964).

Statistical Analysis

All measurements were carried out in five rats and presented as mean±SD. The significance of differences was determined by one-way ANOVA followed by Duncan's test for multiple comparisons using a MINITAB 12 computer program (Minitab Inc., State College, PA). A probability level of $P \leq 0.05$ was considered statistically significant.

Results an Discussion

Properties of gum arabic (Acacia senegal)

Data in Table (1) shows the chemical composition and nutritional value of GA samples. From such data it could be noticed that moisture, total protein, crude fat, crude fiber, ash

and carbohydrates content of GA were 11.43 ± 1.05, 3.24 ± 0.82, 0.43 ± 0.09, 78.98 ± 5.67, 2.59 ± 0.45 5 and 3.33 ± 0.64 %, respectively. Results indicated that the moisture content of Sudanese gum is significantly ($p \leq 0.05$) lower than the value reported by FAO (1990). Also, total protein and ash value are falls within the range reported by FAO (1990). The chemical composition parameters of GA may vary slightly depending many factors including origin, climate, harvest season, tree age and processing conditions (Flindt et al., 2005; Hassan et al., 2005, Siddig et al., 2005; Elhassaneen et al., 2014-b). Therefore, there are some differences between the chemical composition of the GA taken from Acacia senegal and Acacia seya (Sabah El-Kheir et al., (2008). Also, the content of protein and total soluble fiber in gum samples collected from kordofan and Damazin regions are significantly different (Karamalla et al., 1998 and Sabah El-Kheir et al., (2008).

On the other side, the nutritional evaluation parameters of GA including 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) samples was shown in Table (2). Data of those parameters are in accordance with that obtained by many authors (reviewed in Montenegro et al., 2012 and Mohammed, 2013; Elhassaneen et al., 2014; Hegazy, (2014); Abd El-Khader, (2018). Such as mentioned by several authors, the characteristics of GA and consequently the nutritional value may vary significantly, depending on the origin, geographical conditions (climate and

soil), age of the trees, and even on the place of exudation on the tree etc., (Karamalla et al.,1998; Abd El-Khader, 2018).
The physical properties of GA samples were shown in Table (2). From such data it could be noticed that GA had specific rotation (-27.11 ± -1.08 degree), relative viscosity (14.56 ± 0.94), solubility (25.81 ± 0.76 Percentage, w/v), refractive index (1.38 ± 0.07), pH (4.58 ± 0.12) and average molecular mass (394.00 ± 4.00 kDa). Those data agree with those previously obtained by FAO, (1998), Sabah El-Kheir et al., (2008), Karamalla et al., (1998), Montenegro et al., (2012), Mohamed, (2013) and Abd El-Khader, (2018). In this context, Montenegro et al., (2012) reported that GA functional properties are related to its structure i.e. solubility, viscosity, degree of interaction with water and oil in an emulsion, microencapsulation ability, among others. The highly branched structure of the GA molecules leads to compact relatively small hydrodynamic volume and, consequently GA will only become a viscous solution at high concentrations. Additionally, the viscosity of GA solutions could be modified by interaction with acids or bases as these ones change the electrostatic charge on the macromolecule. In very acidic solutions, acid groups neutralize so inducing a more compact conformation of the polymer which leads to a decreased viscosity; while a basic solution (less compact molecule) results in maximum viscosity around pH 5.0-5.5. In very basic solutions, the ionic strength increment reduces the electrostatic repulsion between GA molecules producing a more compact conformation of the biopolymer and thus reducing the viscosity of the solution

(Williams et al., 1990 and Williams and Phillips, 2000; Elhassaeen et al., 2014-b).

Table 1. Chemical composition and nutritional evaluation of GA

Property	Value
Chemical composition	
Moisture (%)	11.43 ± 1.05
Total protein (%)	3.24 ± 0.82
Crude fat (%)	0.43 ± 0.09
Crude fiber (%)	78.98 ± 5.67
Ash (%)	2.59 ± 0.45
Carbohydrates (%)	3.33 ± 0.64
Nutritional evaluation	
Energy (Kcal/100g)	30.15 ± 3.86
G.D.R. (g) for protein (63 g)	1944.44 ± 1165
G.D.R. (g) for energy (2900 Kcal)	9618.57 ± 13.56
P.S./ 80 g (One loaf, %) For protein (63g)	4.11 ± 0.51
P.S./80 g (One loaf, %) For energy (63g)	0.83 ± 0.09

* 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). Data represent mean value of three replicates ± SD.

Table 2. Physical properties of GA samples Property Value	
Specific rotation (degree)	-27.11 ± -1.08
Relative viscosity	14.56 ± 0.94
Solubility (Percentage, w/v)	25.81 ± 0.76
Refractive index	1.38 ± 0.07
pH	4.58 ± 0.12
Average molecular mass (kDa)	394.00 ± 4.00

Data represent mean value of three replicates ± SD.

Food industry applications

Proximate chemical analysis and nutritional evaluation of wheat flour control and composite (wheat flour + GA) samples

Table (3) showed the Proximate chemical analysis and nutritional evaluation of wheat flour control and composite (wheat flour + GA) samples. From such data it could be noticed that the addition of GA by 4% to wheat flour leads to significant increasing in total protein, crude fat, minerals, crude fiber and carbohydrates content in the sample in comparison with the control sample. In similar study, Abd El-Khader, (2018) reported that the addition of 4.0 g.100 kg−1 GA resulted in a difference of 377.38% and 11.11% for fiber and ash contents in comparison with the control sample. On the other direction, nutritional evaluation properties of flour and its

baked products should be altered as the result of the chemical composition changes. Those 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 addition of GA up by 4% to the wheat flour, the value of those parameters was significant ($p \leq 0.05$) altering in comparison with the control wheat flour sample. The total energy and P.S./energy and protein were decreased while the GDR/energy and protein were increased. Data of the present study are in accordance with that reported by several authors (Montenegro et al., 2012; Hegazy 2014; Abd El-Khader, 2018; El-Harby, E. N. (2019).). Such obtained data with the others confirmed that GA mixed diets are low in total energy subsequently could be used successfully in on diet programs for the obese persons and obesity treatment managments.

Table 3. Chemical composition and nutritional evaluation of wheat flour control and composite (wheat flour + 4 g.100g-1 GA) samples.

Property	Control samples (Wheat flour)	Composite samples (Wheat flour + GA, 4 g.100g-1)
Chemical composition		
Moisture (%)	12.87 ± 0.56 a	11.71 ± 1.17 a
Total protein (%)	12.11 ±	3.49 ± 0.65b

	1.05 a	
Crude fat (%)	1.64 ± 0.11 a	0.51 ± 0.10 b
Crude fiber (%)	1.02 ± 0.07 b	74.97 ± 4.16 a
Ash (%)	0.82 ± 0.12b	2.61 ± 0.12 a
Carbohydrates (%)	71.54 ± 3.98 a	6.71 ± 1.06b
Nutritional evaluation		
Energy (Kcal/100g)	349.36 ± 10.16 a	45.39 ± 2.65 b
G.D.R. (g) for protein (63 g)	520.23 ± 9.89 b	1805.16 ± 14.56 a
G.D.R. (g) for energy (2900 Kcal)	830.09 ± 10.16 b	6389.07 ± 20.65 a
P.S./ 80 g (One loaf, %) For protein (63g)	15.38 ± 0.67 a	4.43 ± 0.98 b
P.S./80 g (One loaf, %) For energy (63g)	9.64 ± 0.79 a	1.25 ± 0.10 b

* 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). Data represent mean value of three replicates ± SD. Means in the same row with different letters is significantly different at $p \leq 0.05$

The effect of GA on the rheological properties of wheat flour

Farinograph parameters

The farinograph parameters results (Table 4) show the effect of GA on the qualitative rheological properties of the wheat flour dough, which are important during backing processing. The results show that the control dough sample has a significant ($p \leq 0.05$) higher absorption (56.3 ± 1.92) than the composite (wheat flour + 4 g.100g-1 GA) dough samples (52.4 ± 2.77). The present data are in accordance with that obtained by Mohamed, (2013), Elhassaneen et al., (2014) and Hegazy, W. H. (2014), the control dough sample has a significant ($p \leq 0.05$) higher absorption than the composite dough samples and also that with the increasing amount of GA the absorption is gradually decreasing. Also, Nasr, (1998) noticed that this decrease in the water absorption value in wheat flour samples could be related to the decrease in the quantity of the protein. Dough development time (min), statistically significant difference was found between the control sample (2.8 ± 0.3) and the composite (7.1 ± 1.03) dough samples. The increasing dough development time illustrates that the composite dough with GA a longer relaxation time (the dough is tougher). Such data are in agreement with that reported by Pecivova et al., (2011), Mohamed (2013) and Elhassaneen et al., (2014-a) who mentioned that the addition of GA decreased the elastic modulus at 25 °C. 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 (Khalil et al., 1976, Nasr, 1998, Hegazy, 2014). Dough stability in minutes is the most important index for dough strength. Addition of GA to wheat flour samples showed markedly

longer stability periods (10.7 ± 0.81) than the control samples (6.1 ± 1.07). Such affect could be due to the effect of GA on the quality of protein flour in particular the binding force property (Mohamed et al., 2013; Elhassaneen et al., 2014-a). On the other side, FQN, an improvement in the quality of the dough occurred after the addition of GA, when the FQN value significantly ($p \leq 0.05$) increased in comparison with the control sample. Such as reported by Mohamed, (2013) and Elhassaneen et al., (2014), FQN determines the quality of dough subsequently influences the quality of the final bakery product. Finally, pH-farinograph, results shows that the values of the composite samples were not affect significantly with the control sample. Our results are in agreement with that observed by Elhassaneen et al., (2014-a).

Table 4. Farinograph results of wheat flour control and composite (wheat flour + 4 g.100g-1 GA) dough samples.

Parameters	Control sample (wheat flour)	Treated sample (wheat flour + GA)
Water absorption (%)	56.3 ± 1.92 a	52.4 ± 2.77 b
Dough development time (min)	2.8 ± 0.3 b	7.1 ± 1.03 a
Arrival time (min)	1.3 ± 0.25 b	2.1 ± 0.09 a
Stability (min)	6.1 ± 1.07 b	10.7 ± 0.81 a

Farinograph quality number (FQN)	145 ± 5.11 b	161 ± 3.79 a
pH- farinograph	6.14 ± 0.86 a	6.08 ± 0.96 a

*Each value represents the mean value of three replicates ±SD. Means in the same row with different letters are significantly different at p≤0.05

Extensograph parameters

The farinograph results of wheat flour control and composite (wheat flour + 4 g.100g-1 GA) dough samples were shown in Table (5). From such data it could be noticed that the control dough sample (wheat flour) has a significant lower extensibility (169 ± 2.54) than the composite samples (wheat flour + GA) dough (195 ± 1.73). 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 (551 ± 4.39) than the control samples (506 ± 5.04). The effect of GA on increasing the extensibility of the wheat flour may be due to the alteration of the viscosity (Mohammed, 2013; Elhassaneen et al., 2014; El-Harby, 2019) and forced the gluten net work (Abdel-Hamid et al., 1986). Also, several authors with the present study suggest that GA has antioxidant activity which could be easily prevented the oxidation mechanism usually decreases dough extensibility (Khalil et al., 1976; Al-Majed et al., 2002 and 2003; Elhassaneen et al., 2014; Abd El-Khader, 2018). Also, GA has scavenging of free radical species including reactive oxygen species (ROS) (Aruoma, 1994; Rdwan et al., 2018; Ahmed, 2022). Therefore, oxygen (O2) 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 (See Figure 1).

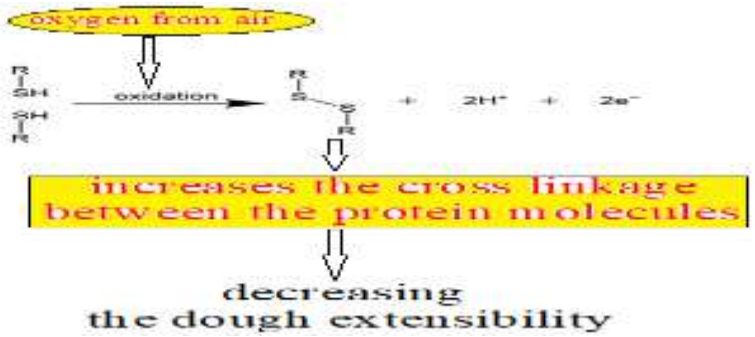

Figure (1). Decreasing the dough extensibility by air oxygen

Table 5. Extensograph results of wheat flour control and composite (wheat flour + 4 g.100g-1 GA) dough samples.

Parameters	Control sample (wheat flour)	Treated sample (wheat flour + GA)
Extensibility (mm)	169 ± 2.54 b	195 ± 1.73 a
Relative resistance to extension (B.U.)	506 ± 5.04 b	551 ± 4.39 a
Proportional number	2.79 ± 0.38 a	2.75 ± 0.29 a
Energy (cm2)	113 ± 1.67 b	125 ± 2.09 a

*Each value represents the mean value of three replicates ±SD. Means in the same row with different letters are significantly different at $p \leq 0.05$

Therapeutic applications

Effects of GA in liver functions of rats exposure to B(a)P

Liver functions of rats exposure to B(a)P and intervened GA powder were shown in Table (6) and Figure (2). From such data it could be noticed that exposure of rats to B(a)P caused a significant ($p \leq 0.05$) increasing in AST (64.82%), ALT (107.72%) and ALP (114.43%) compared to normal control group. Intervention of the rat diets with GA powders (2 to 4 g/100g diet) prevented the rising of mean serum AST, ALT and ALP activities. The rate of preventative effect was elevation with the increasing of the GA powder level intervention. The percent of change in the liver enzymatic activities compare the normal control group were recorded 44.16, 22.98 and 16.37% (For ALT); 64.55, 47.14, 26.86 and 21.36% (for AST) and 107.72, 73.83 and 32.20% (for ALT), and 114.43, 89.89 and 42.82 % (for ALP) with the rat diets intervened by 2, 3 and 4 g/100g of GA powder, respectively.

Liver is a vital organ present in all vertebrates. It has a wide range of functions, including detoxification, protein synthesis, and production of biochemical necessary for digestion (Voet and Voet, 1990). This organ plays a major role in metabolism and has a number of functions in the body, including glycogen storage, decomposition of red blood cells, plasma protein synthesis, hormone production, and detoxification. It produces bile, an alkaline compound which aids in digestion via the emulsification of lipids. The liver's highly specialized tissues regulate a wide variety of high-volume biochemical reactions, including the synthesis and breakdown of small and complex molecules, many of which

are necessary for normal vital functions (Maton et al., 1993). B(a)P is one of the most commonly used hepatotoxins

Table 6. Effects of gum arabic (GA) intervention on liver functions of rats exposed to B(a)P

Value	Gp1 (Normal control)	Gp2 (Model control)	GA (%, w/w) intervention/treated groups		
			GP3 (T1, 2%)	GP4 (T2, 3%	GP4 (T3, 4%)
Serum aspartate aminotransferase (AST,U/L)					
Mean (n=5)	66.01 d	108.80 a	95.16 b	81.18 c	76.82 cd
SD	5.68	9.35	8.80	9.77	8.82
% of Change	0.00	64.82	44.16	22.98	16.37
Serum alanine aminotransferase (ALT,U/L)					
Mean (n=5)	37.47 c	77.82 a	65.13 a	49.53 b	46.47 b
SD	4.55	8.81	9.84	5.46	7.81
% of Change	0.00	107.72	73.83	32.20	24.03
Serum alkaline phosphatase (ALP,U/L)					
Mean (n=5)	147.42 e	316.11 a	279.93 b	210.54 c	181.44 d
SD	14.23	22.36	24.23	19.48	19.51
% of Change	0.00	114.43	89.89	42.82	23.08

* Means in the same row with different letters are significantly different at $p \leq 0.05$

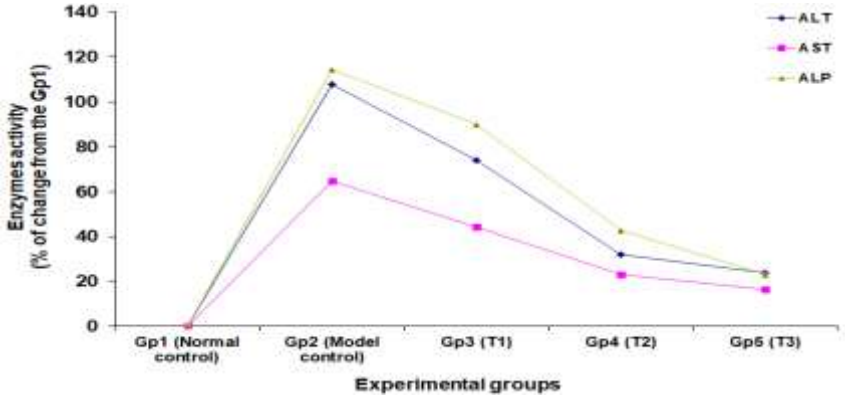

Figure 2. Effects of gum arabic (GA) intervention on liver functions (% of change from the GP1) of rats exposed to B(a)P. Each value represents mean of five replicates.

in the experimental study of liver diseases including cancer. The hepatotoxic effects (cancer) of B(a)P are largely due to its active metabolites, oxides, hydroxyls, polyhydroxyls and quinones radicals (Elhassaneen, 1996). These activated radicals bind covalently to the macromolecules (DNA, RNA and proteins) and induce peroxidative degradation of membrane lipids of cell wall membrane, mitochondria, lysosomes and endoplasmic reticulum rich in polyunsaturated fatty acids (Elhassaneen, 1996, Elhassaneen et al.,1997, Elhassaneen et al., 2022-b). This leads to the formation of DNA-BP adducts subsequently cancer initiation as well as lipid peroxides. This lipid peroxidative degradation of biomembranes is one of the principle causes of hepatotoxicity of B(a)P (Elhassaneen, 2004 and Al-Badawy, 2013). This is evidenced by an elevation in the serum marker enzymes namely AST, ALT, ALP and decrease in protein (Elhassaneen and Al-Badawy, 2013). In the

assessment of liver damage by B(a)P the determination of enzyme levels such as AST, ALT and ALP is largely used. Necrosis or membrane damage releases the enzyme into circulation and hence it can be measured in the serum. High levels of AST indicates liver damage, such as that caused by viral hepatitis as well as cardiac infarction and muscle injury. Therefore ALT is more specific to the liver, and is thus a better parameter for detecting liver injury. Elevated levels of serum enzymes are indicative of cellular leakage and loss of functional integrity of cell membrane in liver (Drotman and Lawhan, 1978; Elhassaneen and Al-Badawy, 2013). Serum ALP levels on other hand is related to the function of hepatic cell. Increase in serum level of ALP is due to increased synthesis, in presence of increasing biliary pressure (Muriel and Garcipiana, 1992; Elhassaneen and Al-Badawy, 2013).

The present data reported that intervention with GA to the rats suffering from liver disorders induced by B(a)P significant ($p \leq 0.05$) improving in the liver functions. In this concern, Gmal al-din et al (2003) studied that protective effect of GA against acetaminophen-induced hepatotoxicity in mice. Also, Mochida et al. (1996) studied the effect of GA on macrophage, which play an important role in the regulation of immunological process in rats, activation by their ability to produce superoxide anions in vitro, and found that GA suppresses macrophage activation in vitro. Furthermore, several authors reported that pre-treatment with some phytochemicals such as found in GA were able to reduce the liver damage including suppress the elevation of AST and ALT through the improvement of antioxidant defense system in red

blood cells (Beattic et al., 2005; and Arafa and Elmaadawy, 2016; Kotb, 2018; El-Harby, 2019).

Effects of GA in biological antioxidants (liver cells glutathione fractions) levels of rats exposure to B(a)P

Liver glutathione fractions (GSH and GSSG) of rats exposure to B(a)P and intervened GA powder were shown in Table (7) and Figure (3). From such data it could be noticed that the mean value of GSH, GSSG and GSH/GSSG for normal control group were -38.35, -14.99 and -27.47%. On the other side, intervention with GA powder, lead to significantly ($P \leq 0.05$) increased in GSH and GSSG concentrations and GSH/GSSG ratio in liver ells by -26.00, -20.57 and -10.05%;-11.53, -8.14 and -5.04%; and -16.35, -13.53 and -5.28% compared to normal control group, respectively.

In general, GSH is a tripeptide-thiol (γ-glutamyl cysteinyl-glycine) that has received considerable attention in terms of its biosynthesis, regulation, and various intracellular functions (Reed and Beatty, 1980; Larsson et al., 1983; Ehassaneen et al., 2013). Among of those functions are two constructing roles in detoxifications as a key conjugate of electrophilic intermediates, principally via glutathione-s-transferase activities in phase II metabolism, and as an important antioxidant. Also, the antioxidant roles of GSH include its associate in the activities of glutathione enzymes family including GSH-Px and GSH-Rd (Halliwell and Gutteridge, 1985 and Elhassaneen et al., 2016). A fall in glutathione fractions (GSH and GSSG) observed in model/ B[a]P rats group generally accompanied by a concomitant decreased in

the ratio of GSH/GSSG. In this context, Di Giulio (1991) reported that a more fundamental effect of ROS-generating constituents as the B[a]P development, however, is their effect on what can be referred to as the redox status (GSH/GSSG) of tissues/cells. Several studies have been addressed directly the issue of effects of pro-oxidants on redox status. For example, Elhassaneen et al., (2004) found that increased fluxes of ROS might be decreased in the GSH/GSSG ratio, due either to direct radical scavenging or to increased GSH peroxidase activity. This effect could also occur indirectly due to reduced NADPH availability [necessary for glutathione reductase (GSH-Rd) activity] resulting, for example, from oxidations in the first step of the redox cycle (Elhassanee, 2004). Also, the previous effect could be one of the most important reasons for reducing the GSH/GSSG ratio in B[a]P hepatotoxicity rats. The GA is rich in bioactive constituents which exhibited antioxidant roles against ROS formation as the hepatotoxicity development through several proposed mechanisms such as rising of redox status (GSH/GSSG ratio) in the tissues.

Table 7. Effects of gum arabic (GA) intervention on liver biological antioxidants (liver cells glutathione fractions) levels of rats exposed to B(a)P

Value	Gp1 (Normal control)	Gp2 (Model control)	GA (%, w/w) intervention/treated groups		
			GP3 (T1, 2%)	GP4 (T2, 3%	GP4 (T3, 4%)
Reduced glutathione concentration (GSH, µmol/L)					

Mean (n=5)	10.27 a	6.33 d	7.60 bc	8.16 b	9.24 ab
SD	1.20	1.54	1.03	0.69	1.95
% of Change	0.00	-38.35	-26.00	-20.57	-10.05
Oxidized glutathione concentration (GSSG, µmol/L)					
Mean (n=5)	0.90 a	0.77bc	0.80 bc	0.83 a	0.86 a
SD	0.20	0.30	0.12	0.16	0.25
% of Change	0.00	-14.99	-11.53	-8.14	-5.04
GSH/GSSG ratio					
Mean (n=5)	11.41 a	8.27 bc	9.5b	9.87 b	10.81 ab
SD	1.08	1.30	1.07	1.11	0.99
% of Change	0.00	-27.47	-16.35	-13.53	-5.28

* Means in the same row with different letters are significantly different at $p \leq 0.05$

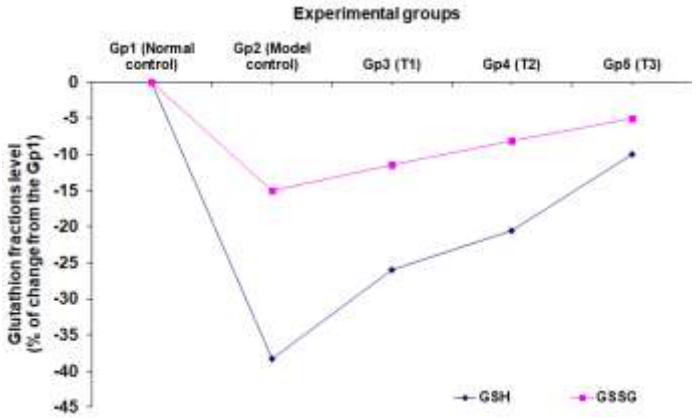

Figure 3. Effects of gum arabic (GA) intervention on liver biological antioxidants (liver cells glutathione fractions) (% of change from the GP1) of rats exposed to B(a)P. Each value represents mean of five replicates.

5.3.3. Effects of GA on serum and liver tissue biological oxidants levels of rats exposure to B(a)P

Liver lipid peroxidation of rats exposure to B[a]P and intervened with GA were shown in Table (8) and Figures (4). The liver lipid peroxidation (MDA) level was increased by 201.62% by B[a]P subjection, and this level was significantly decreased in the treated groups [B(a)P+ GA). The rate of MDA decreasing exhibited dose-response behavior with the GA levels treatments. Several studies have documented that potent of antioxidant activity of GA where by mitigation of lipid peroxidation and oxidative stress in several in vitro and in vivo systems were demonstrated (Nabavi et al., 2012-b; Elhassaneen et al., 2014-b, Hegazy, 2014). Also, Hasegawa et al., (1995) found that previous drinking of bioactive compounds such

found in GA clearly protected against the changes in liver lipid peroxide levels, MDA. Also, liver cells lipid peroxide levels decreased in all B[a]P-exposed rat groups and the serum samples MDA exhibited the opposite direction (Fayez, 2015). Such data confirmed by Hasegawa et al., (1995) and Fayez, (2015) who reported that secretion of lipoprotein from liver to blood might be blocked because of intracellular structural failure and/or because of the energy depletion suggested by the marked decrease in glycogen content. So, the increases of serum MDA were clearly inhibited by GA intervention at this time. A marked fall in serum triglyceride levels was noted in all B(a)P treated animals probably being related to the low levels of serum lipid peroxide in all treated groups.

Table 8. Effects of gum arabic (GA) intervention on liver biological oxidants (liver cells malonaldehyde, MDA, nanomoles/mg tissue protein) levels of rats exposed to B(a)P

Value	Gp1 (Normal control)	Gp2 (Model control)	GA (%, w/w) intervention/treated groups		
			GP3 (T1, 2%)	GP4 (T2, 3%	GP4 (T3, 4%)
Mean (n=5)	4.57 e	13.78 a	10.69 b	8.07 c	7.09 cd
SD	0.56	1.33	1.03	1.11	1.23
% of Change	0.00	201.62	134.10	76.59	55.30

* Means in the same row with different letters are significantly different at $p \leq 0.05$

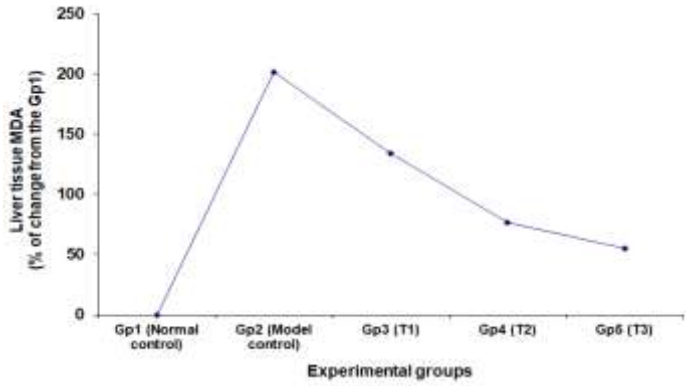

Figure 4. Effects of gum arabic (GA) intervention on liver biological oxidants (liver cells malonaldehyde, MDA, % of change from the GP1) of rats exposed to B(a)P. Each value represents mean of five replicates.

Effects of GA intervention on liver cells cytochrome p450 levels of rats exposed to B(a)P

Effects of GA intervention on liver cells cytochrome p450 levels of rats exposed to B(a)P was shown in Table (9) and Figure (5). Exposure of rats with B(a)P caused a significant increased ($p \leq 0.05$) in cytochrome P450 (60.36%) compared to normal control group. Intervention with GA in rats diets (2-4 g/100g w/w) decreased the rising in mean serum cytochrome P450 activity. The rate of deceasing was exhibited dose-response GA levels. The rate of decreasing in the cytochrome P450 activities were 34.30, 16.42 and 9.16% with the rat diets blended with 2, 3, and 4 g/100g of GA, respectively. In the line with this study, Liu et al., (2015) found that B(a)P treatment brought about a significant increase in the activities of cytochrome P450 in lungs of mice and the activities of this

enzyme was markedly decreased by the administration of bioactive compounds such as found in GA.

Table 9. Effects of gum arabic (GA) intervention on liver cells cytochrome p450 (Cyt P450, nanomoles/mg tissue protein) levels of rats exposed to B(a)P

Value	Gp1 (Normal control)	Gp2 (Model control)	GA (%, w/w) intervention/treated groups		
			GP3 (T1, 2%)	GP4 (T2, 3%	GP4 (T3, 4%)
Mean (n=5)	1.81 d	2.91a	2.44 b	2.11 bc	1.98 c
SD	0.25	0.23	0.37	0.25	0.15
% of Change	0.00	60.36	34.30	16.42	9.16

* Means in the same row with different letters are significantly different at $p \leq 0.05$

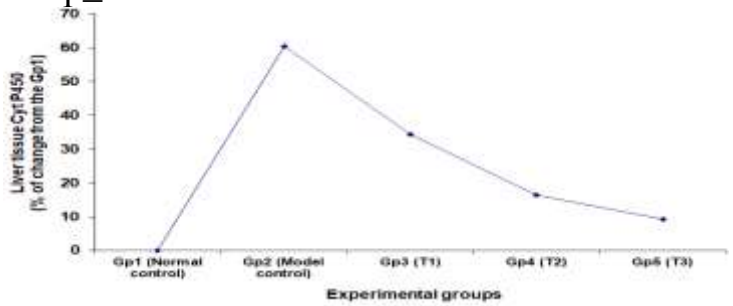

Figure 5. Effects of gum arabic (GA) intervention on on liver cells cytochrome p450 (Cyt P450, % of change from the GP1)

of rats exposed to B(a)P. Each value represents mean of five replicates.

Conclusion

B(a)P is considered as a ubiquitous environmental and food contaminant, and a top risk factor in the development of liver diseases. Intervention with GA successfully applied as functional food for containing several classes of bioactive constituents and exhibited different biological roles that are able to prevent or inhibit liver injuries induced by chemical toxin i.e. B(a)P. GA exhibit inhibiting effects probably by improving the liver functions, modulating regulators of drug metabolizing enzymes (cytochrome P450) and inhibiting the lipid peroxidation parameters thereby adversely affecting the injuries process to the benefit of the biological systems. Therefore, data of the present study recommended that GA by a concentration up to 4% (w/w) to be included in our daily dishes, beverages and pharmaceutical formulae.

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يقصد بالفجوة الغذائية النسبة ما بين معدل الاستهلاك ومعدل الإنتاج للأغذية المختلفة فى دولة ما، لتعبر الفجوة عن زيادة الاستهلاك عن معدل الإنتاج. وعلى الجانب الاخر، ياتى متزامنا مع الفجوة الغذائية تفاقم العلاجات اوالأدوية المُخلقة كيميائياً. لذلك اجريت الدراسة الحالية في إطار تجربة لفتح آفاق جديدة لاستخدام الصمغ العربي (GA) في بعض تطبيقات الصناعات الغذائية واتغذية العلاجية. بالنسبة لتطبيقات الصناعات الغذائية، فإن خلط دقيق القمح مع الصمغ العربي بمستوى ٤٪ أدى إلى تحسين خصائص العجين (بخصائص الفارينوجراف والاكستنسوجراف)، مما سينعكس إيجابًا على خصائص الخبز الناتج. بالنسبة لتطبيقات التغذية العلاجية، فإن التدخل الغذائى باستخدام GA بمستويات ٢ إلى ٤ ٪ قادر على منع أو تثبيط إصابات الكبد التي يسببها السم الكيميائي الشائع الانتشار وهو البنزوبيرين. ولقد اظهر GA تأثيرات مثبطة لإصابات الكبد على الأرجح عن طريق تحسين وظائف الكبد، وتعديل منظمات إنزيمات استقلاب الدواء السيتوكروم (P450)واجزاء الجلوتاثيون (الصورة المختزلة، GSH، والصورة المؤكسدة، GSSG) وكذلك تثبيط مؤشر أكسدة الدهون (محتوى المالونالديهيد، (MDA) في خلايا الكبد. وفي النهاية، أوصت نتائج الدراسة الحالية بإدراج GA بتركيز يصل إلى ٤٪ (وزن / وزن) في أطباقنا اليومية والمشروبات والمركبات الصيدلانية.

الكلمات المفتاحية: التركيب الكيميائي، الفارينوجراف، الاكستنسوجراف، بنزو (أ) بيرين، الجلوتاثيون، السيتوكروم p450 ، المالونالديهيد.