

NUTRITIONAL CHARACTERISTICS OF SOYBEAN AFTER THERMAL PROCESSING BY TOASTING

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This paper deals with the characteristics of soybean processed by a new technical version of the toaster aimed to be used for small amounts. The research was conducted on a thin and a thick layer of soybean, and the results indicate that only a thin layer can be toasted satisfactorily due to large differences in urease activity ranging from 0.01 to 0.26 mgN/g/min and trypsin inhibitor activity (2.53 to 4.04 mg/g) in thick layers. Further more, it was determined that after toasting a thin layer of soybean at the temperatures of 125°C, 130°C and 135°C for 10- and 15-minute periods, the most favorable treatment for monogastric animals was 125°C/15min (2.12 mgTI/g trypsin inhibitor activity), and for polygastric (ruminant) animals 130°C/10 min (0.00 mgN/g/min urease).

Key words: soy, toasting, temperature, urease, trypsin inhibitor activity

INTRODUCTION

Soybean contains highly valuable proteins and oil (on average ranging from 39 - 41% protein and 18 – 21% oil), which makes it a very good feed alternative to animal proteins and oils (Vrataric and Sudaric, 2000). Namely, according to their digestibility and aminoacid composition, soybean proteins are very similar to proteins of animal origin, except that sulfur aminoacid (cystine and methionine) contents are a little lower (Anderson and Wolf; 1995).

However, full fat soybean has very limited use, because it contains a number of harmful components that diminish its nutritional value. Namely, the harmful components inhibit digestive enzymes, which disturbs the metabolism of animals fed full fat soybean, leading to growth decrease, and even death of the animal (Leiner 1980; Del Rosario *et al.*, 2001).

Several inhibitors in soybean have been isolated up to the present, but the trypsin inhibitor has the most serious consequences. Soybean contains three genetically related kinds of trypsin inhibitor: TIA, TIB and TIC that differ in their electrophoretic mobility. The value used the most is trypsin inhibitor activity (TIA). The acceptable activity level is determined in relation to that in full fat soybean. Ac-

cordingly, a decrease of trypsin inhibitor activity of 90 – 95% compared to full fat soybean indicates satisfactory heat processing. The success indicator for heat processing is urease, a thermolabile enzyme. Decrease of its activity under the influence of heat in relation to untreated full fat soybean indicates successful processing (Sanderson *et al.*, 1982; Miranda *et al.*, 1999; Trugo *et al.*, 2000).

Thus, heat processing ought to have a positive effect upon the nutritional value of the bean. Consequently, thermal processing aims to inactivate antinutritional factors present in full fat soybean and not to cause any nutritional damage to proteins in the process (Monari, 1990; Miranda *et al.*, 1999).

Heat processing does not influence the total protein content, but it may cause considerable changes in some properties of the proteins. Due to denaturation, solubility of the proteins is decreased, but their digestibility increases (Obendorf and Hobbs, 1970; Monari, 1990).

The most common procedures for thermal processing of soybean are cooking, toasting and extrusion. Cooking is a relatively simple procedure in which the soybean is cooked in water or steam and dried. Extrusion involves pushing the material through a series of restriction rings by means of a system of coils, which creates high pressure (30 – 40 bars) and high temperature as the consequence of friction and movement of the processed beans. Roasting or toasting is dry heating of the soybean, which generally decreases its initial moisture. The bean temperature varies from 110 to 165°C. Many procedures for processing full fat soybean have been perfected up to the present time. It is important to stress that all of the processes are valid and satisfactory as long as they can be controlled. Namely, a too high temperature causes damage to the protein, which decreases the quality of the final product (Katic, 1992; Ristic *et al.*, 1999; Golema *et al.*, 1999; Kricka *et al.*, 2001).

Because a problem of this kind recently appeared in Croatia, a new model of soybean toaster has been constructed. A work protocol was suggested in order to study the new model, i.e. the temperature and the time of toasting (125°C for 15 minutes). This paper treats the influence of the temperature and the duration of the toasting process on the crude protein content, as well as urease and trypsin inhibitor activity. The optimal work conditions for this kind of toaster are suggested.

MATERIAL AND METHODS

A toaster prototype was constructed in cooperation with the firm “Seting–Inženjering” and the Faculty of Agriculture, Zagreb University. The toaster consists of a housing with a door, and a built-in perforated board of dimensions 800x800 mm. Hot air is drawn out of the toaster by means of an axial fan. Three PT 1000 probes for measuring temperature were built in to the toaster; two for measuring air temperature at the entrance and at the exit of the toaster and one for measuring the temperature of the soybean in the air current. The temperature can be regulated manually or automatically.

Thick (150 mm) and thin layers (30 mm) of soybean, with respective masses of 72 and 14,4 kg per batch were studied. Toasting was done at bean tem-

peratures of 125°C, 130°C and 135°C for 10 or 15 minutes starting with the moment when the desired bean temperature was reached. After the heat processing the soybean was cooled down to room temperature.

All measurements were made in ten repetitions and the values obtained were processed statistically.

In order to accomplish satisfactory thermal processing, it is necessary to support it by simple and reliable laboratory procedures. Thus, nutritional values are shown as crude protein content, urease activity (mgN/g/min) trypsin inhibitor (mgTI/g) and the percentage degradation of TIA. Crude protein (Nx6.25) was determined by the Kjeldahl method, using sulfuric acid with mercury as the catalyst. Urease activity in full fat and thermally processed soybean was determined in a buffered urea solution. A sample of ground soybean was mixed in the solution for 30 minutes at the temperature of 30°C. Urease from the soybean breaks urea down and produces ammonia which changes the pH of the solution. The difference between pH at the beginning and that after the 30-minute mixing gives the urease activity in mgN/g/min. This should not exceed 0.1 – 0.3 mgN/g of dry matter per minute (Misra *et al.*, 1985; Katic, 1992; Jurkovic, 1993; Katic *et al.*, 1994; Monari, 1990; Marshman *et al.*, 1998).

Trypsin inhibitor activity in full fat and thermally processed soybean was determined by the method of Kakade *et al.* (1969) as modified by Jurkovic (1993). This method determines total and residue inhibitor by measuring the product of substrate (casein) breakdown at the temperature of 28°C; it is shown as trypsin inhibitor unit per gram of sample.

RESULTS AND DISCUSSION

The first tests were done according to the instructions of the producers. Soybean with 12% moisture was toasted in a layer 150 mm thick for 15 minutes at the bean temperature of 125°C. The temperature was measured at the entrance and at the exit of the toaster, as well as at the top and bottom of the soybean layer. Table 1 displays the values acquired.

Table 1. Air temperature and the temperature of the soybean in the thick layer (125°C/15 min)

	Air t (°C)		Bean (°C)	
	entrance	exit	upper area	lower area
Average	130.31	92.38	125.19	114.75
Min	125	90	125	106
Max	134	96	129	121
s.d.	2.4958	2.1871	2.4824	5.2598

It can be seen that the average bean temperature in the upper area was to 125.19°C. However, after the hot air had passed through the thick layer, the average soybean temperature at the bottom was 114,75°C, which does not fulfill the set requirements. With the purpose of accepting or rejecting thick soybean layers

for toasting, the nutritional characteristics of the product were examined. Samples were taken from the upper area, the middle and the lower area of the soybean layer. Table 2 displays average values for crude protein, urease, trypsin inhibitor activity and its relative degradation.

Table 2. Nutritional characteristics of soybean heat treated in a thick layer (125°C/15 min)

Sample	Crude protein (%)	Urease (mg N/g/min)	TIA (mgTI/g)	TIA degradation (%)
upper	43.20	0.01	2.53	91.6
middle	43.04	0.19	3.14	89.6
lower	43.25	0.26	4.04	86.7

Since there was significant variation of urease activity inside the thick layer amounting to 260 times, as well as TIA up to 16 times, and differences in the temperature of the beans inside the layer, further research was conducted on a layer 30 mm thick, which was the depth of the upper position of the thick layer.

Thin layers of soybean were heated at 125°C, 130°C and 135°C for 10- or 15-minutes. Table 3 displays the average values of the measured parameters.

Table 3. The input and output air temperature and the input and output temperature of soybeans toasted in a thin layer

	Input bean temperature - 125°C						
	10 min			15 min			
	t _{in} (°C)	t _{OUT} (°C)	(°C)	t _{in} (°C)	t _{OUT} (°C)	(°C)	
x	130.55	119.09	126.36	129.93	121.16	125.94	
min	128	107	125	126	119	124	
max	135	126	129	134	124	129	
s.d.	2.3393	5.5938	1.7477	2.5421	1.6278	1.5692	
	Input bean temperature - 130°C						
	x	134.72	123.00	130.18	135.44	125.13	131.31
	min	130	116	126	132	116	128
	max	138	127	133	139	129	135
	s.d.	3.1334	3.7683	1.9909	2.3655	3.50	2.1823
	Input bean temperature - 135°C						
	x	140.36	129.64	135.73	141.25	130.50	136.81
	min	136	126	132	140	124	135
	max	145	132	140	143	134	139
	s.d.	2.7666	2.3779	2.4124	1.2383	3.0332	1.2230

t_{in} – air temperature at the entrance to the toaster (°C)

t_{OUT} – air temperature at the exit of the toaster (°C)

– temperature of the soybean in the hot air current (°C)

It is obvious that the set values were reached at all of the tested temperatures, which means that a thin soybean layer must be used with a toaster of this size. The nutritional values of the different products are shown in Table 4.

Table 4. Nutritional characteristics of full fat soybean and the soybean products toasted in a thin layer at the bean temperature of 125°C, 130°C and 135°C for 10- or 15-minutes (with 7.5% average bean moisture)

SAMPLE	Crude protein (%)	Urease (mgN/g/min)	TIA (mgTI/g)	TIA degradation (%)
Full fat soybean	40.95	4.72	30.39	0
125°C/10min	42.91	0.03	2.34	92.1
125°C/15min	43.02	0.02	2.12	92.3
130°C/10min	42.12	0.00	2.28	92.4
130°C/15min	43.07	0.00	2.19	92.7
135°C/10min	43.58	0.00	2.13	92.9
135°C/15min	43.61	0.00	2.09	93.1

It can be noted that the full fat soybean had 4.72 mgN/g/min of urease activity and a very high trypsin inhibitor activity (30,39 mg/g). As urease is used as an indicator of satisfactory thermal processing, which corresponds with the decrease of trypsin inhibitor in the soybean, it can be claimed that toasting as a thermal processing procedure completely fulfills the requirements placed on soybean as a protein feed.

The recommendation of the FEFAC committee is to use the trypsin inhibitor as a control measure for monogastric animals, and urease activity as a control measure for polygastric animals (ruminants). The committee also recommends that the correlation between the protein content in full fat soybean and the trypsin inhibitor activity in a properly conducted thermal processing procedure should be limited to 10%. Based on this our results show that the set (input) temperature of the soybean and the duration of the process (125°C/15 min) fulfill the set requirements (Monari, 1990).

However, to increase security we recommend toasting soybeans for monogastric animals at 125°C for 15 minutes, and soybeans for polygastric animals (ruminants) at 130°C for 10 minutes.

CONCLUSION

Regarding thermal processing of soybean in toasters intended for use in family farms, it can be claimed that these devices exclusively require a thin layer of soybean to be used due to the great difference of urease and trypsin inhibitor activity found in a thick layer. The difference was from 0.01 to 0.26 mgN/g/min for urease and from 2,53 to 4,04 mg trypsin inhibitor per gram, which is not acceptable for safe animal nutrition.

In order to meet the recommendation of the FEFAC committee and to increase nutrition safety, the bean temperature for monogastric animals should be 125°C for at least 15 minutes, and for polygastric animals (ruminants) the bean temperature should be 130°C for at least 10 minutes.

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NUTRITIVNA SVOJSTVA SOJE POSLE TERMIČKE OBRADJE TOSTIRANJEM

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SADRŽAJ

Cilj ovog rada je bio ispitivanje karakteristika soje obrađene novim tehnološkim termičkim postupkom predviđenim za manje količine ovog hraniva. Ispitivanja su izvršena na tankim i debelim slojevima soje a rezultati su ukazali da se samo tostiranjem u tankom sloju mogu dobiti zadovoljavajući rezultati. Tostiranje u debljim slojevima ima za posledicu velike razlike u aktivnosti ureaze i tripsin inhibitora. Dodatnim istraživanjima je dokazano da je za monogastrične životinje optimalan tretman soje u tankom sloju na temperaturi od 125 °C i u trajanju od 15 minuta (2.12 TI/g aktivnosti tripsin inhibitora). Za preživare je neophodan tretman na temperaturi od 130 °C u trajanju od 10 minuta (0.00 mgN/min ureze).