**ISSN 1110-0419**

***Annals Of Agric. Sc., Moshtohor, Vol. 43(2): 627-647, (2005)***

# PREPARING SOME MEAT PRODUCTS USING SOYBEAN SEEDS AFTER REMOVING THE ANTINUTRITIONAL MATTERS

**By**

**Abd El-Aleem, I.M.* and Mohamed, M.H.****

* Agric. Chem. Dept. and ** Food Sci. Dept., Fac. of Agric. Moshtohor, Zagazig Univ. (Benha Branch), Egypt.

## ABSTRACT

This study was carried out to remove the antinutritional matters from soybean seeds to be used in beef sausage and beef burger products. Crude protein content in raw soybean seeds was 44.82%, while, the antinutritional factors: trypsin inhibitor, chymotrypsin inhibitor, hemagglutinating, total phenolic compounds and phytic acid were: 31.6 mg/g, 3.40 mg/g, 713 U/g, 0.75% and 1.21%, respectively.

Autoclaving was effective in removing all antinutritional matters except phytic acid, however, roasting was most effective for its reduction.

In order to reduce the cost of meat products and to improve their physico-chemical properties, meat was replaced by rehydrated soybean flour at the levels of 0, 10, 15, 20, 25 and 30%.

So, it could be recommended to apply replacement level to 20% soybean, treated with autoclaved, from meat used in prepared sausage and beef burger.

## INTRODUCTION

The growing third world population and its domestic animals need protein. The cheapest protein are those derived from plant material.

Beef burger is versatile, easy to prepare and relatively inexpensive. Thus, it is one of the most popular meat products and is a multi-billion dollar commodity in the United States (Cross *et al.*, 1980).

Legume seeds are important source of energy and protein in many part of the world. However, their nutritional value may be limited in part by the presence of undesirable components known as antinutritional factors (ANFs), such as proteinase inhibitors, lectins (hemagglutinnis), amylase inhibitors, tannins, phytic acid and vicine.

Lectins (hemagglutinin, phytohemagglutinin) are proteins or glycoproteins that are capable of agglutinating red blood cells and can bind to specific carbohydrate residues in cell membranes (Lis and Sharon, 1972, Sharon and Lis, 1990). They are widely distributed in nature and have been isolated from plants, animals and microorganisms.

Lectins have been identified in numerous seeds such as soybean, pinto bean, castor bean, jack bean, mungbean, lima bean, kidney bean, navybean, pea, lentil and faba bean (Chen *et al.*, 1977; Staron, 1977 and Bau *et al.*, 1997).

The lectin and trypsin inhibitor can both affect pancreas function. Their combined action, either additively or synergistically, may have considerable implications and consequences for the use of legume meal or proteins in human and animal nutrition (Grant *et al.*, 1987).

Proteinase inhibitors (PI) are antinutritional factors which occur in the seeds of many plants belonging to the legume family. These inhibitors and other antinutrional factors (ANFs) are the subject of a recent review written by El-Morsi (1996). Trypsin inhibitors in legumes were shown to have an adverse effect on animal nutrition due to these inhibitory properties on major pancreatic proteinases (Sato and Herman, 1990 and Arentoft *et al.*, 1991) as well as reduced animal weight gain (Herkelman *et al.*, 1992 and Saikia *et al.*, 1999).

Polyphenolic compounds, tannins, phytic acid and vicine are among the antinutritive factors detected in many legume seed, (El-Morsi, 1996 and Vijayakumari *et al.*, 1998). Tannins are known to decrease protein digestibility either by binding with digestive enzyme as trypsin and chymotrypsin or binding directly to dietary proteins (Jambunathan and Singh, 1981). The levels of these compounds were determined in soybean seed by some investigators (Friedman *et al.*, 1991 and Foda and Abd El-Aleem, 1998).

Soaking slightly reduces the levels of trypsin in legume seeds (Zaki *et al.*, 1996) while, different heat treatment destroy most of them (Umoren *et al.*, 1997; Aarti *et al.*, 1999; Zaki *et al.*, 1999 and Seda *et al.*, 2002).

Fermentation of soybean seeds decreased fat, available carbohydrates, phytic acid, trypsin inhibitor activity and total vicine content and increased crude protein, non protein nitrogen, true protein, fiber content, pH value, total volatile nitrogen and ammonia (Paredes-Lopez and Harry, 1989).

There are three types of soy protein products that can be used as extenders and binders in meat products: soy flour, soy concentrate and isolated soy protein (Richert, 1991).

Several studies have been carried out to retain sensory and textural attributes through fat reduction by replacing fat with water, water and phosphate (Miller *et al.*, 1993 and Frederick *et al.*, 1994), carbohydrate and protein based on fat substitutes (Dexter *et al.*, 1993 and Carballo *et al.*, 1995) and vegetable gums (Osburn and Keton, 1994 and Trius *et al.*, 1994)

The purpose of the present study was to test the effect of autoclaving or roasting on antinutritive matters, protein digestibility and amino acid composition in soybean seeds. After that defatted soybean seeds were used to prepare beef sausage and burger meat.

## MATERIALS AND METHODS

### Materials:

Soybean seeds (Giza 21 variety) were obtained from Agricultural Research Center, Giza, Egypt.

Raw beef meat and mutton fat purchased from supermarkets of Kalyobia governorate. Spices ingredients (black pepper, cloves, cubeb, cumin, garlic, nutmeg, fennel, coriander, laurel and cardamom) were purchased from local market.

### Treatments:

**Autoclaving treatment:** Soybean seeds were autoclaved at 121°C for 10, 20, 30, and 40 min.

**Roasting treatment:** Soybean seeds were roasted by heat at 140°C for 10, 20, 30 and 40 min.

The seeds were cleaned and finely ground. Hexane (b.p. 40-60°C) was used for the extraction of oil from the ground seeds.

**Preparation of beef sausage and burger samples**:

Visible fat tissues were trimmed from lean meat, then minced by electric chopper. Mutton fat tissues also, were minced. Soybean flour was rehydrated by mixing with distilled water at ratio 1 : 2 (w:w) and added by levels, 0 (control), 10, 15, 20, 25, 30 and 35% from beef meat to prepare sausage and burger. The formula of beef sausage and burger are shown in table (A):

**Table (A): The formula of beef sausage and beef burger prepared in laboratory*.**

| Component | Sausage | Burger | Spices mixture |
|---|---|---|---|
| Beef meat (%) | 70.60 | 62.00 | <u>For sausage:</u> Fennel 59.76%, coriander 27.09%, cubeb 3.19%, black pepper 3.19%, clove 3.19%, laurel 1.99% and cardamom 1.59%. |
| Mutton fat (%) | 14.00 | - | |
| Water (as ice flakes) (%) | 7.00 | 10.00 | |
| Starch (%) | 4.65 | - | |
| Sodium pyrophosphate(%) | 0.30 | - | |
| Salt (NaCl) (%) | 2.00 | 1.50 | |
| Garlic (%) | 0.24 | - | |
| Skimmilk powder (%) | 0.40 | - | |
| Glucose (%) | 0.10 | - | |
| Ascorbic acid (%) | 0.04 | - | <u>For burger:</u> Black pepper 5.61%, cardamom 2.24%, cloves 2.24%, cubeb 22.42%, cumin 11.21%, garlic 56.05%, and nutmeg 0.22%. |
| Sodium nitrite (%) | 0.01 | - | |
| Ground onion (%) | - | 7.00 | |
| Egg (%) | - | 7.00 | |
| Semolina (%) | - | 12.00 | |
| Spices mixture (%) | 0.66 | 0.50 | |

***Source [Moghazy and El-Shaarawy (2001) and Moghazy *et al.* (2004)]**

**Methods:**

**Chemical analysis**: Moisture, crude protein, ether extract and ash contents were determined according to A.O.A.C. (1995). Carbohydrates content was calculated by difference.

**Assay of trypsin inhibitors (TI):** The trypsin inhibitors was measured according to Stauffer (1993).

**Assay of chymotrypsin inhibitors (CI)** was measured as described by Samirnoff *et al.* (1976).

**Determination of Hemagglutinating activity (HA):** Lectin activity was determined by measuring its hemagglutinating action according to the method described by Thompson *et al.* (1983).

**Determination of total phenols (TPC):** The polyphenolic compounds were determined as described by Swain and Hills (1959).

**Determination of phytic acid (PA):** Phytic acid was estimated colorimmetrically using Wade reagent (Latta and Eskin, 1980).

***In vitro* protein digestibility:** The digestibility of protein *in vitro* was carried out as described by Santosh and Chauhan (1986).

**Determination of amino acids:** Amino acid analyzer (Model 121) was used to determine amino acid in soybean seeds as described by Moore *et al.* (1958). Cystine was microbiologically determined as described by Barton (1952). Tryptophan was colorimetrically determined in the alkaline hydrolysate of samples according to the method of Blouth *et al.* (1963).

**Freshness tests**: Total volatile nitrogen (TVN) was determined according to the methods mentioned by Winton and Winton (1958). Thiobarbituric acid (TBA) value, as a measure of oxidative rancidity was determined according to Harold *et al.* (1981). pH value of meat product samples was measured using digital pH-meter model SA 210 according to the method of Woye Woda *et al.* (1986).

**Water holding capacity (WHC) and plasticity** were measured according to the method described by Soloviev (1966).

**Cooking loss and shrinkage** were determined according to Darweash and Moghazy (1998).

**Sensory evaluation** were evaluated according to Watts *et al.* (1989).

**Statistical analysis** was applied on the results of organoleptic evaluation of different samples of beef sausage and beef burger which were treated as data for complete randomization design. Least significant difference (L.S.D.) was calculated at 0.05 level of significance according to Snedecor and Cochran (1980).

## RESULTS AND DISCUSSION

**Chemical composition of soybean seeds:**

Data in Table (1) show that crude protein content of soybean seeds was 44.82%, followed by ether extract (25.30%), total carbohydrate (24.28%) and ash content were 5.60%, (dry weight basis), while moisture content was 8.30%. These results confirms the view that soybean seeds are considered to be an excellent source of protein. Results are in agreement with Foda and Abd El-Aleem (1998).

**Table (1): Chemical composition of raw dry soybean seeds.**

| Components | | |
|---|---|---|
| Moisture | (%) | 8.30 |
| Ash* | (%) | 5.60 |
| Ether extract* | (%) | 25.30 |
| Crude protein* | (%) | 44.82 |
| Total carbohydrate* | (%) | 24.28 |
| Trypsin inhibitor * | (mg/g) | 31.60 |
| Chymotrypsin inhibitor* | (mg/g) | 3.40 |
| Hemagglutinating * | (U/g) | 713 |
| Total phenolic compounds* | (%) | 0.75 |
| Phytic acid* | (%) | 1.21 |

***: On dry weight basis.**

**Antinutritional matters in soybean seeds:**

Data in the same Table showed that the levels of antinutritional matters were determined in soybean seeds and found to be 31.6 mg/g, 3.4 mg/g, 713 U/g, 0.75% and 1.21% for trypsin inhibitor (TI), chymotrypsin inhibitor (CI), hemagglutinating (HA), total phenolic compounds (TPC) and phytic acid (PA), respectively.

The presence of antinutritional matters in soybean seeds was in agreement with many other workers (Friedman *et al.*, 1991 and Foda and Abd El-Aleem, 1998).

**Effect of autoclaving and roasting on antinutritional matters of soybean seeds:**

The effect of various heating methods of soybean seeds on TI, CI, HA, TPC and PA contents were examined and the results are presented in Fig (1) which indicated that autoclaving and roasting of soybean seed reduced the levels of antinutritional matters.

Results show that autoclaving and roasting soybean seeds for 40 min inactivated trypsin inhibitor to 87.6% and 77.7%, respectively. Under the same conditions chymotrypsin inhibitor was more resistant to heat treatment compared to trypsin inhibitor.

The hemagglutinine was totally destroyed after 30 min. autoclaved and 40 min roasted soybean seeds. As shown in Fig. (1) all treatments resulted in decrease of TPC and PA.

Autoclaving seems more effect on destruction of TPC compared with roasting, but less effect on destruction of phytic acid compared with roasting. Similar observation was reported by Umoren *et al.* (1997), Aarti *et al.* (1999) and Zaki *et al.* (1999), they found that cooking and autoclaving on the levels of total free phenols and phytic acid in seed, autoclaving seemed to be the most efficient

for reduction in content of the antiutrients except phytic acid and improving protein digestibility index.

**Effect of heating in an autoclave and roaster on the amino acids composition of soybean seeds:**

The results of amino acid analysis of soybean dry seeds as well as seed heated in autoclave for 40 min and seeds roasted for 40 min. are presented in Table (2).

The provisional amino acid scoring pattern proposed by FAO (1973) qualified an ideal protein as one in which 36% of the total essential amino acids.

The data shown in Table (2) indicated that soybean seed proteins had higher E/T ratio than proposed 36% for an ideal protein. Little changes were observed in some essential amino acids as a result of autoclaving and roasting which are in agreement with results of Friedman *et al.* (1991) who reported no changes in amino acid composition of soybean seed after 30 min autoclave heated.

**Table (2): Effect of heating in an autoclaving and roasting on amino acids composition of soybean seeds (g/100 g protein).**

| Amino acids | Dry seeds | Autoclaving (40 min) | Roasting (40 min) |
|---|---|---|---|
| **Essential amino acids (EAA):** | | | |
| Lysine | 5.94 | 5.82 | 5.10 |
| Leucine | 7.83 | 7.84 | 7.68 |
| Isoleucine | 4.39 | 4.39 | 4.35 |
| Cysteine | 1.40 | 1.38 | 1.32 |
| Methionine | 1.50 | 1.47 | 1.43 |
| Phenylalanine | 4.90 | 4.75 | 4.75 |
| Tyrosine | 3.77 | 3.80 | 3.74 |
| Therionine | 3.89 | 3.91 | 3.88 |
| Valine | 4.52 | 4.52 | 4.46 |
| Trptophan | 0.85 | 0.78 | 0.69 |
| Total EAA | 38.99 | 38.66 | 37.40 |
| **Non essential amino acids (NEAA):** | | | |
| Hestidine | 2.54 | 2.60 | 2.54 |
| Arginine | 6.16 | 6.12 | 5.89 |
| Asparatic | 11.31 | 11.35 | 11.36 |
| Glutamic | 16.87 | 16.90 | 16.85 |
| Serine | 4.58 | 4.58 | 4.54 |
| Proline | 5.63 | 5.44 | 5.39 |
| Glycine | 4.13 | 4.23 | 4.17 |
| Alanine | 4.28 | 4.21 | 4.18 |
| Total NEAA | 55.50 | 55.43 | 54.92 |
| Total amino acids | 94.49 | 94.09 | 92.32 |
| E/T (%) | 41.26 | 41.10 | 40.51 |

**Effect of heating in an autoclave and roaster on the protein digestibility index of soybean seeds:**

Data in Table (3) show the effect of heating in an autoclave and roaster on the protein digestibility index of soybean seeds. Results show that increasing heating time improved protein digestibility for both autoclaved and roasted soybean seeds. The optimum conditions for maximum digestibility was heating for 40 min by autoclaved.

The increase in protein digestibility after heat treatment could be partially attributed to protein denaturation which improve protein susceptibility to enzyme attack. Furthermore inactivation of trypsine inhibitor would certainly improve *in vitro* protein digestibility (Zaki *et al.*, 1996).

Vijayakumari *et al.* (1998) found that autoclaving seemed to be best method for eliminating the contents of antinutrients. It also improved the protein digestibility index.

**Table (3): Effect of heating in an autoclave and roaster on the protein digestibility index of soybean seeds**

| Heating time | Protein digestibility index after autoclaved seeds (%) | Protein digestibility index after roasted seeds (%) |
|---|---|---|
| Without heating | 73.20 | 73.20 |
| Heating 10 min | 77.30 | 74.98 |
| Heating 20 min | 82.90 | 79.92 |
| Heating 30 min | 85.60 | 82.10 |
| Heating 40 min | 87.20 | 84.90 |

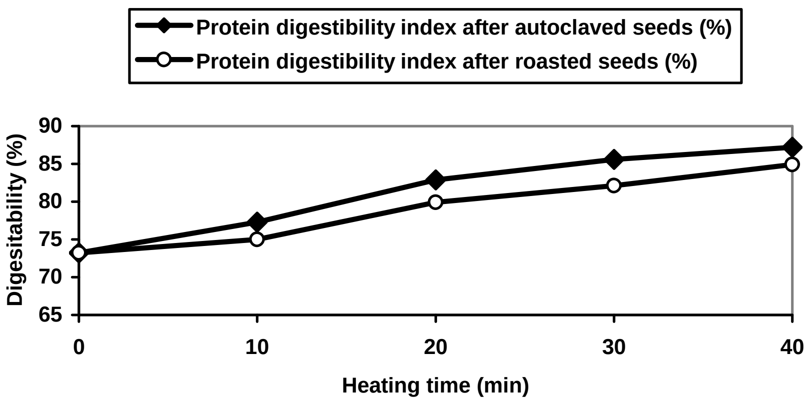



**Fig. (2): Effect of heating in an autoclave and roaster on the protein digestibility index of soybean seeds**

**Evaluation of products prepared (beef sausage and beef burger) with replacement part of used meat by treated soybean:**

**a) Beef sausage:**

Data in Table (4) show moisture, crude protein, ether extract, ash and total carbohydrates content in beef sausage prepared in laboratory with replacement part of meat used by levels of soybean treated with autoclaved or roasted (0, 10, 15, 20, 25 and 30%). Moisture content of fresh sausage treatments ranged from 57.17-60.50%, but, after frying all sausage treatments ranged from 48.63-52.63%. Crude protein and ether extract content were decreased with increasing the level of replacement levels with rehydrated soybean flour (autoclaved or roasted) compared with control sample, while, ash and total carbohydrate content were opposite direction. This is mainly due to the lower content of protein and fat content in the replace ingredients. On the contrary, ash and total carbohydrates increased by increasing the replacement levels. These results are in agreement with those reported by Faheid *et al.* (1998).

Also, results in the same table indicated that moisture content and ether extract decreased after frying compared with fresh sausage treatments, while crude protein, ash and total carbohydrates increased. Crude protein content decreased in all treatments with increasing the levels of replacement levels for part meat by rehydrated soybean flour. The percentage of decreased for crude protein reached to 7.41 and 4.90% by replacement with soybean treated (autoclaved and roasted), respectively, at level 30% compared to control sample. But, increasing of crude protein after frying may be due to decrease in ether extract content (data calculated on dry weight basis) due to escape of some fats in cooking process and/or lowering of meat with increasing the level of replacement as mentioned by Nuzhat *et al.* (2002).

Data in Table (5) indicate the physico-chemical properties of beef sausage with series levels of rehydrated souybean flour replacement besides changes in TVN, TBA, pH value WHC, plasticity and cooking loss in prepared beef sausage. TVN amounted to 9.71 mg/100 g in fresh beef sausage (control) and increased after frying to 9.92 mg/100 g. Adding rehydrated soybean flour (treated with autoclaving) at levels from 10 to 30% in fresh or fried beef sausage decreased TVN to 6.65 and 6.90 mg/100 g. While reached to 6.94 and 7.10 mg/100 g in case using rehydrated soybean flour (treated with roasted). Also, TBA took the same trend and revealed 0.65 and 0.68 mg malonaldhyde/kg in fresh and fried beef sausage (control) and decreased to 0.45 to 0.49 mg/kg, respectively for autoclaved rehydrated soybean flour, while reached to 0.44 and 0.49 mg/kg for roasted rehydrated soybean flour. On the contrary pH value was 5.80 and 5.85 in fresh and fried beef sausage (control) and increased gradually to 6.07 and 6.09, respectively for autoclaved rehydrated soybean flour, while reached to 6.08 and 6.09 for roasted rehydrated soybean.

Concerning WHC it was 1.45 $cm^2$/0.3 g in fresh beef sausage (control) and decreased gradually to 0.65 and 0.55 $cm^2$/0.3 g sample preparing for autoclaved and roasted rehydrated soybean flour, respectively. Also, plasticity decreased from 3.15 to 1.95 and 1.80 $cm^2$/0.3 g for autoclaved and roasted rehydrated soybean flour, respectively. Cooking loss percentage was 14.49 in

fresh beef sausage (control) and decreased gradually to 4.53 and 4.49 for autoclaved and roasted rehydrated soybean flour, respectively. These results are in agreement with Moghazy *et al.* (2004).

Total volatile nitrogen (TVN), TBA, WHC, plasticity and cooking loss were decreased with increasing of replacement levels (0 to 30% soybean from meat used). Also, TBA was increasing after frying compared with fresh samples may be due to the decreased of moisture content because the results calculated on wet weight basis. The decrease of WHC and cooking loss were suitable characterization.

Data in Table (6) indicate that sensory evaluation (color, aroma, taste, texture, palatability and total scores) in beef sausage prepared in laboratory with replacement by soybean (0 to 30%). Results show that there are significant differences ($P<0.05$) for color, taste and total score between control sample and other treatments, except there is no significant differences ($P>0.05$) in aroma between control sample (0%) and treatments with replacement level 10% of soybean treated with autoclaved or roasted.

Anyhow, the soybean flour added to sausage samples could be separated into two groups, hence there is no significant differences ($P>0.05$) between any two samples with the same group. The first group includes sausage treatments replacement levels 10, 15 and 20% of soybean treated with autoclaved, while, at levels 10 and 15% of soybean treated with roasted.

The second group include sausage treatments replacement with 25 and 30% of soybean treated with autoclaved, while, 20, 25 and 30% for soybean roasted. In the same time there is significant difference ($P<0.05$) between the two groups.

**Table (6): Sensory evaluation of beef sausage prepared with rehydrated soybean flour.**

| Treatment | | Color | Aroma | Taste | Texture | Palatability | Total score |
|---|---|---|---|---|---|---|---|
| Control | | $9.7\pm0.15^{a}$ | $9.7\pm0.15^{a}$ | $9.7\pm0.15^{a}$ | $9.7\pm0.48^{a}$ | $9.7\pm0.48^{a}$ | $48.5\pm2.22^{a}$ |
| Soyabean autoclaving | 10 | $9.1\pm0.10^{b}$ | $9.1\pm0.10^{ab}$ | $9.1\pm0.10^{b}$ | $9.2\pm0.42^{ab}$ | $9.3\pm0.48^{ab}$ | $45.8\pm1.32^{b}$ |
| | 15 | $8.8\pm0.13^{bc}$ | $8.7\pm0.15^{bc}$ | $8.8\pm0.13^{b}$ | $9.1\pm0.57^{ab}$ | $8.9\pm0.32^{b}$ | $44.3\pm1.49^{b}$ |
| | 20 | $8.7\pm0.21^{bc}$ | $8.6\pm0.15^{bc}$ | $8.7\pm0.15^{bc}$ | $8.9\pm0.71^{b}$ | $8.7\pm0.71^{b}$ | $43.6\pm2.50^{b}$ |
| | 25 | $7.6\pm0.31^{d}$ | $7.6\pm0.31^{de}$ | $7.4\pm0.31^{d}$ | $7.3\pm1.34^{de}$ | $7.5\pm1.08^{d}$ | $37.4\pm3.98^{cd}$ |
| | 30 | $6.7\pm0.21^{e}$ | $7.1\pm0.50^{e}$ | $6.7\pm0.26^{e}$ | $6.9\pm1.20^{e}$ | $6.8\pm0.92^{ef}$ | $34.2\pm4.16^{e}$ |
| Soyabean Roasting | 10 | $9.0\pm0.15^{b}$ | $9.1\pm0.10^{ab}$ | $8.8\pm0.13^{b}$ | $8.8\pm0.42^{b}$ | $8.7\pm0.67^{bc}$ | $44.4\pm1.35^{b}$ |
| | 15 | $8.9\pm0.18^{b}$ | $8.6\pm0.16^{bc}$ | $8.7\pm0.15^{bc}$ | $8.6\pm0.52^{bc}$ | $8.7\pm0.48^{bc}$ | $43.5\pm1.58^{b}$ |
| | 20 | $8.4\pm0.22^{c}$ | $8.3\pm0.30^{cd}$ | $8.2\pm0.20^{c}$ | $8.0\pm0.67^{cd}$ | $8.1\pm0.57^{cd}$ | $41.0\pm2.00^{c}$ |
| | 25 | $7.3\pm0.15^{d}$ | $6.9\pm0.31^{e}$ | $7.3\pm0.15^{d}$ | $7.1\pm0.88^{d}$ | $7.2\pm0.79^{e}$ | $35.8\pm2.86^{de}$ |
| | 30 | $6.0\pm0.30^{f}$ | $6.1\pm0.31^{f}$ | $5.90\pm0.23^{f}$ | $6.40\pm1.26^{e}$ | $6.40\pm0.97^{f}$ | $30.80\pm3.68^{f}$ |
| LSD | | 0.57 | 0.73 | 0.53 | 0.74 | 0.63 | 2.36 |

**a, b, c, d, e & f: There is no significant difference between any two means, with the same attribute, have the same letter ($P > 0.05$).**

So, it could be recommended to apply replacement level with 20% soybean treated with autoclaved from meat used in prepared sausage, 15% for used soybean roasted.

**b) Beef burger:**

Data in Table (7) show moisture, crude protein, ether extract, ash and total carbohydrate content in beef burger prepared in laboratory with replacement levels of rehydrated soybean flour treated with autoclaved or roasted (0, 10, 15, 20, 25 and 30%). Moisture content of fresh beef burger (control) was 66.79%, while it was ranged from 65.58 to 66.79% in all treatments. Moisture content decreased after frying in all treatments, where it ranged from 52.99 to 54.81%.

Crude protein and ether extract contents decreased with increasing the level of replacement by rehydrated soybean compared to control sample, while ash and total carbohydrates content were increased with increasing replacement levels (0 to 35%) for autoclaved or roasted treated.

Also, results in the same table indicate that moisture, crude protein, ash and total carbohydrate contents decreased after frying compared with fresh beef burger treatments, wherever, ether extract content increased.

Crude protein content decreased in all treatments with increasing the level of replacement for part meat used by rehydrated soybean flower (autoclaved or roasted). The percentage of decreasing reached to 6.31 and 7.64% for crude protein at level 30% for rehydrated soybean flower (autoclaved and roasted) compared to fresh control sample, while were 5.14 and 3.73% after frying, respectively. But, the decreasing of crude protein after frying may be due to increasing in ether extract content (data calculated on dry weight basis). These results are in agreement with Abd El-Salam and Hassanin (1987) and El-Mansy *et al.* (2002).

Data in Table (8) indicate the physicochemical properties of beef burger with series levels of rehydrated soybean replacement besides changes in TVN, TBA, pH value, WHC, plasticity, cooking loss and shrinkage in prepared beef burger.

Total volatile nitrogen (TVN) amounted to 9.75 mg/100 g in fresh beef burger and increased after frying to 10.80 mg/100 g. Adding rehydrated soybean treated with autoclaved at levels from 10 to 30% in fresh or fried beef burger decreased TVN to 5.60 and 6.50 mg/100 g, respectively, while reached to 6.40 and 7.15 mg/100 g, respectively for roasted rehydrated soybean. TBA took the same trend and revealed 0.50 and 52 mg malonaldhyde/kg in fresh and fried beef burger (control) and decreased to 0.37 and 0.39; 0.38 and 0.41 mg/kg, for autoclaved and roasted rehydrated soybean, respectively. On the contrary pH value was 5.42 and 5.65 in fresh and fried beef burger (control) and increased gradually to 5.55 and 5.85, respectively for autoclaved rehydrated soybean, while reached to 5.60 and 5.88, respectively for roasted rehydrated soybean. Concerning WHC it was 4.75 $cm^2$/0.3 g in fresh beef burger and decreased gradually to 2.60 and 4.20 $cm^2$/0.3 g sample preparing for autoclaved and roasted rehydrated soybean, respectively, While plasticity increased from 1.65 $cm^2$/0.3 g in control to 1.85 and 1.90 $cm^2$/0.3 g for autoclaved and roasted rehydrated soybean, respectively. Cooking loss percentage and shrinkage after frying were

16.11 and 12.98 in fresh beef burger and decreased gradually to 9.62 and 7.76; 9.26 and 6.95 for autoclaved and roasted rehydrated soybean, respectively. These results are in agreement with El-Mansy *et al.* (2002) and Modi *et al.* (2003).

Data in Table (9) indicate that sensory evaluation (color, aroma, taste, texture, palatability and total scores) in prepared beef burger treatments in laboratory with replacement by soybean treated with autoclave or roaster (0 to 30%). Results indicated that there were no significant differences (P>0.05) for all properties tested except cut between control sample and all treatments at 15% replacement levels.

**Table (9): Sensory evaluation of beef burger with rehydrated soybean flour.**

| Treatment | | Color | Aroma | Taste | Texture | Palatability | Total score |
|---|---|---|---|---|---|---|---|
| Control | | 9.4±0.27$^{a}$ | 9.1±0.20$^{a}$ | 9.4±0.67$^{a}$ | 9.4±0.52$^{a}$ | 9.3±0.27$^{a}$ | 46.6±2.26$^{a}$ |
| Soyabean autoclaving | 10 | 9.2±0.21$^{a}$ | 8.9±0.16$^{ab}$ | 9.3±0.45$^{ab}$ | 9.1±0.35$^{ab}$ | 8.8±0.27$^{b}$ | 45.3±1.65$^{ab}$ |
| | 15 | 8.9±0.28$^{ab}$ | 8.6±0.28$^{ab}$ | 9.2±0.42$^{abc}$ | 8.9±0.38$^{abc}$ | 8.7±0.32$^{b}$ | 44.3±2.48$^{abc}$ |
| | 20 | 8.7±0.16$^{ab}$ | 8.5±0.23$^{ab}$ | 9.0±0.46$^{abc}$ | 8.7±0.35$^{bcd}$ | 8.6±0.25$^{b}$ | 43.5±2.01$^{bc}$ |
| | 25 | 8.5±0.21$^{b}$ | 8.3±0.13$^{bc}$ | 8.8±0.49$^{bcde}$ | 8.2±0.46$^{def}$ | 8.4±0.31$^{bc}$ | 42.2±1.32$^{cd}$ |
| | 30 | 8.3±0.36$^{b}$ | 7.8±0.19$^{cd}$ | 8.1±0.53$^{f}$ | 7.6±0.62$^{ef}$ | 8.1±0.35$^{cd}$ | 39.9±2.14$^{de}$ |
| Soyabean roasting | 10 | 9.3±0.19$^{a}$ | 9.0±0.25$^{a}$ | 9.3±0.53$^{ab}$ | 9.3±0.42$^{ab}$ | 8.7±0.35$^{b}$ | 45.6±2.06$^{a}$ |
| | 15 | 8.9±0.23$^{ab}$ | 8.8±0.23$^{ab}$ | 8.9±0.73$^{abc}$ | 8.9±0.55$^{abc}$ | 8.6±0.41$^{b}$ | 44.1±2.47$^{abc}$ |
| | 20 | 8.6±0.16$^{ab}$ | 8.4±0.17$^{bc}$ | 8.7±0.67$^{cde}$ | 8.7±0.42$^{bcd}$ | 8.5±0.19$^{bc}$ | 42.9±1.74$^{bc}$ |
| | 25 | 8.5±0.17$^{b}$ | 8.3±0.19$^{bcd}$ | 8.5±0.50$^{def}$ | 8.3±0.46$^{cde}$ | 8.2±0.13$^{bc}$ | 41.8±1.46$^{cde}$ |
| | 30 | 8.0±0.23$^{c}$ | 7.7±0.27$^{d}$ | 8.3±0.70$^{ef}$ | 7.5±0.78$^{f}$ | 7.7±0.42$^{d}$ | 39.2±2.43$^{e}$ |
| LSD | | 0.81 | 0.60 | 0.53 | 0.70 | 0.44 | 2.86 |

**a, b, c, d, e & f: There is no significant difference between any two means, with the same attribute, have the same letter (P > 0.05).**

Anyhow, the treatment of beef burger samples could be separated into two groups, hence there is no significant differences (P>0.05) between any two samples with the same group. The first group includes beef burger treatments replacement levels 10, 15 and 20% of soybean treated with autoclave, while 10 and 15% of soybean treated with roaster.

The second group includes beef burger treatments replacement with 25 and 30% soybean treated with autoclaved, while 20, 25 and 30% soybean roasted. In the same time there is significant difference (P<0.05) between the two groups.

So, it could be recommended to apply replacement level with 20% soybean treated with autoclaved from meat used in prepared sausage and beef burger.

## REFERENCES

Aarti, D.; Neelam, K.; Saroj, B. and Bishnoi, S. (1999): Effect of various domestic processing and cooking methods on phytic acid and HCl extractability of calcium, phosphorus and iron of pigeonpes. Nutrition and health 13(3): 161-169.

Abd El-Salam, M.A. and Hassanin, T.M. (1987): Utilization of defatted soy flour and chickpea for preparing minced fish patties. Agric. Res. Review, 65(3): 531-540.

Arentoft, A.M.; Mortensen, K. and Sorensen, H. (1991): Pea proteinase inhibitory activity. Appl. Biol. 17: 211-215.

A.O.A.C. (1995): Official Methods of Analysis, Association of Official Analytical Chemists, 16th Ed., Virginia, U.S.A.

Barton, W.E.C. (1952): The microbiological assay of vitamin B complex and amino acids. London, Isac Pitman and sons Ltd. P. 117.

Bau, H.M.; Villaume, C.; Nicolas, J.P. and Mejean, L. (1997): Effect of germination on chemical composition, biochemical constituents and antinutritional factors of soybean (*Glycine max*) seeds. J. Sci. Food Agric., 73: 1-9.

Blouth, O.J.; Chareinski, M. and Berbec, H. (1963): Cysteine and tryptophan determination by microbiological technique. Anal. Bioch., Vol. 8: 69-78.

Carballo, J. Barreto, G. and Jimenez Colmenero, F. (1995). Starch and egg white influence on properties of Bologna sausage as related to fat content. J. Food Sci. 60: 673-677.

Chen, L.H.; Thacker, R.R. and Pan, S.H. (1977): Effect of germination on hemagglutinating activities of pea and bean seeds. J. Food Sci., 42: 1666-1669.

Cross, H.R.; Berry, R.W. and Wells, L.H. (1980). Effect of total level and source on the chemical sensory and cooking properties of ground beef. J. Food Sci. 45:791-793.

Darweash, B.M. and Moghazy, E.A. (1998). Evaluation of chemical and nutritional properties of beef burgers extended with beef ribs bone protein isolate. Egypt. J. Appl. Sci., 13(2): 109-125.

Dexter, D.R.; Sofos, J.N. and Schmidt, G.R. (1993). Quality characteristics of turkey Bologna formulated with carrageenan, starch, milk and soy protein. J. Muscle Foods 4: 207-223 (1993).

El-Mansy, H.A.; Mahmoud, M.H.M. and Abo El-Azm, H.A. (2002): Utilization of tempeh in some meat products. J. Annals of Agric. Sc. Moshtohor, 40(1): 971-985.

El-Morsi, E.A. (1996): Review: Studies on antinutritional factors in some Egyptian legume seeds. In "The proceeding of the fourth Arabic Conference for horticultural crops, 25-28" March, Fac. of Agric., Minia Univ.

Faheid, S.M.M.; El-Akel, A.T. and Mohamed, S.E. (1998): Quality attributes of beef burger supplemented with different sources of plant proteins and the relationship between different cooking methods. Egypt. J. Appl. Sci., 13(7): 217-237.

FAO (1973). United Nations Food and Agriculture Orgnization Energy and protein requirements. Joint FAO/WHO Ad. HOC committee (March-April, 1971). Rome.

Foda, F.F. and Abd El-Aleem, I.M. (1998): Nutritional imporovement of some legume proteins. Annals of Agric. Sci. Moshtohor 36(3): 1519-1532.

Frederick, T.L.; Miller, F.M.; Tinney, K.S.; Bye, L.R. and Ramsey, C.B. (1994). Characteristics of 95% lean beef German sausages varying in phosphate and added water. J. Food Sci. 59: 453-455.

Friedman, M.; David, L.B.; Anne, H.B. and Theodore, H. (1991): Comparison of a commercial soybean cultivar and an isoline lacking the kuntiz trypsin inhibitor: composition, nutritional value and effects of heating. J. Agric. Food Chem. 39: 327-335.

Grant, G.; Watt, W.B.; Stewart, J.C. and Pusztai, A. (1987): Effect of dietary soybean (*Glycine max*) lectin and trypsin inhibitor upon the pancrease of rats. Med. Scines 15: 197-1198.

Harold, E.; Ronald, S.K. and Ronald, S. (1981): Person's chemical analysis of foods. 8th Ed. Photolypeset by input Tybesetting Ltd., London Sw198 Dr printed in 8 Great Britain by Butler and Tammer Ltd.

Herkelman, K.L.; Cromwell, G.L.; Stahly, T.S.; Pfeiffer, T.W. and Knabe, D.A. (1992): Apparent digestibility of amino acids in raw and heated conventional and low-trypsin-inhibitor soybeans for pigs. J. Anim. Sci. 70: 818-826.

Jambunathan, R. and Singh, U. (1981): Grain quality of pigeopea. In: Proceedings of the international workshop on pigeonpea Vol I ICRISAT. Hyderabad. Andhra Pradesh India 15-19 December, 1980.

Latta, M. and Eskin, N.A. (1980): A simple and rapid colorimetric method for phytate determination. J. Agric. Food Chem. 28: 1313-1315.

Lis, H. and Sharon, N. (1972): Soybean (*Glycinemax*) agglutinin. Methods Enzymol. 28: 360-366.

Miller, M.F.; Andersen, M.K.; Ramsey, C.B. and Reagan, J.O. (1993). Physical and sensory characteristics of low fat ground beef patties. J. Food Sci. 58: 461-463.

Modi, V.K.; Mahendrakar, N.S.; Rao, D.N. and Sachindra, N.M. (2003): Quality of buffalo meat burger containing legume flours as binders. Meat Sci., 66(1): 143-149.

Moghazy, E.A. and El-Shaarawy, M.O.A. (2001): Quality attributes of beef burger as affected by using proplies and frozen storage. Egypt. J. Agric. Res., 79(4): 1499-1512.

Moghazy, E.A.; Sharaf, S.M. and El-Seesy, T.A. (2004): Effect of substitutines mutton tailfat with vegetable oil on quality attributes of healthy beef sausage. Egypt. J. Appl. Sci., 19(5): 191-205.

Moore, S.; Spachman, D.E. and Stein, W. (1958): Chromatography of amino acid on sulphonated polystyrene resins. Anal Chem. 30: 1185-1190.

Nuzhat, H.; Imran, P.; Sultan, S.; Zobia, J. and Asif, I. (2002): Incorporation of legumes as non-meat protein exenders in fresh beef sausages. Pakistan J. Agric. Sci., 39(3): 236-239.

Osburn, V.N. and Keton, J.T. (1994). Konjac flour gel as fat substitute in low-fat prerigor fresh pork sausage. J. Food Sci. 59: 484-489.

Paredes-Lopez, O. and Harry, G.I. (1989). Changes in selected chemical and antinutritional components during tempeh preparation using fresh and hardened common beans. J. Food Sci. 54(4): 968-970.

Richert, S.H. (1991). Soy products. Presented at low-fat ground beef symposium, Baton Rouga, La., Feb. 11-12.

Saikia, P.; Sarkar, C.P. and Broua, I. (1999): Chemical composition, antinutritional factors and effect of cooking on nutritional quality of rice bean. Food Chem., 67: 347.

Samirnoff, P.; Khalef, S.; Birle, Y. and Applebaum (1976): Trypsin and chymotrypsin inhibitors from chick peas (*Cicer arietinum*). Biochem. J. 157: 745-751.

Santosh, K. and Chauhan, B.M. (1986) Effect of domestic processing and cooking and *in vitro* protein digestibility of moth bean. J. Food Sci., 51 (4): 1083-1084.

Sato, T. and Herman, L. (1990): Morphometry and elemental analysis of rat exocrine pancreas following administration of trypsin inhibitor. Acta. Anat. 137: 65-76.

Seda, H.A.; Gehan, S.; Mahmoud, A. and Hania, F. (2002): The effect of gamma irradiation or roasting on antinutritional factors of peanut kernels. J. Agric. Sci. Mansoura Univ., 27(1): 341-353.

Sharon, N. and Lis, H. (1990): Legume lectins a large family of homologous proteins. FASEB J. 4: 3198-3208.

Snedecor, G.W. and Cochran, W.G. (1980): Statistical Methods. 7$^{th}$ Ed. Oxford and IBIT Pub. Co.

Soloviev, V.E. (1966). Aging of meat. Food industry Pub., Moscow.

Staron, T. (1977): Les produits toxiques contenus dans les sources potentielles. Text presented in EEC, Brussels, Belgium, 13 January 1977. (c.f. Bau *et al*., 1997).

Stauffer, C.E. (1993): Trypsin inhibitor measurement: Effect of order of reagent addition. Cereal Chem., 70: 111-112.

Swain, T. and Hills, W.F. (1959): The phenolic constituents of *Prumus domestica* L. The quantitative analysis of phenolic constituents. J. Sci. Food Agric. 10: 63-69.

Thompson, L.U.; Rea, R.L. and Jenkins, D.J.A. (1983): Effect of heat processing on hemagglutinin activity in red kidney beans: J. Food Sci. 48: 235-236.

Trius, A.; Sebranek, J.G.; Rust, R.E. and Carr, J.M. (1994). Low-fat bologna and beaker sausage: Effect of carrageenans and chloride salts. J. Food Sci. 59: 941-945.

Umoren, U.F.; Tewe, O. and Jackai, L. (1997): Protein quality of raw and autoclaved cowpea. Plant Foods for Human Nutrition 50(4): 301-315.

Vijayakumari, K.; Siddhuraju, P.; Pugalenthi, M. and Janardhanan, K. (1998): Effect of soaking and heat processing on the levels of antinutrients and digestible proteins in seeds of *Vigna aconitifolia* and *Vigna sinensis*. Food Chem., 63(2): 259-264.

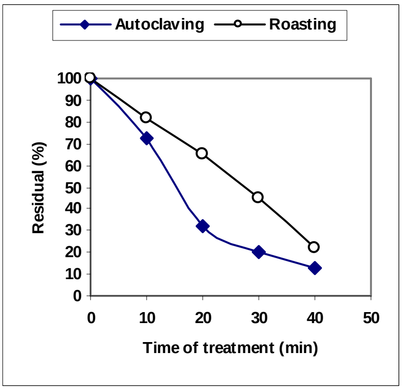
Watts, B.M.; Yamaki, G.L.; Jeffery, L.E. and Elias, L.G. (1989). Basic sensory methods for food evaluation. 1st Ed., The International Development Res. Center Pub., Ottawa, Canada.

Winton, A.L. and Winton, R.B. (1958): Okoloff magnesium oxide distillation volumetric method. "The analysis of Food" P.848, John Willey. New York and Chapman, London.

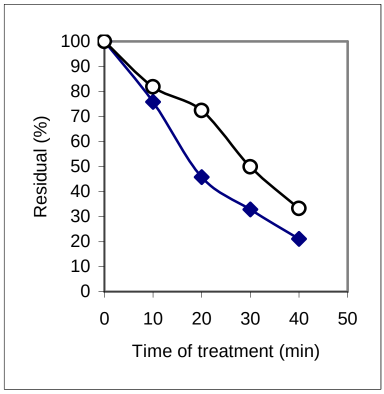
Woye Woda, A.D.; Shaw, S.J.; Ke, P.J. and Burns, B.G. (1986): Recommended Laboratory Methods for Assessment of Fish Quality. Canadian Technical Report of Fisheries and Aquatic Science, No. 1448.

Zaki, A.M.; Aboul Fetouh, S.A.; Mohany, H. and El-Morsi, E.A. (1996): Biochemical changes of some chemical constituents in chickpea seeds during germination and processing. Annals of Agric. Sci. Moshtohor, 34: 995-1022.

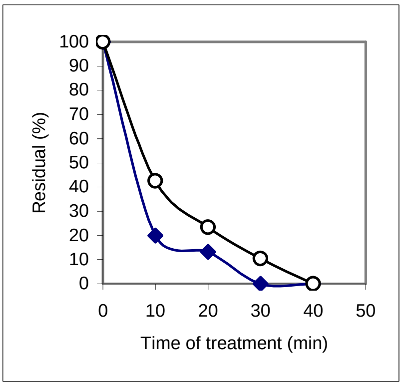
Zaki, A.M.; Ismail, H.A.; Abdel-Naem, G.F. and El-Morsi, A.E. (1999): Antinutritional factors and in vitro digestibility in Guar seed as affected by germination and autoclaving. J. Agric. Sci. Mansoura Univ. 24(11): 7023-7037.



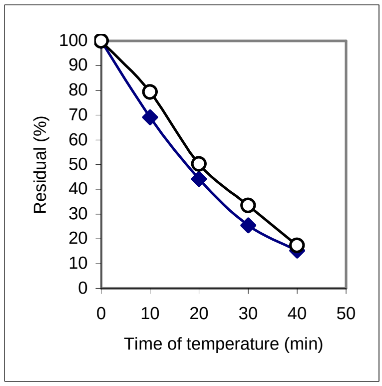

**Trypsin inhibitor (TI)**



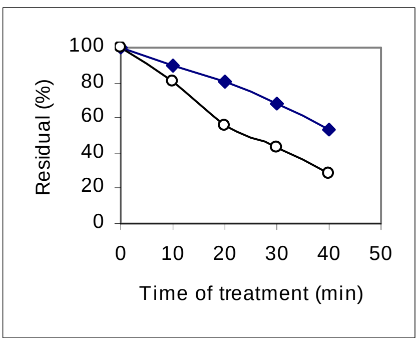

**Chymotrypsin inhibitor (CI)**




**Hemagglutinine (HA)**




**Total phenolic compounds (TPC)**




**Phytic acid (PA)**

**Fig. (1): Effect of autoclaving and roasting on the antinutritional matters of soybean seeds**

**Table (4): Chemical composition of beef sausage prepared with rehydrated soybean flour.**

| Replacement with soybean (%) | | Moisture | | Crude protein* | | Ether extract* | | Ash* | | Carbohydrate* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fresh | After frying | Fresh | After frying | Fresh | After frying | Fresh | After frying | Fresh | After frying |
| Control (0) | | 60.50 | 52.63 | 36.66 | 37.67 | 44.09 | 40.48 | 7.45 | 8.30 | 11.81 | 13.57 |
| Autoclaving | 10 | 59.80 | 51.76 | 35.05 | 36.85 | 43.89 | 38.15 | 7.51 | 8.65 | 13.56 | 16.36 |
| | 15 | 59.12 | 50.15 | 34.15 | 36.75 | 42.94 | 37.04 | 7.52 | 8.70 | 15.39 | 18.19 |
| | 20 | 58.87 | 49.84 | 32.65 | 35.47 | 42.39 | 36.43 | 7.54 | 8.81 | 17.43 | 19.30 |
| | 25 | 57.71 | 48.93 | 31.05 | 35.63 | 42.15 | 35.56 | 7.55 | 8.94 | 19.26 | 19.88 |
| | 30 | 57.41 | 48.63 | 29.25 | 34.27 | 41.90 | 34.45 | 7.60 | 9.00 | 21.25 | 22.28 |
| Roasting | 10 | 60.22 | 52.06 | 35.15 | 36.38 | 43.86 | 39.94 | 7.50 | 8.30 | 13.50 | 15.40 |
| | 15 | 59.74 | 52.25 | 34.32 | 35.99 | 42.65 | 38.35 | 7.53 | 8.72 | 15.50 | 16.95 |
| | 20 | 58.23 | 51.85 | 33.16 | 35.15 | 42.17 | 37.53 | 7.60 | 8.81 | 17.08 | 18.52 |
| | 25 | 57.78 | 51.21 | 32.04 | 34.13 | 41.64 | 36.39 | 7.63 | 8.82 | 18.69 | 20.67 |
| | 30 | 57.17 | 50.48 | 30.25 | 33.89 | 40.61 | 34.31 | 7.67 | 9.05 | 21.47 | 22.76 |

*** (on dry weight basis)**

**Table (5): Physico-chemical of beef sausage prepared with rehydrated soybean flour.**

| Replacement with soybean (%) | | TVN (mg/100 g) | | TBA (mg/kg) | | pH value | | WHC ($cm^2$/0.3 g) | | Plasticity ($cm^2$/0.3 g) | | Frying loss (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fresh | After frying | Fresh | After frying | Fresh | After frying | Fresh | After frying | Fresh | After frying | Fresh | After frying |
| Control (0) | | 9.71 | 9.92 | 0.65 | 0.68 | 5.80 | 5.85 | 1.55 | - | 3.15 | - | 14.49 | - |
| Autoclaving | 10 | 9.10 | 9.31 | 0.60 | 0.63 | 5.90 | 5.96 | 1.45 | - | 2.90 | - | 13.56 | - |
| | 15 | 8.45 | 8.70 | 0.58 | 0.62 | 6.00 | 6.03 | 1.40 | - | 2.70 | - | 10.28 | - |
| | 20 | 7.68 | 8.10 | 0.56 | 0.58 | 6.02 | 6.05 | 1.15 | - | 2.55 | - | 6.46 | - |
| | 25 | 7.20 | 7.60 | 0.50 | 0.55 | 6.04 | 6.07 | 0.85 | - | 2.20 | - | 5.46 | - |
| | 30 | 6.65 | 6.90 | 0.45 | 0.49 | 6.07 | 6.09 | 0.65 | - | 1.95 | - | 4.53 | - |
| Roasting | 10 | 9.23 | 9.60 | 0.58 | 0.64 | 6.01 | 6.04 | 1.50 | - | 2.95 | - | 14.59 | - |
| | 15 | 8.30 | 8.80 | 0.55 | 0.58 | 6.03 | 6.05 | 1.40 | - | 2.68 | - | 9.63 | - |
| | 20 | 7.80 | 8.24 | 0.50 | 0.56 | 6.04 | 6.06 | 1.30 | - | 2.45 | - | 6.24 | - |
| | 25 | 7.15 | 7.48 | 0.46 | 0.52 | 6.05 | 6.07 | 0.90 | - | 2.15 | - | 5.23 | - |
| | 30 | 6.94 | 7.10 | 0.44 | 0.49 | 6.08 | 6.09 | 0.55 | - | 1.80 | - | 4.49 | - |

**TVN: Total volatile nitrogen** **TBA: Thiobarbituric acid** **WHC: Water holding capacity**

**Table (7): Chemical composition of beef burger prepared with rehydrated soybean flour.**

| Replacement with soybean (%) | | Moisture | | Crude protein* | | Ether extract* | | Ash* | | Carbohydrate* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fresh | After frying | Fresh | After frying | Fresh | After frying | Fresh | After frying | Fresh | After frying |
| Control (0) | | 66.79 | 54.81 | 54.09 | 48.76 | 17.81 | 21.41 | 7.31 | 7.10 | 20.79 | 22.73 |
| Autoclaving | 10 | 66.51 | 54.03 | 51.67 | 47.32 | 16.77 | 20.615 | 7.36 | 7.18 | 24.21 | 24.89 |
| | 15 | 66.49 | 53.29 | 50.13 | 46.97 | 15.66 | 19.86 | 7.38 | 7.24 | 26.83 | 25.94 |
| | 20 | 66.43 | 53.16 | 49.76 | 46.30 | 14.37 | 19.22 | 7.41 | 7.27 | 28.47 | 27.23 |
| | 25 | 66.15 | 53.14 | 48.34 | 46.42 | 13.72 | 18.20 | 7.42 | 7.31 | 30.53 | 28.08 |
| | 30 | 65.66 | 52.99 | 47.78 | 43.62 | 12.70 | 17.47 | 7.40 | 7.34 | 32.12 | 31.58 |
| Roasting | 10 | 66.73 | 53.91 | 51.06 | 49.20 | 16.47 | 19.08 | 7.38 | 7.03 | 25.11 | 24.71 |
| | 15 | 66.66 | 53.61 | 49.62 | 48.78 | 15.72 | 18.14 | 7.40 | 7.15 | 27.27 | 25.94 |
| | 20 | 66.26 | 53.42 | 48.97 | 47.41 | 14.54 | 17.52 | 7.42 | 7.18 | 29.08 | 27.90 |
| | 25 | 66.16 | 53.24 | 47.34 | 46.96 | 13.68 | 16.68 | 7.40 | 7.23 | 31.59 | 29.14 |
| | 30 | 65.58 | 53.20 | 46.45 | 45.03 | 12.96 | 16.16 | 7.42 | 7.29 | 33.18 | 31.53 |

*** (on dry weight basis)**

**Table (8): Physico-chemical of beefburger prepared with rehydrated soybean flour**

| Replacement with soybean (%) | | TVN (mg/100 g) | | TBA (mg/kg) | | pH value | | WHC ($cm^2$/0.3 g) | | Plasticity ($cm^2$/0.3 g) | | Cooking loss (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fresh | After frying | Fresh | After frying | Fresh | After frying | Fresh | After frying | Fresh | After frying | Fresh | After frying |
| 0 | | 9.75 | 10.80 | 0.50 | 0.52 | 5.42 | 5.65 | 4.75 | - | 1.65 | - | 16.11 | - |
| Autoclaving | 10 | 9.50 | 10.30 | 0.48 | 0.49 | 5.44 | 5.69 | 4.50 | - | 1.65 | - | 14.25 | - |
| | 15 | 9.00 | 9.80 | 0.45 | 0.47 | 5.48 | 5.71 | 4.10 | - | 1.70 | - | 12.93 | - |
| | 20 | 8.10 | 8.20 | 0.42 | 0.45 | 5.50 | 5.76 | 3.40 | - | 1.75 | - | 12.56 | - |
| | 25 | 6.90 | 7.60 | 0.40 | 0.43 | 5.53 | 5.80 | 3.10 | - | 1.80 | - | 10.19 | - |
| | 30 | 5.60 | 6.50 | 0.37 | 0.39 | 5.55 | 5.85 | 2.60 | - | 1.85 | - | 9.62 | - |
| Roasting | 10 | 9.60 | 10.40 | 0.49 | 0.51 | 5.46 | 5.70 | 7.85 | - | 1.70 | | 14.83 | - |
| | 15 | 9.25 | 10.00 | 0.45 | 0.48 | 5.51 | 5.75 | 8.05 | - | 1.75 | | 13.2 | - |
| | 20 | 8.15 | 9.10 | 0.43 | 0.46 | 5.55 | 5.78 | 5.40 | - | 1.80 | | 11.37 | - |
| | 25 | 7.10 | 8.00 | 0.41 | 0.43 | 5.58 | 5.82 | 4.70 | - | 1.85 | - | 10.88 | - |
| | 30 | 6.40 | 7.15 | 0.38 | 0.41 | 5.60 | 5.88 | 4.20 | - | 1.90 | - | 9.26 | - |

**TVN: Total volatile nitrogen** **TBA: Thiobarbituric acid** **WHC: Water holding capacity**