EXTRUSION-COOKED BROAD BEANS IN CHICKEN DIETS

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INTRODUCTION

The broad bean (*Vicia Faba*) is a legume with a high protein (up to 28%) and a high lysine (6 g/16 g N) content, which is cultivated in many countries. It is used to different extents as a food as well as an animal feed. The utilization of this crop is less than its potential offers, particularly in animal feeding. For example, in the East European countries it is more popular to cultivate that plant as a green fodder for animals than for its beans which are little used.

One way in which broad beans can be made more nutritious is to process them thermally. In our experiments we wanted to get information what can be the effect of extrusion-cooking on the nutritional value of processed broad beans and how could such beans compete with post-extracted soybeans - a commonly used component in feed formulations.

MATERIALS AND METHODS

Whole broad beans of the Polish variety *Bobik Nadwislanski* were used. The beans were grounded in a hammer mill to a particle size of 0,1-0,01 mm. A number of samples of the obtained raw material was processed in a single screw extrusion-cooker to produce products of different properties.

The process variables were: screw rotational speed, feed moisture content, compression ratio of the screw, die diameter and process temperature profile along the barrel. Results of each set of conditions in triplo replications were recorded and analyzed statistically.

Table 1. Composition of Broad Beans Used

Protein (Nx6.25) (%)	Carbo-hydrate (%)	Fat (%)	Ash (%)	Fibre (%)	Moisture content[a] (% w/w)	PDI[b] (%)	Particle Size ($Mx10^{-3}$)
28.6	**61.8**	**1.14**	**3.51**	**3.96**	**10.0**	**74.0**	**0.01-0.1**

[a] Dry basis.
[b] Protein dispersibility index

The single-screw extrusion cooker was a Polish design unit type TS-45 with L/D = 12 and screw's diameter of 45 mm.

Experiments were carried out using 3 different screws:

- **c.r. of 1,15**
- **c.r. of 2,4**
- **c.r. of 3,0**

Die diameters: 4, 6, and 10

Screw rpm: 60-120

Temperatures were measured with thermo-couples mounted at desired locations on the inside surface of the barrel.

All experiments were repeated at selected feed moisture contents in the range 20-30%.

The throughput, energy input (including heat) and the mechanical and structural properties of the product were determined for each run.

Following product characteristics were deter-mined using standard methods:

- **Bulk density: determined by weighing a specified volume of pro-duct vibrated on a Rossen-Muller apparatus**
- **WAI and PDI measured on 50 ml of the material according to the AOAC methods**
- **Sensory evaluation: the colour (browning effect), taste, texture, structure etc.**

The nutritional value of the processed broad beans was assessed by feeding trials on 16 groups each of 27 or 54 broiler chickens Euribrid, aged between 1 day and 8 weeks (first step, 0-4 weeks, second step, 5-8 weeks) by replacing post-extracted soybeans grits in their daily ration, following standardized rules for feeding trials.

The objective of the feeding trials was the determination of the effect of each feed portion by measuring:

- growth of chickens after 4 and 8 weeks of feeding;
- feed consumption per kg of body growth (feed conversion ratio);
- percentage of the chicken body weight recovered in the slaughter-house (butchered effectiveness).

Table 2. Scheme of the Feeding Trials[a]

Chicken group	Feed	Number in group	Mixture code	
			0-4 weeks	5-8 weeks
I	Wheat + barley + soybeans	27	S-1	F-1
II	Wheat + barley+soybeans+aa[b]	27	S-2	F-2
III	Wheat + barley +uncooked broad beans	54	S-3	F-3
IV	Wheat + barley +uncooked broad beans+aa	54	S-4	F-4
V	Wheat + barley+extrusion-cooked broad beans	54	S-5	F-5
VI	Wheat + barley+extrusion-cooked broad beans+aa	54	S-6	F-6
VII	Wheat + barley+extrusion-cooked broad beans with 6% NaOH	54	S-7	F-7
VIII	Wheat + barley+extrusion-cooked broad beans with 6% NaOH + aa	54	S-8	F-8

[a]All experiments carried out in duplicate.
[b]aa, Addition of lysine and methionine (see Table 3).

Table 3. Composition of the Feeds Used (%)

Materials	Mixtures							
	S-1	S-3	S-5	S-7	F-1	F-3	F-5	F-7
Wheat grits	42,1	31,0	31,0	31,4	51,0	40,0	40,0	40,4
Uncooked broad beans	-	20,0	-	-	-	20,0	-	-
Extrusion-cooked broad beans	-	-	20,0	-	-	-	20,0	-
Broad beans extrusion-cooked with NaOH	-	-	-	20,0	-	-	-	20,0
Barley grits	20,0	20,1	20,1	20,1	24,0	24,1	24,1	24,1
Soybeans grits (toasted)	34,0	25,0	25,0	25,0	21,1	12,0	12,0	12,0
Calcium carbonate	1,02	1,02	1,2	1,2	1,2	1,2	1,2	1,2
Calcium phosphate	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Salt	0,7	0,7	0,7	0,3	0,7	0,7	0,7	0,3
Trace minerals and vitamins[a]	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Supplement of lysine[b] in kg of feed (g)	0,34	-	-	-	3,25	2,85	2,85	2,85
Supplement of methionine in kg of feed (g)	2,14	2,60	2,60	2,60	2,76	2,88	2,88	2,88

[a]Polish commercial composition of the indispensable trace minerals and vitamins for broilers
[b]1 kg of chicken feed should contain: 11-5 g of lysine and 5-5 g of methionine.

RESULTS AND DISCUSSION

The factors found to have the biggest influence on the physical and chemical properties of extrusion-cooked broad beans were:

- process temperature,
- feed moisture content
- the shear rate created by the screw in the pumping zone of the extruder.

Unsuitable process conditions caused serious operating difficulties, such as blockage, which of course decrease the extruder throughput. In practice, optimum process conditions are determined as a compromise between the required product properties, satisfactory throughput and energy input to the extruder

At temperatures higher than 180°C there was a decrease in product quality (Maillard effects), particularly when the feed moisture content was less than 24%.

The water content of the material slightly influenced the functional properties of the product and the extruder output.

Higher feed moisture contents produced a more compact and harder product, with greater bulk density

Table 4. Some Properties of the Products Obtained by Extrusion-cooking of Broad Beans Under Different Process Conditions

	Bulk density (kg m^{-3})	Water absorbtion (%)	Color and texture (-)	Energy Input (kWh kg^{-1})	Output (kg h^{-1})
T=140 d=6 n=1,33 f.m.c.=24	**445**	**164**	**Moderate**	**0,18**	**23,2**
T=160 d=6 n=1,33 f.m.c.=26	**460**	**155**	**Good**	**0,16**	**26,8**
T=180 d=8 n=1,5 f.m.c.=28	**470**	**124**	**Moderate**	**0,13**	**31,5**
T=200 d=8 n=1,5 f.m.c.=30	**478**	**101**	**Bad**	**0,13**	**32,2**
T=160 d=4 n=1,33 f.m.c.=22	**425**	**168**	**Bad**	**-**	**Blockage**

T-temperature (ºC); d-diameter (mm); n-rotational speed (rev s^{-1}); f.m.c.-feed moisture content (% w/w, dry basis)

Table 5. Extrusion Conditions Selected as Optimum

Feed Moisture Content (% w/w, dry basis)	Com-press. Ratio (-)	Temp.[a] (°C)	Die Diam. (mm)	Bulk Density ($kg\ m^{-3}$)	WAI (%)	PDI (%)	Out-put ($kg\ h^{-1}$)	Screw Rotat. Speed ($rev.\ s^{-1}$)	Energy Input ($kWh\ kg^{-1}$)
26	3,0	170	8	460	150	21	30	1,33	0,15

[a] Temperature in the high pressure zone of the extruder.

The results of the feeding trials showed a much greater chicken growth using extruded broad beans than with the same proportion of unprocessed material. When unprocessed broad beans were used in the chicken diet formulation, the decrease in growth was about 18% compared with the control group (group I).

The addition of synthetic amino acids helped a little bit but the weight gain was still less than in the control group.

Broilers in group V weighed 1648 g by the eighth week, 150 g more than those in group III fed on a mixture containing unprocessed beans. With supplementary lysine and methionine in the feed formulation (group VI), the production effectiveness of the chicken was similar to that in the control group fed with soybeans (1804 g, against 1809 g). The same trend was observed in feed conversion ratio, which also showed that extrusion-cooking increased the feed value of broad beans.

Increasing the disintegration of the broad bean protein structure, by the addition of sodium hydroxide prior to extrusion-cooking, did not produce any significant effect.

In our investigation no negative influence of the different feed formulation on the healthy conditions of the chickens was observed.

Tabela 6. Results of the Feeding Tests

Production effectiveness	Chicken group							
	I	II	III	IV	V	VI	VII	VIII
1. Chicken weight: by fourth week (g)	721	705	642	626	626	651	631	635
by fourth week (relative to control, %)	100	98	89	87	87	90	88	88
by eight week (g)	1815	1809	1497	1606	1648	1804	1635	1738
by eight week (relative to control, %)	100	99	82	88	91	99	90	96
2. Feed conversion ratio (kg kg^{-1})	2,67	2,56	3,10	2,89	2,96	2,71	2,84	2,67
3. Butchered effectiveness (%)[a]	68,7	69,7	68,6	70,0	69,4	69,9	68,5	69,1

[a] Weight of chicken carcass as % of body weight.

CONCLUSIONS

- **In the light of the results obtained during the feeding trials, it can be concluded that extrusion-cooking is a good way of improving the animal feed quality of broad beans. In the feed formulation for chicken rations, extruded broad beans can replace at least 60% of post-extracted soybeans, which can be very important, particularly in those markets where soy is expensive and/or has to be imported.**
- **The cost of processing by extrusion-cooking in comparison with conventional thermal processing of vegetable materials is relatively low. The total energy input was about 0,15 kWh/ kg, which is approximately half the cost of, for example, autoclaving. The resulting increase in production effectiveness more than compensates for the cost of processing.**

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