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Technology and Characteristics of Beefburger Containing Plant Substitutes

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ABSTRACT

The chemical and technological properties of soybean, faba bean, chickpea and white rice flour, as well as their effects on the quality of beefburger containing them, were investigated. The results showed that soybean flour was considered the best of the four meat substitutes. It was rich in protein, high in essential amino acids, except methionine, and easily mixed with the free water and fat of meat to give a stable mixture similar to the control. However, from an economical point of view and considerations of availability, broken rice and faba bean flours were preferred. Also, the study showed that polyacrylamide gel electrophoresis was useful for the identification of plant proteins in beefburger.

INTRODUCTION

In developed countries, a considerable proportion of meat production is converted to sausage, beefburger and meat patties (Peterson & Tressler, 1963). In 1971, the USDA's food and nutrition workers recommended the use of up to 30% hydrated textured vegetable products to replace up to 30% of the meat (Williams & Zabik, 1975). The studies of Trumic *et al.* (1982) showed that vegetable meat substitutes, particularly textured soy bean protein, were successful in preparing different types of minced meat products. The same observations were also reported by Youssef (1980) when he used chickpea and faba beans.

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The partial utilization of low price imported frozen beef meat in preparing beefburger, using the Egyptian local available plant materials as meat substitutes, was the main objective of this work.

MATERIALS AND METHODS

Materials

Meat
A representative sample, consisting of 100 kg low price brisket boneless frozen beef cuts, was utilized in this study. This meat was imported from West Germany packed in polyethylene film and kept frozen in cartons at −20°C. Such samples were taken as one batch from cold stores of Alexandria Meat Preparation and Processing Factory, Qabbari, Alexandria, Egypt, 1985.

Meat substitutes
Defatted soy bean flour. The textured defatted soy bean flour (type Mira–tex) was brought from Staley Co. Amsterdam, Holland, to use as a meat replacer in this study.

Chickpea seeds, decorticated faba bean, and white rice. Chickpea seeds, (*Cicer arietinum* L.) var. (Shamy), white rice (*Oryza sativa*) and decorticated faba beans (*Vicia faba*) were obtained from the local market at Alexandria and used as a meat replacer in this study after adequate preparation.

Spices
A mixture (powder) of 50% black pepper, 30% coriander, 5% cubeb, 5% cloves, 5% cinnamon and 5% red pepper was used as a seasoning agent.

Methods

Technological methods
Legumes and cereal flour preparation. The whole chickpea, dehulled faba bean and white rice were first soaked in running tap water for a few minutes, then dried at 40°C in a cabinet dryer to complete drying (a few hours) and ground in an electric mill 'National Mod. Mx-291 N' type, to pass through a 60 mesh sieve. The dried flour of each source was mixed with a certain amount of water according to its water absorption before use in processing of beefburger.

Processing of beefburger. Beefburger ingredients and preparation are shown in Fig. 1. It was shaped into a round form of 10 cm diameter, $\frac{1}{2}$ cm thickness and 60 g weight. Each beefburger was surrounded with two pieces of butter paper before being packaged in polyethylene bags. Each bag contained three pieces. An electronic sealing machine was used to weld the spaces around each piece and also the bag opening. The packaged beefburgers were stored at −22°C and 92% relative humidity.

Water and fat absorption. Water and fat absorption were determined according to the method of Hulse *et al.* (1977).

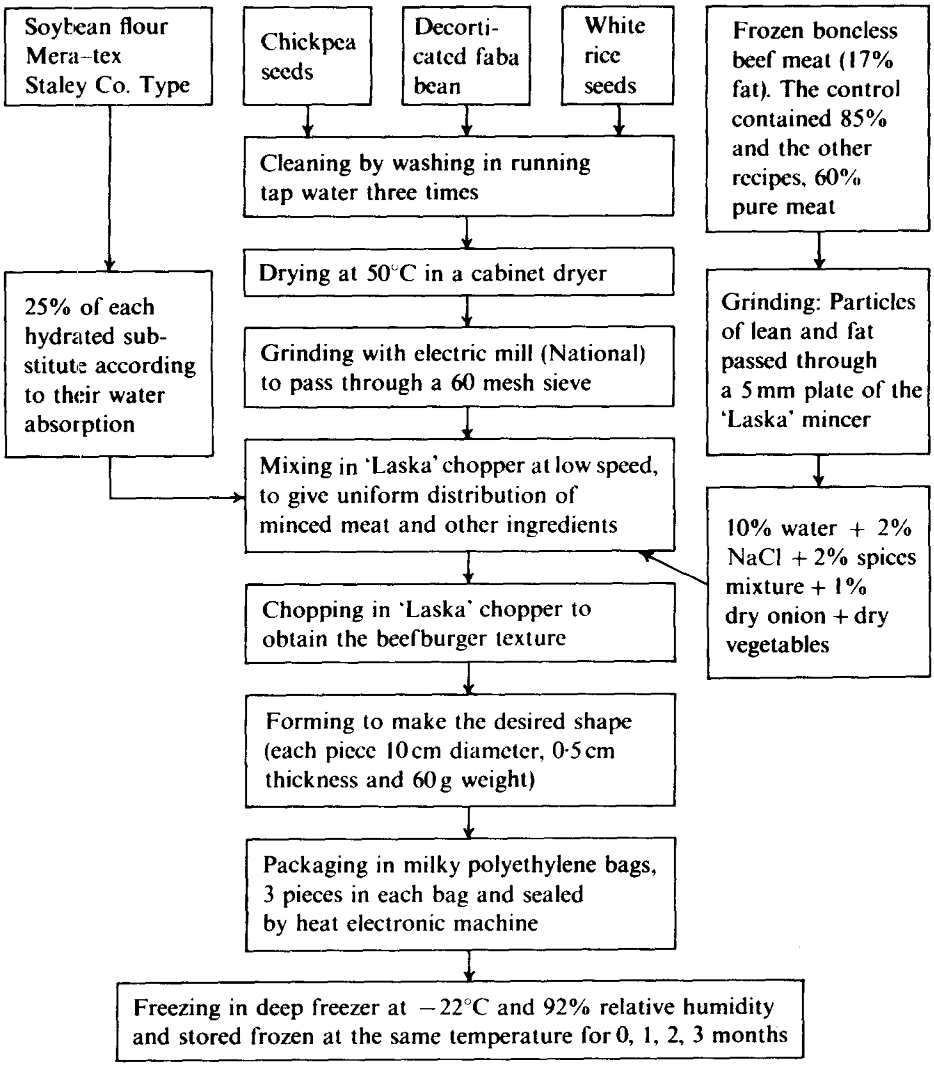


Fig. 1. Flow sheet of beefburger ingredients, preparation and processing.

Cooking loss and shrinkage. Beefburger samples were weighed immediately before and after frying in cotton seed oil for 1–2 min at 240°C. The percentages of cooking loss and shrinkage were calculated as mentioned by Hegazy (1981).

Chemical methods. The moisture content, crude protein, crude fat and total ash were determined in triplicate according to the AOAC (1980).

Fractionation of meat proteins. The methods described by King (1966) and Aman (1983) were used to fractionate meat proteins into sarcoplasmic, myofibrillar, denatured and stroma proteins.

Amino acid composition. The total amino acids in protein were determined according to the method of Moore (1958) using a Beckman Amino Acid Analyzer (Model 119 CL).

Electrophoretic separation of proteins. A polyacrylamide gel electrophoresis (PAGE) technique was used to fractionate water-soluble proteins of plant materials and beefburger samples. Electrophoresis was performed using the PANTA-PHOR and/or the MONO-PHOR apparatus. Electrophoretic conditions, staining and destaining methods were followed as described by Stegemann *et al.* (1986).

Organoleptic evaluation. Beefburgers were judged for their quality after frying in cotton seed oil for 1–2 min at 240°C. The samples were tested for colour, flavour, tenderness, taste and overall acceptability, according to the method designed by the Deutsche Landwirtschaftliche Geselschaft (DLG) (1973). Ten trained panellists were asked to score the organoleptic properties of the samples by giving grades ranging from zero to ten according to the following scheme: 10, ideal; 9, excellent; 8, very good; 7, good; 6, fairly good; 5, acceptable; 4, fair; 3, poor fair; 2, poor; 1, very poor; 0, repulsive. Any food item obtaining less than 50% on the score of overall acceptability must be rejected. The following grading system was recommended:

1 Fancy grade having at least 90% of the score.
2 Very good grade having at least 80% of the score.
3 Medium grade having at least 70% of the score.
4 Standard grade having at least 50% of the score.

RESULTS AND DISCUSSION

Characterization of beef meat and plant meat substitutes

The results shown in Table 1 indicate that beef meat is rich in protein and crude fat and nearly free of carbohydrate. The total nitrogen of beef meat

TABLE 1
Chemical Composition and Amino Acid Content of Beefmeat

Constituents	%
Moisture	72·7
Crude proteins	79·1
Protein fractions as per cent of total protein	
Non-protein nitrogen	18·6
Protein nitrogen	81·4
Sarcoplasmic proteins	21·4
Myofibrillar proteins	22·7
Denatured and stroma proteins	37·3
Crude fat	17·2
Ash	3·66
Carbohydrates[a]	Traces
Amino Acid Composition ($g\,16\,gN^{-1}$)	
Arginine	7·70
Histidine	2·90
Lysine	7·20
Tyrosine	3·40
Phenylalanine	4·90
Methionine	3·30
Threonine	5·40
Leucine	7·70
Isoleucine	5·00
Valine	3·60

[a]Measured by difference.

consists of 18·6% of non-protein nitrogen and 81·4% protein nitrogen. The meat protein contains 21·4% sarcoplasmic, 22·7% myofibrillar and 37·3% denatured and stroma protein fractions. It is rich in lysine, methionine, and threonine, the most limiting amino acids of plant proteins, and contains less valine than plant meat substitutes (see Table 2).

Table 2 shows that, among the plant meat substitutes, the dicotyledon seeds (legumes) of soybean, chickpea and faba bean contain more crude protein, fat, ash, lysine, isoleucine, histidine and less carbohydrate, methionine, arginine, leucine and tyrosine than monocotyledon (grains) such as white rice. Also, soybean contains the highest amounts of crude protein, ash, valine, phenylalanine, a medium amount of fat and the lowest amounts of carbohydrate and histidine, while chickpea had the highest levels of histidine and tyrosine, and the lowest value of isoleucine and faba bean had the lowest value of methionine.

The water and fat absorption were highest in soybean, followed by chickpea, faba bean and white rice flours, respectively.

The above results for beef meat agree with those reported by Lotfi *et al.*

TABLE 2
Chemical Composition and Amino Acid Content of Some Plant Meat Substitutes

Constituents	*Defatted soybean*	*Chickpea*	*Faba bean*	*White rice*
Moisture	7·00	7·00	9·06	14·4
Crude proteins	53·8	23·7	37·5	9·11
Crude fat	1·08	6·62	0·77	0·47
Carbohydrate[a]	37·6	68·3	58·8	90·0
Ash	7·53	1·39	2·96	0·47
Water absorption (%)	400	200	130	120
Fat absorption (%)	224	146	151	130
Amino Acid Composition ($g\,16\,gN^{-1}$)				
Arginine	7·71	7·33	6·18	8·80
Histidine	2·63	4·65	3·67	1·50
Lysine	6·66	6·99	6·56	1·80
Tyrosine	3·40	4·90	3·30	5·60
Phenylalanine	5·90	4·11	4·53	4·40
Methionine	1·33	1·34	0·66	2·40
Threonine	3·70	3·63	3·39	3·60
Leucine	8·14	7·93	7·04	8·60
Isoleucine	5·59	4·10	6·17	4·40
Valine	6·58	4·43	4·58	6·40

[a]Calculated by differences.

(1978), Skelley *et al.* (1978), Kramer *et al.* (1979), El-Aswad *et al.* (1980) and Kenawy (1984). Also, similar results for amino acid content of beef meat were obtained by Sosulski & Gerratt (1976) and Evans *et al.* (1979).

For other plant substitutes, the results for chemical composition of defatted soybean flour differed from those mentioned by Meyer (1971) and Nasser (1985). Results for other plant substitutes agree with those of Bhatty (1974), Kenawy (1984) and Moharram *et al.* (1985).

Characteristics of beefburger containing plant meat substitutes

Table 3 shows that addition of meat substitutes led to an increase in the levels of moisture by 12–34% and carbohydrate by 7–29% and to a decrease in protein of 9–24%, fat 3–5% and ash 1–5% except in the case of soybean addition, which caused a noticeable rise in ash content. Among the plant meat substitutes, soybean, rich in protein and ash, poor in fat and carbohydrate, gave a beefburger highest in protein, ash and fat content and lowest in carbohydrates. In contrast, white rice was rich in carbohydrate and poor in other components. Generally, few differences were observed between

TABLE 3
Chemical Composition and Amino Acid Contents of Beefburger Containing Plant Meat Substitutes (on a Dry Weight Basis)

	Beefburger (control)[a]	*Beefburger containing 25% hydrated flour of*			
		Soybean	*Chickpea*	*Faba bean*	*White rice*
Chemical constituents (%)					
Moisture	64·0	72·6	71·3	64·8	65·6
Crude protein	67·8	58·3	51·1	52·1	43·7
Crude fat	17·1	14·2	14·9	12·1	12·1
Carbohydrate[b]	0·47	12·7	20·9	23·7	34·6
Ash	14·6	14·8	13·2	12·1	9·56
Amino acid content ($g\,16\,gN^{-1}$)					
Arginine	6·55	5·09	5·21	5·35	5·73
Histidine	2·24	1·75	1·90	2·04	1·87
Lysine	5·66	4·43	4·56	4·82	4·35
Tyrosine	2·86	2·22	2·41	2·43	2·42
Phenylanine	5·02	3·83	3·87	4·11	4·14
Methionine	1·13	0·97	0·88	0·86	0·95
Threonine	3·15	2·54	2·51	2·64	2·67
Leucine	6·92	5·35	5·52	5·76	5·96
Isoleucine	4·85	3·65	3·68	4·00	3·90
Valine	5·59	4·16	4·30	4·52	4·75

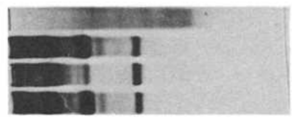
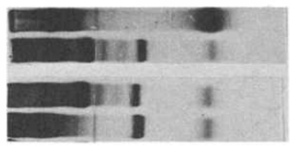
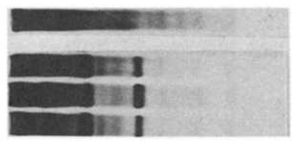
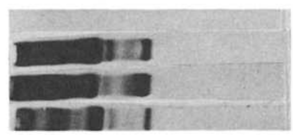
[a]Free from plant meat substitutes.
[b]Calculated by differences.

the composition of beefburger containing chickpea and faba bean. Also, addition of plant materials reduced the amino acid content of beefburger. The reductions were 9–10% in histidine, 22% in methionine, 14% to 17% in arginine, leucine and isoleucine and 18% to 21% in other amino acids. On the other hand, slight differences were noticed between the amino acid contents of beefburger containing different types of plant meat substitutes. These results agree with those reported by Keeton & Melton (1978), Nofal (1981) and Miles *et al.* (1984). Also these findings indicate that the components which seem to limit the application of plant meat substitutes in preparing beefburger are their protein and carbohydrates.

Electrophoretic properties of the beefburger

The results of the preliminary experiments for optimizing the conditions required for electrophoretic separation of both beef meat and plant meat substitute proteins indicated that acetone was better than chloroform in defatting meat, and the water-soluble extracts of full-fat whole frozen, thawed and/or the drip of meat can be used directly to fractionate their proteins by the standard PAGE technique. The same was noticed with the plant meat substitutes but after defatting. The water-soluble proteins were fractionated into five bands in both beef meat and faba bean, four bands in both chickpea and rice and three bands in soybean. These bands differed completely in their intensity and electrophoretic relative mobility (Table 4).

TABLE 4
Standard PAGE of Beefburger Containing Plant Meat Substitutes

Analysed sample	*Electrophoretic patterns*
Whole frozen beefburger Drip of beefburger Thawed beefburger	
Soybean flour Whole frozen soybean beefburger Drip of soybean beefburger Thawed soybean beefburger	
Chickpea flour Whole frozen chickpea beefburger Drip of chickpea beefburger Thawed chickpea beefburger	
Faba bean flour Whole frozen faba bean beefburger Drip of faba bean beefburger Thawed faba bean beefburger	
White rice flour Whole frozen rice beefburger Drip of rice beefburger Thawed rice beefburger	

As shown in Table 5, water-soluble proteins of whole frozen, thawed and the drip of beefburger free from, or containing, plant meat substitutes can be used directly for standard PAGE analysis. The proteins were fractionated into five bands in both beefburger (control) and white rice beefburger, nine bands in soybean beefburger and ten bands in faba bean beefburger. The fractions differed both in their electrophoretic relative mobility and intensity.

These results confirmed the successful use of the standard PAGE in the identification of plant proteins in beefburger.

TABLE 5
Characteristics of the Electrophoretic Protein Bands of Beefburger Containing Plant Protein

Electrophoretic relative mobility	*Beefburger (control)*	*Beefburger containing flour of*			
		Soybean	*Chickpea*	*Faba bean*	*White rice*
	Intensity of bands as cm²				
0·05	3·5			1·0	
0·06			8·0		5·0
0·10		2·0			
0·11				2·7	
0·15	5·6		8·5		8·5
0·22		2·0		9·0	
0·27		10·0			
0·28			6·0		
0·29	6·9				7·6
0·31		3·0			
0·33			1·0		
0·35	4·0	1·6			3·0
0·36				4·5	
0·39				3·0	
0·40			1·0		
0·41		2·0			
0·46	6·4		3·0		
0·47					6·0
0·53		3·0			
0·54				7·0	
0·60				0·7	
0·65			3·0	0·5	
0·70				1·0	
0·78		1·0			
0·82		1·0		1·3	

Cooking and organoleptic properties of beefburger

Cooking loss and shrinkage

Table 6 reveals that drying decreases the weight and volume (shrinkage) of beefburger. Addition of plant meat substitutes reduces losses in the previous parameters. Among the plant meat substitutes, rice, rich in carbohydrate (starch), was the best for reduction of both weight loss and shrinkage followed by soybean, rich in both protein and minerals, then chickpea and, lastly, faba bean. Generally, the results of cooking loss for beefburger containing soybean flour in this work agree with those mentioned by Smith *et al.* (1976) and Miles *et al.* (1984).

TABLE 6
Cooking and Organoleptic Properties of Beefburger containing Plant Meat Substitutes after Frying

Type of beefburger	*Cooking properties*		*Organoleptic properties*			
	Cooking loss (%)	*Shrinkage* (%)	*Colour* (%)	*Flavour* (%)	*Texture* (%)	*Total acceptability* (%)
Beefburger (control)	38·6	39·5	81·3	86·3	78·8	82·1
Beefburger containing 25% hydrated flour of						
Soybean	19·6	22·4	75·0	75·0	80·0	76·6
Chickpea	21·4	26·5	77·5	75·5	78·0	77·0
Faba bean	31·0	34·6	80·0	75·5	79·5	78·3
White rice	16·4	18·1	77·5	82·5	80·0	80·0

Organoleptic properties

Addition of plant meat substitutes improved the texture and lowered the flavour and colour of beefburger. Generally and according to total overall acceptability, the sensory quality of rice beefburger, rich in carbohydrate and poor in protein, was *very good* grade and did not markedly differ from the control. The other types of substituted beefburger showed *good* or *medium* grades in the following descending order: faba bean, chickpea and soybean (Table 6). These findings agree with those reported by Drake *et al.* (1975), Seideman *et al.* (1977) and Youssef (1980).

In conclusion, the results show that soybean is the best meat substitute among the plant sources used in this work. It is rich in protein, with high values of water and fat absorption as well as essential amino acids, except methionine. Also, from a technological viewpoint, it easily mixes with the free water and fat of meat to give a stable mixture similar to the control. However, from an economic viewpoint (and according to the availability of the vegetable sources and their prices in Egyptian markets) rice and faba bean flours are the cheapest and are in mass production locally.

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