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FUNCTIONAL PROPERTIES AND SOME UTILIZATION OF WHEAT GERM PROTEIN PRODUCTS

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ABSTRACT

Defatted wheat germ flour (DWGF) and wheat germ protein isolate (WGPI) were prepared from untreated, treated wheat germ (WG) with conventional heat treatment at 100°C± 3.0 for 20, 40 and 60 min, respectively or microwave treatment for 1.0, 2.0, 3.0 and 4.0 min. The effect of pH and heat treatment on functional properties of DWGF and WGPI were studied. Functional properties of wheat germ protein products were measured over a pH range of 2.0-10.0 in order to evaluate the potential use of this promising protein sources in different food systems. Heat processing for 20 min improved the nitrogen solubility index (NSI) of DWGF, on the other side, the greatest reduction in NSI occurred after microwave treatment for 4.0 min. DWGF acts as emulsifying agent in the acidic and alkaline pH range. WGPI which prepared from microwave treated WG for 3.0 min, tended to be a more efficient in emulsifying the oil. Improving emulsifying properties of WGP products may enhance their use as a functional ingredients in many foods. In additions, DWGF could be used as an egg white substitute in foaming applications. This study suggests a possibility of using of DWGF which prepared from treated WG with conventional heat treatment up to 20 min at 100°C as a one of the primary ingredients in such functional blends that might be useful as a meat extender in some products.

Key words: Wheat germ, Flour, Isolate, Functional properties, Beef patties

INTRODUCTION

In recent years there has been an increasing interest in the utilization of new protein sources, in order to supplement or substitute conventional proteins in fabricated foods. The demand for new plant proteins is increasing with the growing serious protein shortage in many parts of the world. The new proteins should exhibit a moderate cost with respect to the conventional foods and flexible functional properties to allow the preparation of high protein products for a wide range of markets (**Canella, 1978**). The final success of utilizing plant proteins as additives depends greatly upon the favorable characteristics they impart to foods. Therefore, the interrelationship of protein quality and processing parameters which affect the functional performance of protein products is considered deserving

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of an extensive investigation (**Canella *et al* 1985**). Wheat germ is a by-product of wheat milling industry that has the potential as a food ingredient, unique source of high quality proteins, minerals and vitamins. Several studies have indicated superiority of wheat germ over other milling products as a nutritive supplement. Wheat germ contains very high level of essential amino acids and is an excellent source of lysine, methionine and threonine, which are absent in many other cereal proteins (**Miladi *et al* 1972 and Jensen and Martens, 1983**).

Data reported by **Garcia *et al* (1972)** indicated that wheat germ contained a high concentration of nutritionally important trace elements. Wheat germ is also a good source of the vitamins (**Waggle *et al* 1967**). Pure wheat germ contains almost exclusively α and β tocopherols (**Morrison *et al* 1982**). The presence of cholesterol inhibitors in wheat germ was suggested (**Qureshi *et al* 1991**). Mild heat processing or toasting of germ improved its flavor, nutritional value and functional properties (**Shurpalekar and Rao, 1977**). The pH and temperature influence water retention, solubility and foaming properties of wheat germ flour (**Vani and Zayas, 1995 a, b**). Protein isolate was prepared from defatted wheat germ and the functional properties over a wide pH range were evaluated (**Hettiarachchy *et al* 1996**).

The application of microwave processing for both home and institutional meal preparation has increased because of its speed and convenience (**Nelson *et al* 1985**). **Hafez *et al* (1985)** mentioned that microwave heating of soybean for 9 min. decreased protein solubility from 80 to 17%.

Use of wheat germ protein in bakery products, especially in breads (**Vitti *et al* 1979; Godunova *et al* 1986**); biscuits (**Markianova *et al* 1984; Abu-Elmaati *et al* 1996**); cookies (**Bajaj *et al* 1991**); frankfurters and beef patties (**Gnanasambandam and Zayas, 1994; Rocha-Garza and Zayas, 1996**) are reported.

Information is lacking concerning the effect of conventional and microwave heat treatments on the functional properties of wheat germ protein products. Therefore, the specific objectives of this research were to study the effect of conventional heat treatments for 20,40 and 60 min at 100°C±3.0; microwave treatments for 1,2,3,4 and 5 min. on functional properties of wheat germ protein products at different pH values (2,4,6,8,10 and at original pH). Data on functional behavior of defatted wheat germ flour (DWGF); wheat germ protein isolate (WGPI) would be useful for predicting food applications. Thus, the other purpose, to investigate the effect of addition of DWGF to the formulation of beef patties at 2.5, 5.0 and 7.5% level and to study the effect of these additives on quality characteristics of the obtained beef patties.

MATERIAL AND METHODS

MATERIALS

Wheat germ (WG), was obtained from North Cairo Mills Comp., samples of WG were blended to provide a uniform sample, and stored at -18°C till further experimental treatment. Bovine serum albumin (BSA) and egg albumin (EA) powder were purchased from Fluka, chemie AG., Biochemika and A Dwic-El Nasr pharmaceutical chemicals, respec-

tively. All other chemicals used were of reagent grade.

The WG samples were divided in to three portions, the former without heat treatment; the second for conventional heat treatments and the latter for the microwave heat treatments.

METHODS

Heat treatment of WG

The WG samples were heated in an oven at 100°C±3.0 for 20, 40 and 60 min., respectively. After heating, the WG samples were allowed to cool to room temperature (20°C±2) before lipid extraction.

Microwave heat treatments

The WG samples were subjected to microwave heating for 1.0, 2.0 3.0, 4.0 and 5.0 min, respectively at 200 W using a household microwave oven of 2450 MHZ (Moulinex). Each sample was placed in a Pyrex petri dish (8.0 cm diameter by 1.0 cm depth; each petri dish contained approx. 25g) and heated for the required period. The temperature of the WG samples was recorded immediately in several locations as an average of five readings after microwave heating being, 49, 69, 75 and 97°c). After that the WG samples allowed to cool to room temperature before lipid extraction. A dark brownish color, indicating carmelization of the sugar released during microwave heating, and burnt odor became apparent at 5.0 min. in WG. Therefore, under these conditions, optimum microwave treatment time to prepare wheat germ flour was probably around 4.0 min.

Preparation of defatted wheat germ flour (DWGF)

Untreated and treated WG samples were milled by using a coffee mill (National) at high speed till a fine WG mill obtained. The obtained samples were defatted at room temperature, by soaking the samples in hexane for six times (each one, 12 hr.). The resultant defatted samples were dried for 72 hr. at room temperature, and reground, then passed through 60 mesh sieve to obtain fine defatted wheat germ flour (DWGF). The obtained samples were divided into two portions, the first was termed as DWGF; and the second was used for preparation of wheat germ protein isolate.

Preparation of wheat germ protein isolate (WGPI)

Wheat germ protein isolate (WGPI) from DWGF samples were prepared according to **Hettiarachchy *et al* (1996)** by alkaline extraction and subsequent isoelectric precipitation. The precipitate was washed three times with distilled water (pH 4.0). The dispersed samples were lyophilized after being frozen overnight at -18°C; stored at 5°C until further analysis.

Functional properties

Nitrogen solubility

Nitrogen solubility index (NSI %) was determined by the method of **Were *et al* (1997)** based on the method of **Bera and Murkherjee (1989)**. The nitrogen content of the aliquots of the supernatants was measured by the kjeldahl method **(AOAC, 1990)**. NS being expressed as

percent nitrogen extracted from the original sample, and plotted against corresponding pH values and duration of heat treatment.

Emulsifying properties

Emulsifying properties of untreated, treated DWGF, WGPI and bovine serum albumin (BSA) as a standard were determined at pH values as mentioned in nitrogen solubility by the method of **Pearce and Kinsella (1978)**.

Foaming properties

Foam capacity (FC) and foam stability (FS) of untreated, treated DWGF, WGPI and egg albumin (EA) as a reference were measured at different pH values according to **Wilde and Clark (1996)**. Foam expansion was measured immediately within 30 sec. and expressed as a FC. The volume of foam remaining after standing for 20, 40 and 60 min. was recorded as FS.

Water and oil absorption

Water and oil absorption (WA & OA) were assayed, based on the method of **Sosulski and McCurdy (1987); Liu and Hung (1998)**. The samples (one gram) were added to distilled water or corn oil (10 ml for each) in a 30-ml centrifuge tube after adjusting the pH value, as mentioned above for those prepared with distilled water only, and the all samples were mixed with a glass rod to form a homogenous paste. the mixtures were allowed to stand for 30 min. at room temp. After that, the tubes were centrifuged at 2000 xg/15 min., the small amount of residual water or oil was carefully removed by decanting and the tubes were weighed. water absorption or absorbed oil was calculated by weight difference.

Utilization of DWGF as a partial substitute in beef patties

Samples of beef pattie were prepared according to **Ziprin *et al* (1981)** and to a flow diagram presented by **Rocha-Garza and Zayas (1996)**. A rehydrated DWGF with tap water (1:3) were replaced 7.5, 15.0 and 22.5 % of the meat in patties slurry mixtures. Control samples were prepared without DWGF. Slurries were mixed with the ground beef and other formulation, e.g. fat, salt, spices, onion and garlic by blending for 90 sec. in a kitchen Aide mixer. Patties were formed by a patty maker (~50g mold) 0.7 cm thickness and 9.5 cm diameter. Formed patties were placed between squares of polyethylene, layered on plates and packaged in polyethylene in groups and stored in a freezer (-18°C) till further analyses.

Pattie cooking

Before cooking, patties were thawed overnight in a refrigerator at 4°C. From each treatment, three patties were preheated for 15 min at 25°C in conventional electric oven. Patties were cooked at 220°C in electric oven for 6 min. in one side and 4 min. on the other side.

Cooking yield, Loss, dimensional measurements and water holding capacity (WHC)

Patties were weighed before and after cooking to calculate cooking yield and losses from heat treatment. The diameter

was measured in the widest part of each patty before and after cooking. the thickness of patties was measured before and after cooking. Data were reported as percent change in patty diameter (shrinkage) and thickness. WHC was measured by the filter press method of **Volovinskaia and Merkoolova (1958)**. 0.3 g of minced patty was put under an ashless filter paper (No.40) between two glass plates and pressed for 10 min. using 1 kg weight. The outer zone was measured at least 5 times using Digital planimeter (Placom, koizum, KP-92, Japan). Results were presented in cm^2 / 0.3g sample.

Sensory quality evaluation

Multiple comparison test using a 9 - point scale (9 = extreme excellent; 1= extreme inferior was used for sensory quality evaluation of cooked patties, so that an all-beef pattie was presented first as a reference sample (R). plates containing the patties were covered with aluminum foil and kept warm in a conventional oven at 36±2°C. Eight panelists (4x2, each panelist take another chance to evaluate the cooked pattie) of staff member and graduate students in Food Sci. - Dept. were evaluated the appearance, color, flavor, juiciness, tenderness and overall acceptability. The samples were presented to panelists in a randomized order **(Larmond, 1970)**.

Statistical design

Data were analyzed using analysis of variance and Duncan's multiple range test using the statistical Analysis- system **(SAS, 1988)**.

RESULTS AND DISCUSSION

Solubility is a critical property for applications and, in fact, is used diagnostically to assess prior heating and to determine the potential usefulness of various food preparations.

Nitrogen solubility index (NSI%) as a function of pH from 2.0 to 10.0 of defatted wheat germ flour (DWGF) prepared from wheat germ (WG) exposed to conventional heat treatment for 20,40 and 60 min at 100°C±3.0 or microwave heating for 1.0, 2.0, 3.0 and 4.0 min. respectively; wheat germ protein isolates (WGPI) which were prepared from the aforementioned samples; DWGF and WGPI without heat treatments as a reference are reported in Fig. (I). Conventional heat treatment for 20 min improved the NSI. with the minimum of 33% at pH 4.0 and increased values of NSI (94 and 92%) at pH 2.0 and 10.0 respectively, when compared with the untreated DWGF.

This phenomenon was observed in all samples under investigation, meanwhile, the extent was variable. Prolonged heating above 100°C results in a subsequent increase in protein solubility due to dissociation and degradation of polypeptides **(Wolf, 1978)**.

As shown in Fig. (I) nitrogen solubility levels of DWGF were reduced by the application of conventional and microwave heat treatment for 40 and 60 min at 100°C±3.0; 1.0, 2.0, 3.0 and 4.0 min, respectively, the greatest reduction in a solubility occurred after microwave treatment for 4.0 min. This reduction in solubility may be to the irreversible disruption of the quaternary protein structure.

Nitrogen solubility profiles of WGPI dispersed in water at varying pH values

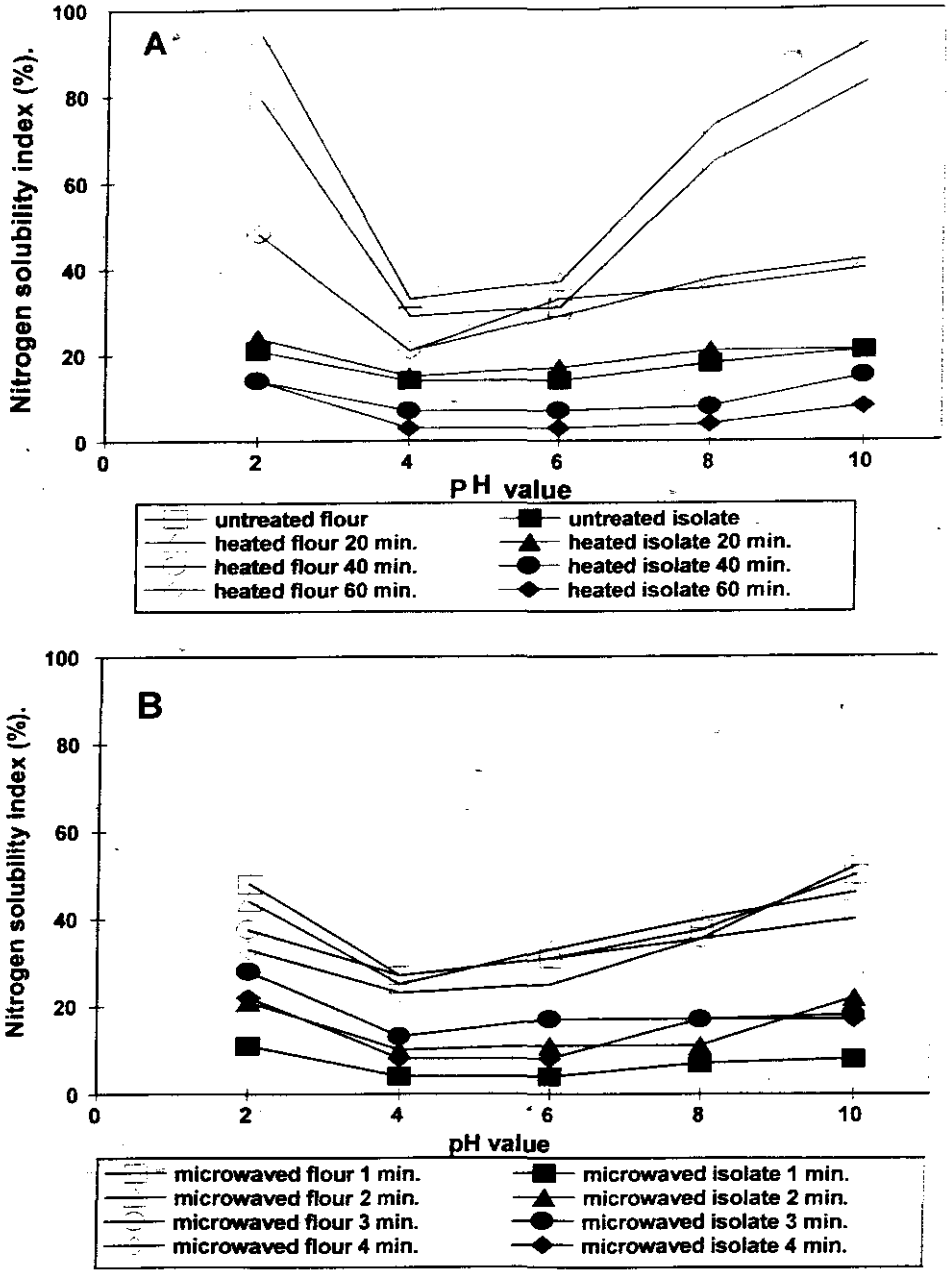

Fig. 1. Nitrogen solubility index (%) of wheat germ protein flour and their protein isolate treated with (A) conventional heat and (B) microwave

(2.0 to 10.0) are shown in Fig. (I). A sharp minimum solubility at the isoelectric point (PI) was not observed with a broad range of minimum solubility between pH values 4.0, 6.0 and 8.0 in most cases was found. For all protein isolate samples, the greatest reduction in solubility was occurred over the pH range examined.

Increasing temperature within the range of 25 to 60°C caused a small increase in solubility of isolates **(Shen, 1976)**. This apparent increase in solubility may be due to temperature induced dissociation of certain oligomeric protein fraction. These data in Fig. (I) indicated that the observed variations in the solubility behavior of various samples of WGPI may be related to the extent of physicochemical changes occurring during preparation of these isolates. Generally, the degree of solubility of a protein in a given aqueous system is net result of both electrostatic and hydrophobic interactions between the protein molecules, conditions under which the electrostatic repulsion's between the molecules is greater than the hydrophobic interactions between the nonpolar patches on the surface favor increased solubility, conversely, conditions under which the hydrophobic interactions are greater than the electrostatic repulsion's will result in intermolecular aggregation and decreased solubility. Physiochemical changes during commercial preparations, which result in irreversible changes in the oligomeric state of the protein, would alter the delicate balance of the above two forces and there by affect the solubility **(Damodaran and Kinsella, 1982)**. From the data shown in Fig. (I), it could be concluded that, the rate of solubility loss was greatly increased with increasing of the duration and manner of treatment, and the other, that protein isolate was for more sensitive to heat treatment than the flour, probably due to the increased of the protein reacting species, as well as, to the irreversible disruption of the quaternary protein structure.

Denaturation and solubility are not always correlated, high solubility data are sometimes obtained from completely denatured protein. However, low solubility is not always a disadvantage and many proteins of limit solubility find uses in the production of foods **(Hermansson, 1979)**.

Solubility of protein is an important prerequisite for emulsifying properties of protein. This is reflected in the correlation between emulsifying capacity and protein solubility and the effect of pH on emulsion formation, namely emulsion formation tends to be significantly lower in the isoelectric range. In some emulsion systems, this relationship is not always apparent because of the high concentration of protein used. **(Kinsella *et al* 1985)**.

The emulsifying activity (EA) value at 500 nm of DWGF and WGPI at different pH values (2.0 to 10.0) was compared with those for bovine serum albumin (BSA) which are known to be protein with good emulsifying properties (Table, I) EA was affected significantly by pH, and heat treatments. EA was pH dependent, the value for DWGF prepared from conventional and microwave WG ranged from 0.047 for microwave sample for 4.0 min, at pH 4.0 to 0.540 for microwave sample for 1.0 min at pH 10.0, whereas those for BSA 0.374 at pH 4.0 and 0.447 at pH 10.0 indicating that DWGF acts as emulsifying agent in the acidic and alkaline pH range. Shifting the pH away

Table I. Effect of conventional and microwave heat treatments on emulsification activity ($O.D_{500\,nm}$) of wheat germ protein products

pH	Bovine serum albumin	Conventional heat treatment (min.)				Microwave treatment (min.)			
		0	20	40	60	1	2	3	4
					Wheat germ protein flour				
2	0.391^{Ca}	0.353^{Bb}	0.281^{Ch}	0.299^{Be}	0.288^{Bf}	0.343^{Cc}	0.335^{Cd}	0.274^{Ci}	0.286^{Bg}
4	0.374^{Ea}	0.211^{Eb}	0.160^{Ed}	0.163^{Ec}	0.112^{Ee}	0.062^{Eh}	0.071^{Eg}	0.107^{Ef}	0.047^{Ei}
6	0.377^{Da}	0.226^{De}	0.234^{Dd}	0.187^{Dg}	0.187^{Dg}	0.301^{Db}	0.249^{Dc}	0.193^{Df}	0.181^{Dh}
8	0.414^{Bb}	0.298^{Cd}	0.282^{Be}	0.211^{Ch}	0.260^{Cg}	0.356^{Bc}	0.470^{Ba}	0.298^{Bd}	0.280^{Cf}
10	0.447^{Ac}	0.430^{Ae}	0.305^{Ai}	0.373^{Ah}	0.375^{Ag}	0.540^{Aa}	0.534^{Ab}	0.436^{Ad}	0.405^{Af}
					Wheat germ protein isolate				
2	0.391^{Cb}	0.227^{Cg}	0.241^{Cf}	0.252^{Ae}	0.209^{Bh}	0.227^{Bg}	0.307^{Bc}	0.468^{Da}	0.279^{Bd}
4	0.374^{Eb}	0.113^{Df}	0.076^{Dh}	0.085^{Dg}	0.072^{Di}	0.156^{De}	0.250^{Dc}	0.532^{Ca}	0.191^{Dd}
6	0.377^{Db}	0.047^{Eh}	0.063^{Ef}	0.063^{Ef}	0.050^{Eg}	0.083^{Ee}	0.115^{Ec}	0.406^{Ea}	0.108^{Ed}
8	0.414^{Bb}	0.233^{Bg}	0.248^{Be}	0.237^{Cf}	0.084^{Ci}	0.223^{Ch}	0.269^{Cc}	0.550^{Ba}	0.263^{Cd}
10	0.447^{Ab}	0.248^{Ag}	0.377^{Ac}	0.239^{Bh}	0.300^{Af}	0.300^{Af}	0.341^{Ad}	0.954^{Aa}	0.313^{Ae}

- Capital and small letters were used for comparison between means in the vertical and horizontal direction, respectively
- Means on the same line followed by different letters are significantly different

from the isoelectric point (PI) apparently improved EA by giving the protein an electrical charge and possibly increasing the protein's solubility. **Takeda *et al* (2001),** indicated that gluten acts as a good emulsifying agent in the acidic pH range.

Generally, both pH and heat treatment affect the emulsifying properties of DWGF and WGPI (Table, I), having a greater effect on the later, except WGPI prepared from the microwave sample for 3.0 ,it was more efficient in emulsifying the oil in comparison with the other samples, even BSA at all pH values. Further studies are necessary to investigate the relationship between the effect of microwave treatment for 3.0 min and selected functional characteristics of WGPI.

EA of DWGF and WGPI was the poorest at pH 4.0 and pH 6.0, respectively, a level which is near the PI of the predominate native WG.

Heating of WG reduced emulsifying properties of WG protein products in comparing to untreated samples and BSA. These observations indicated that, the unfolding and possibly aggregation that occur at high temperature reduce the EA. Heat treatment caused protein denaturation and gradually exposed hydrophobic amino acid residues which are normally buried in the interior of native protein molecules **(Tanford, 1973).**

Exposing the hydrophobic groups could increase hydrophobicity and improve emulsion capacity (EC) (**Morr, 1979**). However, such exposed hydrophobic groups could also undergo hydrophobic interactions, leading to decrease in the hydrophobicity as well as, the EC (**Voutsinas *et al* 1983**).

Results of emulsion stability (ES) of DWGF and WGPI are presented in Fig. (2 and 3), respectively. Generally, the WGP products registered the highest ES at acidic and alkaline pH values after standing 60 min at room temperature. Deamidated wheat protein dispersion had significantly higher EAI and ESI compared to other 3 protein dispersion **Webb *et al* (2002)**. The stability was poorest after standing for 60 min at pH 4.0 and 6.0 for all samples, especially for WGPI except, the microwave heating for 3.0 min. The greatest ES of a protein is not necessarily associated with the highest level of soluble protein (**Mcwatters and Holmes, 1979; Turgeon *et al* 1992**). The pH affected the ES in comparison to the effect of heat treatment till 60 min or microwave treatment till 4.0 min. The ES of DWGF was greatly enhanced at pH 10.0, 2.0 in addition to pH 8.0 for the untreated, treated for 20 min, microwave heating for 3.0 and 4.0 min and standing at room temperature for 60 min. On the other side, ES of DWGF was observed to be lower at pH values 6.0 and 4.0, throughout the standing periods at room temperature (20 to 60 min). In conclusion, the DWGF followed by WGPI had the highest ES at alkaline pH followed by acidic pH. Improving emulsifying properties of WGP products may enhance their use as functional ingredients in many foods including baked goods, confections and meat. WGPI microwaved for 3.0 min. would be superior in liquid applications, where high emulsification ability, high emulsification stability are required such as salad dressing, gravies, soups and meal replacement beverages.

Foam Capacity (FC) or expansion and foam stability (FS) as a function of pH and heat treatments of wheat germ proteins (WGP) and egg albumin (EA) as reference are reported in (Table 2 and Figs 4 & 5), respectively. Conventional heat treatment for 40 and 60 min; and microwave treatment for 2.0 min. affected FC of DWGF, especially in the acid and alkaline pH region in most cases (Table, 2) providing volume increases on whipping of 447% to 474% at pH 2.0 and 362% to 544% at pH 10.0 as compared to the corresponding values of 399% and 199% for the untreated samples. Decrease in FC was noticed at pH 4.0 to 6.0 for WGPI samples prepared from DWGF treated by conventional heat for 60 min and microwave for 1.0, 2.0 and 4.0 min. respectively. Egg albumin (EA) exhibited an improved FC on whipping in the all pH range investigated. This phenomenon could be ascribed to the high solubility of this protein fraction over the whole pH range to form foams.

In fact, the minimum FC after whipping at pH 4.0 for DWGF and WGPI prepared from WG treated for 20 and 60 min, microwaved for 1.0 and 2.0 min; and for 2.0, 1.0, 4.0 and 60 min, respectively, while the greatest FC for WGPI after 0, 40, 60 and 3.0 min at pH 2.0. This likeness between the two patterns is probably to be a scribed to the fact that only the soluble proteins contribute to foam creation. The minimum foaming at pH 4.0 should depend on the strong intermolecular forces which do not allow protein unfolding and spreading at this

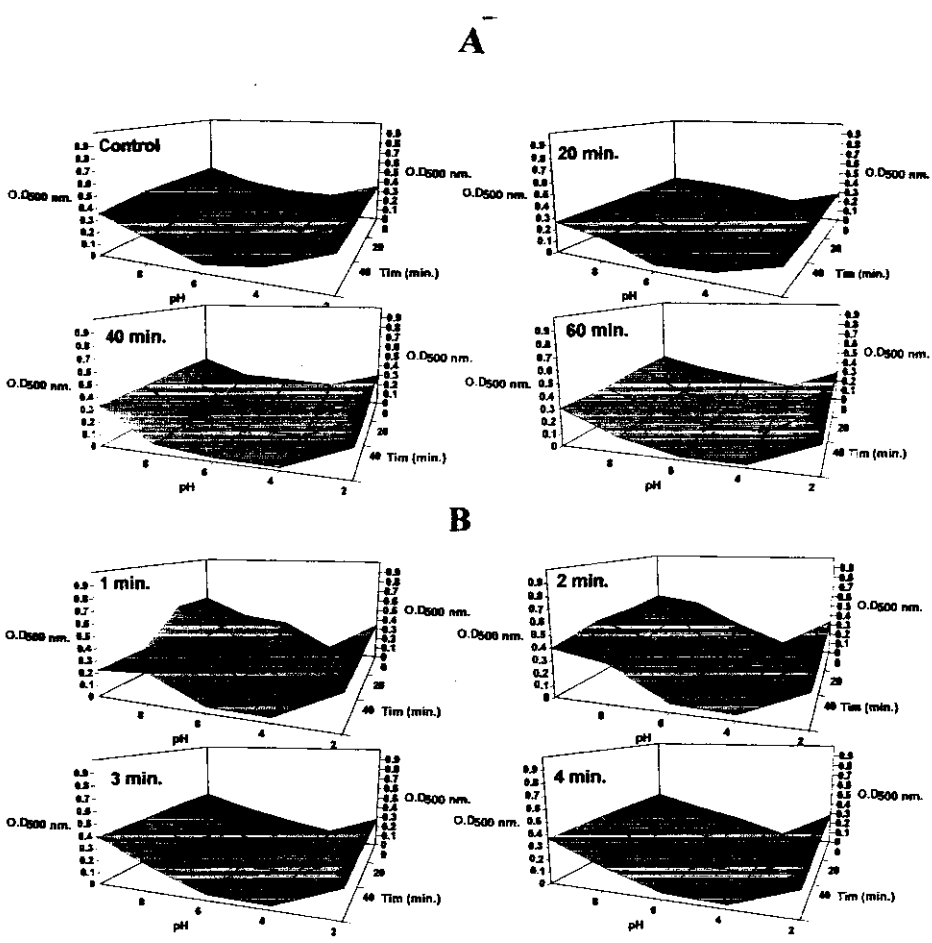

Fig. 2. Emulsification stability (ES) at different pH values of wheat germ protein flour treated (A) for 0, 20, 40 and 60 min. with conventional heat, (B) for 1, 2, 3 and 4 min. with microwave

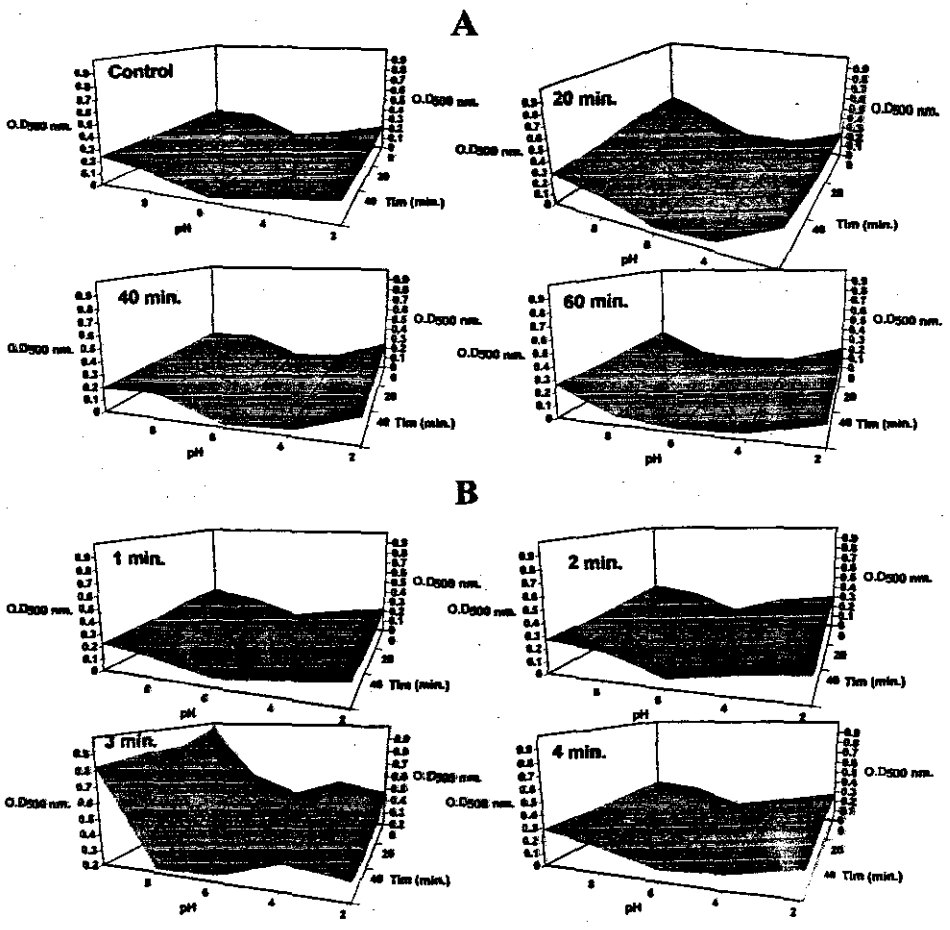

Fig. 3. Emulsification stability (ES) at different pH values of wheat germ protein isolate prepared from treated flour (A) for 0, 20, 40 and 60 min. with conventional heat, (B) for 1, 2, 3 and 4 min. with microwave

iso electric point (PI). It is worth to consider also the effect of the heat treatment which inducing conformation changes in the protein structure, may remarkably reduce the pH dependence on Foam expansion. Finally, FC was influence significantly by pH and heat treatment (Table, 2). Heat denaturation results in increased foaming properties due to increased surface hydrophobicity and flexibility of denatured protein. This may explain why the unmodified samples had lower foaming properties than the modified samples (**Damodaran, 1994**).

Maximum leakage corresponding to the minimum foam stability (FS) occurred for WGPI which prepared from WG treated for 40 and 60 min/100°C, in the pH range 4.0 to 6.0. On the other hand, DWGF prepared from WG treated by heat for 40 and 60 min respectively, exhibited higher FS in all the pH range investigated. Marked effects on FS were observed at alkaline pH values. At alkaline pH, FC was depressed and FS enhanced (Fig. 4 and 5). This latter effect is known to be due to the presence of insoluble particles which can stabilize foams. Some workers have shown that, it was necessary to heat soybean protein to obtain voluminous and stable foams. Meanwhile, **Huffman *et al* (1975)** found that heating was not desirable in whipping sunflower meal because the high temperature affected volume increase. FC requires rapid adsorption of protein at an air water interface during whipping or bubbling, ability to undergo rapid conformation change, and rearrangement at the interface. conversely, FS requires a thick, elastic, cohesive, continuous air permeable protein film around each gas bubble (**Fennema, 1985**). Therefore, the DWGF at the aforementioned conditions could be used as an egg white substitute in foaming applications such as whipped toppings, ice cream, bakery products and desserts.

Water absorption (WA) of WGPI was higher than that of DWGF. WA was increased with time of heat treatment, conventional or microwave treatment (Table, 3). **Hermansson (1973)** reported that highly soluble protein had lower water absorption. Water absorption could also be affected by water physically entrapped within unfolded proteins and by different degree of denaturation (**Fiora *et al* 1990**).

WA indicates the ability of a product to associate with water under specific conditions of pH and temperature. The highest WA was at pH 2.0 for microwave DWGF and WGPI, being from 4.24 - 4.34 g water/ g sample and ranged from 8.52 to 10.96 g water/g sample, respectively, and at pH 4.0 for WGPI prepared from microwave samples for 1.0 and 3.0 min, respectively, and the lowest WA at pH 6.0. WA was maximum for WGPI prepared from microwave samples for 3.0 min, and from conventional heat treatment for 40 and 60 min/ 100°C. It could be noticed that water absorption was significantly affected by pH and different heat treatments (Table, 3). Proteins are capable of binding large quantities of water because of their ability to form hydrogen bonds between water molecules and polar groups of poly peptide chains (**Jones and Tung, 1983**). pH affects the magnitude of the net charge on protein molecules, which in turn alters attractive and repulsive interactions.

Heat denaturation did not lower water imbibing properties of WGPI but improved this property. Water binding capacity of sonicated soy concentrate

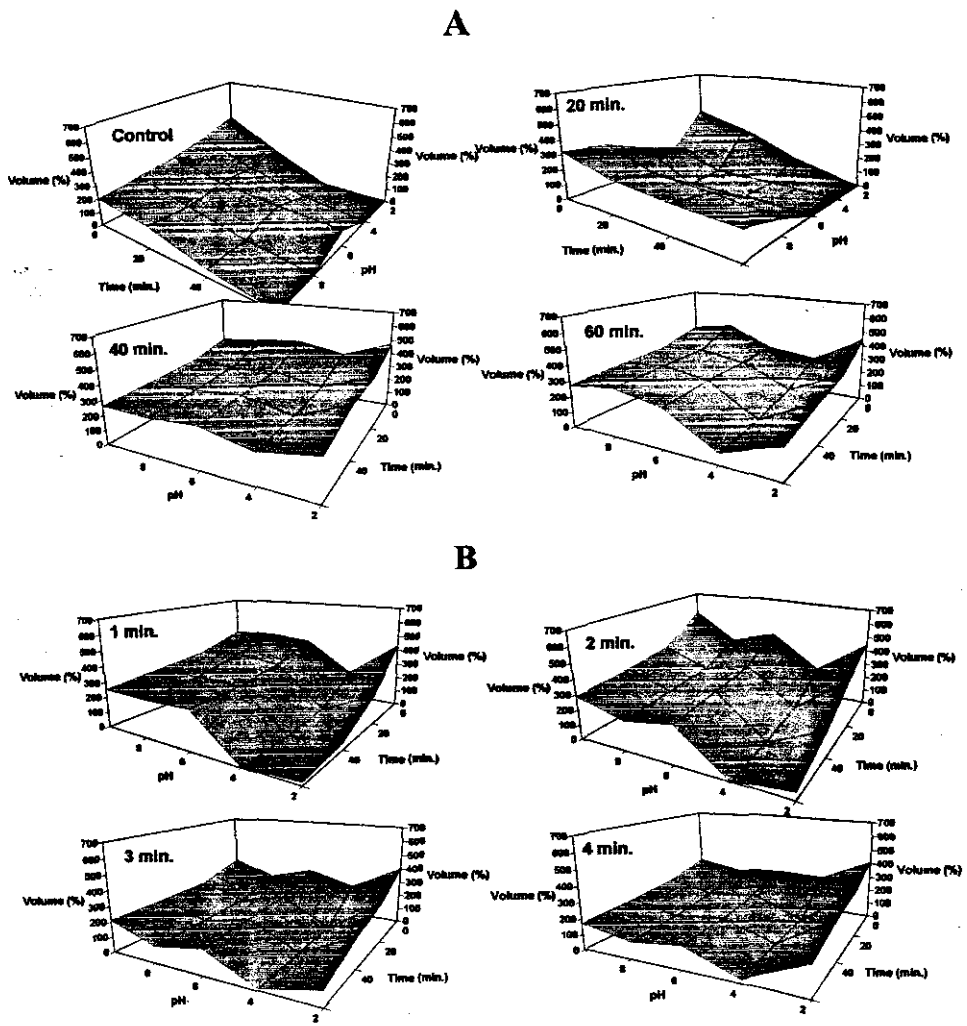

Fig. 4. Foam stability (FS) at different pH values of wheat germ protein flour treated (A) for 0, 20, 40 and 60 min. with conventional heat, (B) for 1, 2, 3 and 4 min. with microwave

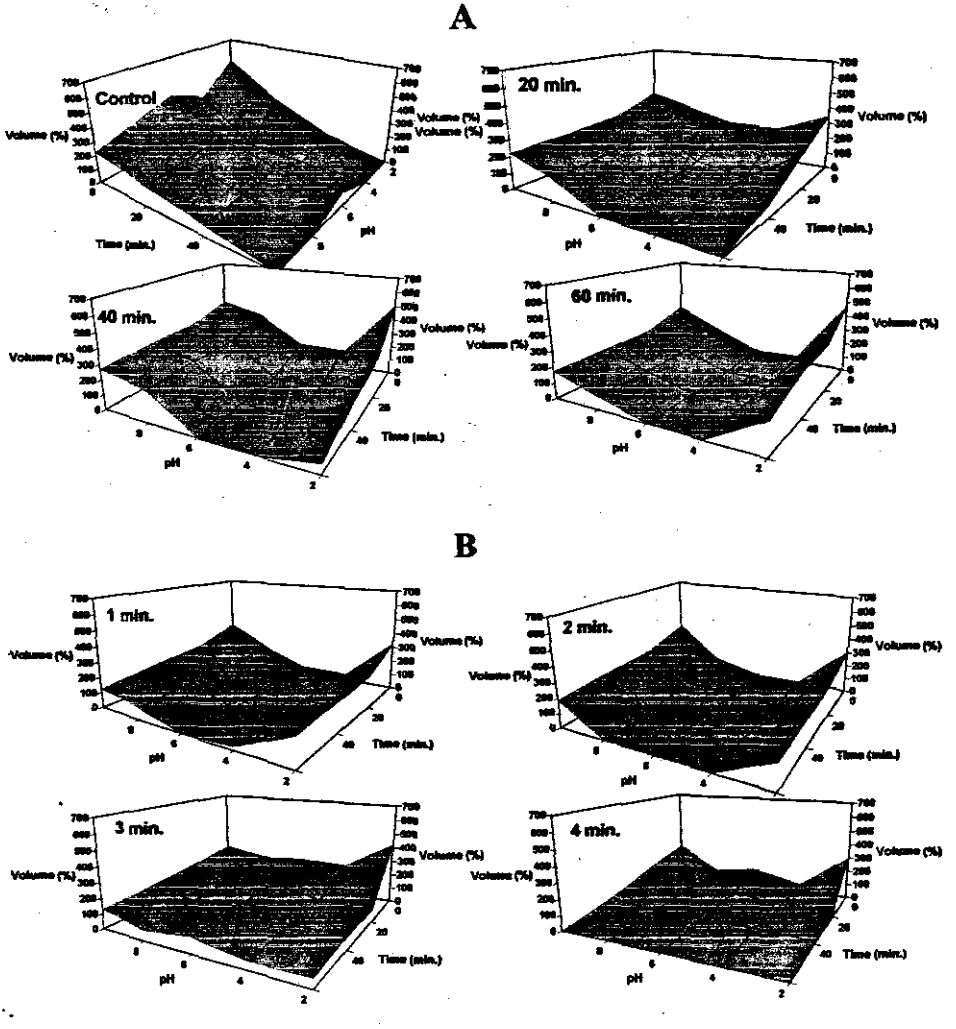

Fig. 5. Foam stability (FS) at different pH values of wheat germ protein isolate prepared from treated flour (A) for 0, 20, 40 and 60 min. with conventional heat, (B) for 1, 2, 3 and 4 min. with microwave

Table 2. Foam capacity (%) of wheat germ protein products treated by conventional heat and microwave treatments

pH	Egg albumin	Conventional heat treatment (min.) 0	20	40	60	Microwave treatment (min.) 1	2	3	4
					Wheat germ protein flour				
2	611^{Aa}	399^{Ag}	377^{Ah}	474^{Ab}	447^{Ac}	431^{Ad}	447^{Bc}	400^{Af}	416^{Ae}
4	577^{Ba}	311^{Bc}	111^{Ei}	348^{Eb}	252^{Ee}	189^{Eh}	200^{Eg}	226^{Df}	253^{Dd}
6	533^{Ca}	255^{Ch}	188^{Di}	411^{Bc}	288^{Df}	395^{Dd}	425^{Cb}	311^{Ce}	256^{Cg}
8	422^{Ec}	222^{Di}	288^{Cf}	385^{Cd}	442^{Ba}	426^{Bb}	338^{De}	226^{Dh}	238^{Eg}
10	511^{Db}	199^{Ei}	322^{Bg}	362^{De}	400^{Cd}	421^{Cc}	544^{Aa}	342^{Bf}	300^{Bh}
					Wheat germ protein isolate				
2	611^{Aa}	522^{Ab}	346^{Bf}	500^{Ac}	469^{Ad}	323^{Ag}	300^{Bh}	422^{Ae}	292^{Ai}
4	577^{Ba}	299^{Db}	213^{Dd}	108^{De}	46^{Df}	38^{Eg}	0^{Dh}	220^{Dc}	46^{Ef}
6	533^{Ca}	411^{Bb}	206^{Ed}	108^{Df}	38^{Eh}	46^{Dg}	0^{Di}	228^{Cc}	124^{Ce}
8	422^{Ea}	322^{Cb}	279^{Cd}	300^{Ce}	177^{Cf}	162^{Cg}	85^{Ch}	206^{Ee}	80^{Di}
10	511^{Da}	22^{Eg}	359^{Ac}	377^{Bb}	315^{Be}	315^{Be}	323^{Ad}	256^{Bf}	256^{Bf}

- Capital and small letters were used for comparison between means in the vertical and horizontal direction, respectively
- Means on the same line followed by different letters are significantly different

Table 3. Water binding capacity (g water/ g sample) of wheat germ protein products as affected by conventional heat and microwave treatments

pH	Conventional heat treatment (min.) 0	20	40	60	Microwave treatment (min.) 1	2	3	4
				Wheat germ protein flour				
2	3.90^{Ad}	2.36^{Cg}	3.78^{De}	3.48^{Df}	4.32^{Ab}	4.24^{Bc}	4.32^{Bb}	4.34^{Da}
4	3.68^{Be}	3.44^{Ag}	4.78^{Ba}	3.54^{Cf}	3.78^{Cd}	3.00^{Eh}	3.92^{Dc}	4.10^{Eb}
6	3.90^{Af}	2.86^{Bh}	5.38^{Aa}	3.94^{Be}	3.48^{Dg}	4.76^{Ac}	4.90^{Ab}	4.54^{Cd}
8	2.88^{Cg}	1.58^{Eh}	4.52^{Cc}	5.30^{Aa}	4.28^{Bd}	4.18^{Ce}	3.26^{Ef}	4.72^{Bb}
10	2.40^{Dg}	1.92^{Dh}	2.94^{Ee}	2.90^{Ef}	3.36^{Ec}	3.08^{Dd}	4.26^{Cb}	5.00^{Aa}
				Wheat germ protein isolate				
2	5.76^{Af}	4.65^{Ag}	8.44^{Ae}	9.44^{Ac}	10.52^{Ab}	8.52^{Ad}	10.96^{Aa}	8.52^{Ad}
4	3.91^{Bg}	3.27^{Ch}	4.64^{Be}	4.20^{Bf}	9.44^{Ba}	6.52^{Bc}	8.40^{Cb}	4.72^{Cd}
6	3.43^{Ef}	2.81^{Eh}	3.20^{Eg}	3.60^{Dd}	4.00^{Ec}	4.04^{Eb}	4.20^{Ea}	3.44^{Ee}
8	3.59^{Df}	3.42^{Bh}	3.60^{De}	3.52^{Eg}	4.40^{Db}	4.28^{Dd}	8.12^{Da}	4.36^{Dc}
10	3.80^{Cg}	3.02^{Dh}	3.92^{Cf}	3.96^{Ce}	7.04^{Cb}	4.96^{Cd}	9.12^{Ba}	5.56^{Bc}

- Capital and small letters were used for comparison between means in the vertical and horizontal direction, respectively
- Means on the same line followed by different letters are significantly different

increased greatly by heating at 100°C (**Hansen, 1978**). Water absorption was influenced significantly by pH and drying methods (**Knorr, 1980**). There has been no reported systematic study on the effect of microwave treatment and pH on WA of WGP products.

The function properties of WGP products which prepared from conventional or microwave WG at original pH of their dispersions in water are reported in Table 4. The DWGF recorded pH value 7.5± 0.1, meanwhile the original pH of WGPI 4.0±0.1. NSI of WGP products varied from 3.0% for WGPI after microwave for 1.0, 2.0 min. and after conventional heat treatment for 60 min. to 69% for DWGF after conventional treatment for 20 min.

WGPI which prepared from microwave treated sample for 3.0 min. showed high EA being 0.588 in comparison to the other treated samples of DWGF and WGPI (Table, 4).On The other direction, WGPI prepared from conventional heat treated samples for 60 min. had a lower EA being 0.066.

No foam formed was observed for WGPI prepared from the conventional treated samples for 60 min. Non of the treated WGP products equaled egg albumin in FC, except the DWGF which prepared from microwave samples for 2.0 min.

WGPI which prepared from microwave samples for 3.0 and 1.0 min recorded higher WA in comparison to the other samples under investigation being 11.09 and 9.92 g water/ g sample, respectively.

Oil absorption (OA) of all WGP products was found to be in reverse relationship with WA (Table, 4). DWGF prepared from microwave WG for 1.0 min and WGPI which prepared from microwave samples for 3.0 min. bound more oil than the other samples being 2.12 g oil / g sample, meanwhile, the values of OA for other treated samples ranged from 1.20 to 1.98 g oil / g sample (Table, 4). This increases may be due to dissociation of the proteins that might occur on heating and also to denaturation which would unmask the non polar residues from the interior of the protein molecules.

The water-oil absorption index (WOAI) is shown in Table, 4. The relative hydrophilic-Lipophilic character of WGP products was reflected by the WOAI which ranged from 1.8 to 3.3 for the treated DWGF and from 2.2 to 5.4 for treated WGPI. When WGP products absorbed greater than twice the amount of oil (WOAI > 2.0) the hydrophilic-lipophilic balance shifted towards the hydrophilic side.

The key for the best EA appeared to be the denaturation of WGP products in conditions in which an excessive increase of the WA was prevented. The results of this study supported the concept that the EA of WGP products depended on the suitable balance between the hydrophilic and lipophilic characteristics rather than merely high values for each one.

Beef patties containing DWGF

Cooking yield, cooking losses, shrinkage and water holding capacity

Cooking yield (CY), cooking losses (CL), shrinkage and water holding capacity (WHC) of all-beef and substituted beef patties with defatted wheat germ flour (DWGF) are presented in Table, 5. As a general trend, CY was increased and CL decreased as level of supplementation

Table 4. Functional properties of wheat germ protein products at original pH

Treatment	Time (min.)	NSI		E.A.*		F. C.**		W.A.		O.A.		W/O.A.I	
		F	I	F	I	F	I	F	I	F	I	F	I
Conventional heat treatment	0	58	13	0.236	0.147	244	155	3.60	4.08	1.98	1.20	1.8	3.4
	20	69	15	0.264	0.109	233	266	2.54	3.59	1.40	1.56	1.8	2.3
	40	27	17	0.249	0.106	354	70	4.46	4.64	1.68	1.76	2.7	2.6
	60	29	3	0.160	0.066	402	0.0	3.38	4.56	1.86	1.36	1.8	3.4
Microwave treatment	1	27	3	0.260	0.155	412	108	4.80	9.92	2.12	1.84	2.3	5.4
	2	29	3	0.245	0.226	544	T	4.06	5.88	1.56	1.34	2.6	4.4
	3	31	11	0.201	0.588	342	84	4.32	11.09	1.32	2.12	3.3	5.2
	4	27	10	0.213	0.153	300	56	3.80	3.76	1.30	1.72	2.9	2.2

* = 0.430 for BSA, **= 522 for egg albumin, F = flour, I = isolate.
NSI = Nitrogen solubility index, E.A.= Emulsification activity, F.C.= Foam capacity, W. A.= Water absorption, O.A.= Oil absorption, W/O A. I.= Water/Oil absorption index

of DWGF was increased (Table, 5). Positive effects on decreased cooking losses of extended beef pattie were noticed, indicating the ability of DWGF to hold water and fat. Such a reverse relationship between CY and CL was observed in the present study. There was no significant differences among treatment in CY for those beef pattie samples containing 7.5, 15.0; 15.0, 22.5; 7.5, 15.0, 22.5; 15.0 and 22.5% rehydrated DWGF which prepared from WG, without heat treatment; with conventional heat treatment for 20, 40 min and microwave for one min., respectively. From the previous observations, it could be recorded that, increasing the levels of DWGF increased CY and decreased CL due to the function of these products.

The degree of shrinkage is important in maintain quality standards of beef patties prepared in food service establishments. Therefore, changes in diameter and thickness must be considered when benefits of meat additives are evaluated, **Rocha-Garza and Zayas (1996)**. Shrinkage of substituted beef patties with DWGF at higher level of substitution was lower and showed the lowest shrinkage (Table, 5) this probably to the higher

Table 5. Cooking yield, cooking losses, shrinkage and water holding capacity of all beef and substituted beef patties with defatted wheat germ flour (DWGF)

Substitution levels of rehydrated (DWGF)	Cooking yield (%)	Cooking loss (%)	Shrinkage	WHC
Control	68.5^{d}	31.5^{b}	26.3^{b}	4.8^{ab}
Without heat treatment				
7.5	76.2^{bc}	23.8^{cd}	22.1^{de}	4.8^{ab}
15.0	75.9^{bc}	24.1^{cd}	22.1^{de}	4.8^{ab}
22.5	80.1^{a}	19.9^{e}	21.1^{ef}	3.7^{d}
Conventional heat treatment for 20.0 min.				
7.5	69.8^{b}	30.2^{b}	25.3^{bc}	4.8^{ab}
15.0	75.3^{bc}	24.7^{c}	24.7^{bcd}	4.3^{c}
22.5	79.1^{ab}	20.9^{de}	18.9^{f}	3.2^{e}
Conventional heat treatment for 40.0 min.				
7.5	74.9^{c}	25.1^{c}	24.2^{bcd}	5.1^{a}
15.0	77.6^{abc}	22.4^{cde}	23.2^{cde}	5.1^{a}
22.5	77.1^{abc}	22.9^{cde}	21.0^{ef}	4.3^{c}
Microwave treatment				
7.5	65.0^{e}	35.0^{a}	35.7^{a}	5.1^{a}
15.0	74.6^{c}	25.4^{c}	22.6^{cde}	4.8^{ab}
22.5	76.4^{bc}	23.6^{cd}	20.5^{ef}	4.4^{bc}

- Means followed by the same letter in the same column do not differ significantly by Duncan's multiple test ($P > 0.05$)

moisture retention of the products containing DWGF, than the other extended patties which containing 7.5% rehydrated DWGF which prepared from microwave WG for one min. show the relative highest. It could be concluded that shrinkage were decreased with increasing levels of DWGF.

Differences among treatments were found, when WHC was discussed (Table, 5). The addition of 22.5% of rehydrated DWGF which prepared from without or with conventional heat treatment for 20 min. was affected WHC of the substituted patties.

Sensory Quality Evaluation

Differences in sensory quality attributes of all-beef and substituted beef parties are shown in Table, 6. All-beef parties and those containing 7.5, 15.0 and 22.5% rehydrated DWGF without heat treatment, conventional heat treatment for 20 and 40 min., and microwave for 1.0 min, respectively were not significantly different in appearance and color in most cases (Table, 6). As rehydrated DWGF increased, however, differences between the samples in flavor were increased especially at higher levels (22.5%), and

Table 6. Average differences in sensory quality attributes of all beef and substituted beef patties with defatted wheat germ flour (DWGF)

Substitution levels of rehydrated (DWGF)	Appearance	Color	Flavor	Juiciness	Tenderness	Overall acceptability
Control	5.0^{bc}	5.0^{ab}	5.0^{cd}	5.0^{cd}	5.0^{cde}	5.0^{bcde}
Without heat treatment						
7.5	6.0^{ab}	5.3^{ab}	5.6^{ab}	5.6^{c}	5.6^{abcd}	5.3^{abcd}
15.0	6.5^{a}	5.6^{ab}	5.6^{ab}	6.6^{a}	6.6^{ab}	6.3^{a}
22.5	5.6^{ab}	5.3^{ab}	4.6^{bcd}	6.3^{ab}	6.0^{abc}	5.3^{abcd}
Conventional heat treatment for 20.0 min.						
7.5	5.3^{abc}	6.0^{a}	5.3^{abc}	7.0^{a}	7.0^{a}	5.6^{abc}
15.0	6.6^{a}	5.0^{ab}	6.3^{a}	7.0^{a}	5.6^{bcd}	6.0^{ab}
22.5	5.6^{ab}	5.0^{ab}	4.3^{cd}	5.0^{cd}	5.3^{bcde}	4.6^{cdef}
Conventional heat treatment for 40.0 min.						
7.5	5.6^{ab}	5.6^{ab}	5.6^{ab}	5.6^{bc}	6.0^{abc}	4.3^{def}
15.0	5.6^{ab}	5.6^{ab}	5.3^{abc}	4.6^{d}	4.3^{de}	4.3^{def}
22.5	5.6^{ab}	5.0^{ab}	4.0^{d}	3.3^{e}	4.0^{e}	4.0^{ef}
Microwave treatment						
7.5	4.0^{c}	4.6^{b}	4.0^{d}	3.6^{e}	4.3^{de}	4.3^{def}
15.0	5.6^{ab}	5.3^{ab}	4.0^{d}	3.6^{e}	4.3^{de}	4.0^{ef}
22.5	5.6^{ab}	5.3^{ab}	4.0^{d}	3.0^{e}	4.0^{e}	3.6^{f}

- Means followed by the same letter in the same column do not differ significantly by Duncan's multiple test ($P > 0.05$)

for those extended with microwave samples at all substitution levels. Juiciness scores for patties containing 15.0%, 22.5; 7.5 and 15.0%; rehydrated DWGF which prepared from WG without heat treatment or conventional heat treatment for 20.0 min, respectively were not significantly different; those containing 22.5 and all substitution levels of rehydrated DWGF which prepared from WG with conventional heat treatment for 40 min and microwaved for one min., respectively, however, had significantly lower juiciness ratings. No significant differences in tenderness could be observed for the pattie samples containing rehydrated DWGF, however, the samples containing 15.0, 22.5 and all extended level of rehy-

drated DWGF which prepared from WG with conventional heat treatment for 40.0 min and microwaved for one min. had the lowest tenderness ratings than the other samples. The change in tenderness resulting from addition of plant proteins was caused by the dilution of myofibril and stromal proteins (**Ahmed and West, 1981**).

Overall acceptability of the substituted beef patties with rehydrated DWGF recorded the above mentioned observations. However, the absence of significant differences in sample means for the selected quality attributes of substituted beef patties in this study may not indicate absence of undesirable effects on sensory properties from the addition of DWGF. Trends suggested a considerable effect from the addition of the samples prepared from microwave WG or due to the addition of increased levels of DWGF. In conclusion, this study suggests a possibility of using of DWGF which prepared from treated WG with conventional heat treatment up to 20 min at 100°C as a one of the primary ingredients in such functional blends that might be useful in producing extended meat products. **Rocha-Garza and Zayas** (1996) reported that, WGPF has potential for use as an extended in ground broiled beef products.

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مجلة حوليات العلوم الزراعية ، كلية الزراعة ، جامعة عين شمس ، القاهرة ، م٤٩ ، ع(١)، ١٣٩ - ١٦٢ ، ٢٠٠٤

الخصائص الوظيفية وبعض استخدامات المنتجات البروتينية لجنين القمح [١٠]

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١- قسم علوم الاغذية - كلية الزراعة - جامعة عين شمس - شبرا الخيمة - القاهرة - مصر

فى هذه الدراسة تم تحضير دقيق جنين القمح منزوع الدهن والبروتين المعزول من جنين القمح غير المعامل أو المعامل حراريا بالطريقة التقليدية على درجة حرارة ١٠٠°م±٣ لمدد زمنية ٢٠، ٤٠ و ٦٠ ق أو المعامل بالميكروويف لفترات زمنية دقيقة، دقيقتان، ثلاث دقائق وأربع دقائق على الترتيب، وتم دراسة تأثير الاختلاف فى درجة الأس الايدروجينى والمعاملة الحرارية على الخصائص الوظيفية للمنتجات البروتينية السابق الإشارة إليها. ولقد تم تقييم الخصائص الوظيفية على مدى من درجات الأس الايدروجينى من ٢ إلى ١٠ بهدف تقييم استخدامات هذه المنتجات البروتينية فى العديد من الأنظمة الغذائية.

ولقد أظهرت المعاملة الحرارية لمدة ٢٠ ق تحسنا فى معامل النيتروجين الذائب لدقيق جنين القمح منزوع الدهن، وعلى الجانب الآخر حدث انخفاض واضح فى معامل النيتروجين الذائب بالمعاملة بالميكروويف لمدة ٤ دقائق. أيضا أوضحت الدراسة إمكانية استخدام دقيق جنين القمح منزوع

الدهن كمادة مستحلبة فى المنتجات المتباينة فى درجة الاس الايدروجينى سواء الوسط الحامضى او القاعدى وكان للمعاملة بالميكروويف لمدة ٣ دقائق من التأثير الواضح فى زيادة مقدرة البروتين المعزول لجنين القمح على استحلاب وثبات المستحلب الناتج والتحسن الحادث يعزز من إمكانية استخدام هذه البروتينات ضمن المنتجات التى تتطلب مقدرة استحلابية عالية وكذلك ثبات هذه المستحلبات. أيضا أظهرت الدراسة إمكانية استخدام دقيق جنين القمح منزوع الدهن كبديل لبياض البيض فى المنتجات التى تحتاج إلى مثل هذه الإضافة.

وتقترح الدراسة بناءا على نتائج التقييم الحسى والاختبارات الفيزيائية الأخرى على فطائر اللحم المجهزة بالاستبدال بنسب ٧,٥، ١٥,٠ و ٢٢,٥% من جنين القمح منزوع الدهن المتأدرت إمكانية استخدام دقيق جنين القمح منزوع الدهن المجهز من جنين القمح المعامل حراريا على ١٠٠°م لمدة ٢٠ ق بنجاح كمكون أساسي ضمن المكونات المستخدمة فى تجهيز منتجات اللحوم مثل فطائر اللحم.

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