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STUDIES ON THE MICROSTRUCTURE OF LUPINE EXTRUDATE*

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A b s t r a c t. Studies on the use of extrusion for the hydrothermic processing of yellow lupine (vars. Iryd and Topaz) meal were carried out. In particular, the influence of process parameters and raw material properties on the process run, extruder efficiency, physical and chemical properties as well as the macro- and microstructure of the extrudate was examined. The studies showed that the proper choice of process parameters, that allow for maximum lipid binding, enabled the production of high quality produce, even in the case of raw materials with increased fat content.

K e y w o r d s: extrusion - cooking, microstructure, lupine, physical properties

INTRODUCTION

Extrusion is more and more widely used not only in food processing but also in fodder production. The processed material undergoes deep reaching changes during hydro-thermic processing in the extrusion cooker. As a result of the combined action of high temperature, pressure, and shearing forces, many antinutritious agents are inactivated. Hence extrusion has been widely applied for refining leguminous seeds. The efficiency of the process is often limited by the very high fat content of the raw material, e.g., in lupine seeds. The present studies concentrated on the influence of process parameters and raw material properties on the lipid binding and on the influence of this binding on other chemical transformations as well as the macro- and microstructure of the extrudate.

MATERIALS AND METHODS

The study material was yellow lupine seed vars. Topaz and Iryd with the characteristic of sowing material. In this way comparability of results from different studies was secured. First, raw material was ground on a hammer milll with a 6 mm sieve. Grinding was then repeated with a 3 mm sieve. Fraction composition of middlings was examined each time (Table 1).

Meal of yellow lupine var. Iryd (Photos 1a and 1b) were extruded on a twin screw extruder 2S-9/5 using the following parameters:
- moisture level of raw material of 15, 19.5, and 25%;

T a b l e 1. Fraction composition of yellow lupine var. Iryd meal

Fraction (mm)	Fraction contribution (%)								ϕ_z (mm)
	>1.6	1.6-1.2	1.2-1.0	1.0-0.8	0.8-0.5	0.5-0.25	<0.25	Σ<0.5	
Rate (%)	1.4	15.0	17.6	18.1	20.7	17.8	9.4	27.2	0.81

* Paper presented at 6 ICA

a b

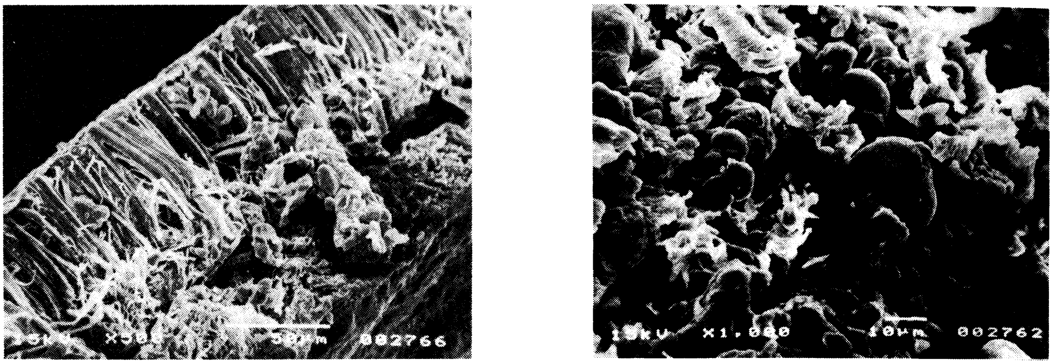


Photo 1. The microstructure of lupine involucre (a) and cotyledons (b) for var. Iryd meal.

- temperature distribution profile of the barrel of 80/100/120/100/100°C, 100/130/160/150/120°C, and 110/160/200/180/140°C.

Expansion ratio was determined as the ratio between the extrudate cross section area and the cross section area of the die. Samples of unground extrudate were taken for the studies of the extrudate microstructure. Some chosen fragments of the preparation were pasted on the preparation blocks with silver paste. Preparations were then covered with carbon and gold in a vacuum sputter JEOL JEE 4X. Microscopic analysis was carried out using a scanning electro nic microscope JSM 5200. Lipid extraction was done by means of hexane, and fibre fractions were determined by means of Goering *et al.* method [1].

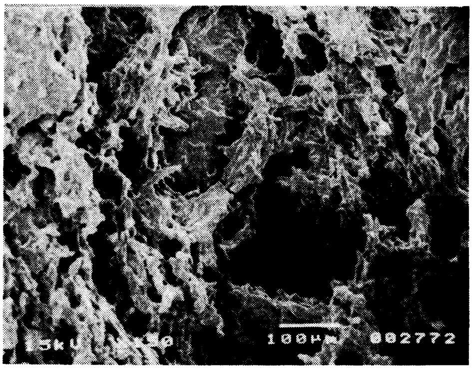
RESULTS AND DISCUSSION

The extrusion of lupine meal depended on numerous process parameters and properties of raw material. Results of the studies with a single screw extruder were presented earlier [4]. Application of a twin screw extruder radically changed the conditions of the extrusion and generated proper lipid binding. Depending on the parameters applied, the extrudate took on the shape ranging from expanded produce with an expansion ratio > 4 to a sawdust-like mass. These drastic changes in the physical properties influenced chemical changes and microstructure, which were seen in prelimnary studies [5].

Studies on the microstructure of lupine extrudate produced from lupine var. Iryd using scanning microscope, were carried out. The initial raw material, i.e., lupine middlings had the structure of a typical leguminous material, which can be seen in Photos 1a and 1b. Attention should be drawn to numerous protein bodies with the diameter of 5-10µm (Photo 1b) that resemble characteristic protein bodies in the soya bean seeds widely described in literature, as well as to the cross section of the seed cover presented in Photo 1b. Raw material presented in Photos 1a and 1b subjected to extrusion, at the three temperature levels and three levels of moisture content, yielded produce with very differentiated macro- and microstructure.

Macro- and microstructure depended on the process temperature, raw material moisture content and chemical transformations, especially in the degree of lipid binding. At the lowest temperature of extrusion 80/100/120/100/100°C and moisture level of 15% the extrudate obtained was in a compact form, porous, with the degree of radial expansion of $X = 4$, with thin walls and numerous air cells (Photo 2a). The extrudate microstructure was characterised by a fibrous-like structure with protein bodies, seen as thickened spots in the carbohydrate mass (Photo 2b).

Increase in the moisture level of raw material up to 19.5% caused significant changes in the macrostructure (Photo 2c) in which thickening of wall of the air cells and marked a



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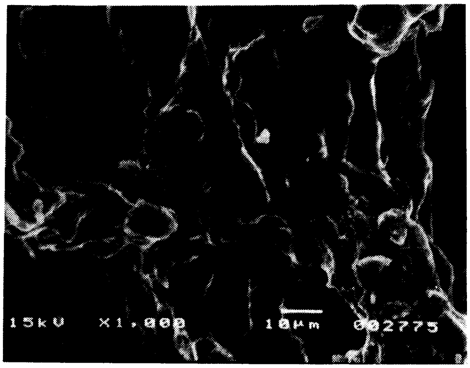

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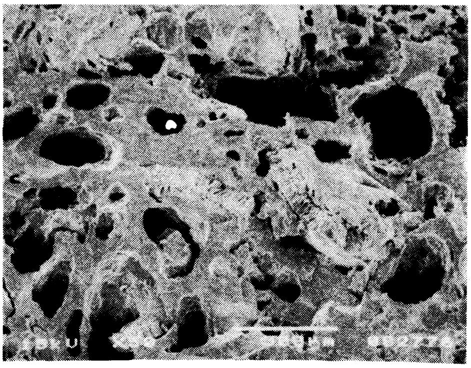

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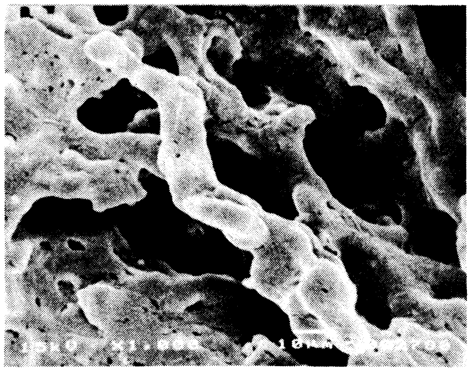

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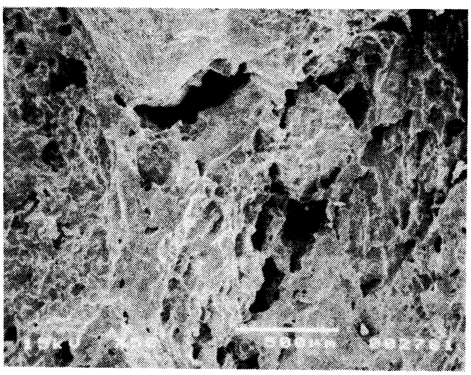

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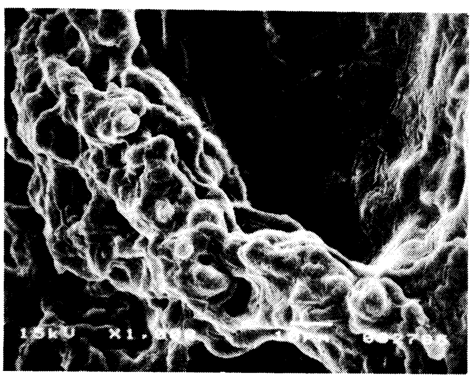

Photo 2. Macro- and microstructure of lupine extrudate. Extrusion temperature of 80/100/120/100/100°C. Raw material moisture content: a,b – 15%, c,d – 19.5%, e,f – 25%.

decrease in porosity was observed. Changes in the macrostructure resulted in changes in the microstructure. Protein bodies were clearly swollen, but the characteristic fibre-like structure was maintained (Photo 2d). The influence of raw material moisture level was clearly noticed in the case of the samples wetted up to the level of 25%. An almost complete disappearance of radial expansion and a clear decrease in the number of air cells was observed (Photo 2e). The picture of the microstructure was also very typical, with clearly visible swollen protein bodies (Photo 2f). Macro- and microstructural changes correspond to lipid complexing. For the samples with a moisture level of 15, 19.5, and 25% the amount of fat extracted with non-polar solvent was 2.95, 3.23, and 3.3%, respectively.

An increase in the extrusion temperature up to a level of 100/130/160/150/120°C caused a clear increase in the lipid extractability. At a moisture level of 15% fat content was 3.85%, at a moisture level of 19% and 25%, raw fat content was, respectively, 3.71 and 3.55%. Clear changes in the macro- and microstructure were also noted. At a moisture level of 15%, compact extrudate structure, with clearly thickened air cell walls was observed (Photo 3a). The disappearance of oval protein bodies and the apperance of fragile, fibrous structures, that merged into bigger surface complexes, in the microstructure was observed (Photo 3b). An increase in the raw material moisture level intensified these changes. The extrudate lost its compact structure (Photo 3e) and took on the form of a loose, sawdust-like mass and then a more and more amorphous mass (Photos 3d and 3f). A similar micro- structure was observed by Salgó *et al.* [6] in the rice flour extrudate with 20% and 60% inclusion of rice germs. The extrudate was obtained at a temperature of 155°C by means of a single -screw extrusion-cooker.

The biggest changes were observed in the samples extruded at the highest extrusion temperatures of 110/160/200/180/140°C. A total disappearance of the fibrous structure took place. On the other hand a structure of amorphous, unordered forms appeared (Photo 4b). With an increase in raw material moisture content the above forms took on a looser structure (Photo 4d) and at a moisture level of 25% they appeared as separate, loose fragments of melted mass (Photo 4f). The macrostructure of all the samples obtained at that temperature were in the form of a loose mass resembling sawdust (Photos 4a, 4c, 4e). This means that tearing the extrudate into fine pieces as it was leaving the matrix had its justification also in the microstructure.

Surprisingly enough, despite the high process temperature applied single protein bodies that were not introduced into the product structure were noticed (Photo 4f). Similar results were also observed by Kozłowska *et al.* [3]. She observed untouched protein bodies in the samples of horse bean steamed at a temperature of 110°C for 5 min. Unprocessed fragments of the seed cover are seen in Photo 4e. It confirmed that during the extrusion process not all the mass is liquefied as has been suggested by a lot of authors.

Extrudate micro- and macrostructure was also formed by carbohydrates. In all the extrudate samples an increase in the amount of nitrogen free extractable substance and a decrease in the raw fibre content was observed. Hence, some of the fibre fractions disintegrated during extrusion and marked as N free extract. Lignin and hemicelluloses call for special attention as well. With an increase in the process temperature a significant decrease in the hemicellulose fractions, by even up to 50% in relation to the raw material, was noticed. Disappearance of the fibrous structure of the extrudate was not only connected with lipid binding but also with a decrease in the content of hemicellulose fractions.

Reverse relations were observed for lignin. The increase in process temperature and the disappearance of fibrous microstructure was accompanied by an increase in the content of fibre fraction.

In the photographs presented here no fat granules are present, even though fat content in the material was 4.07% (Table 2). Part of the fat

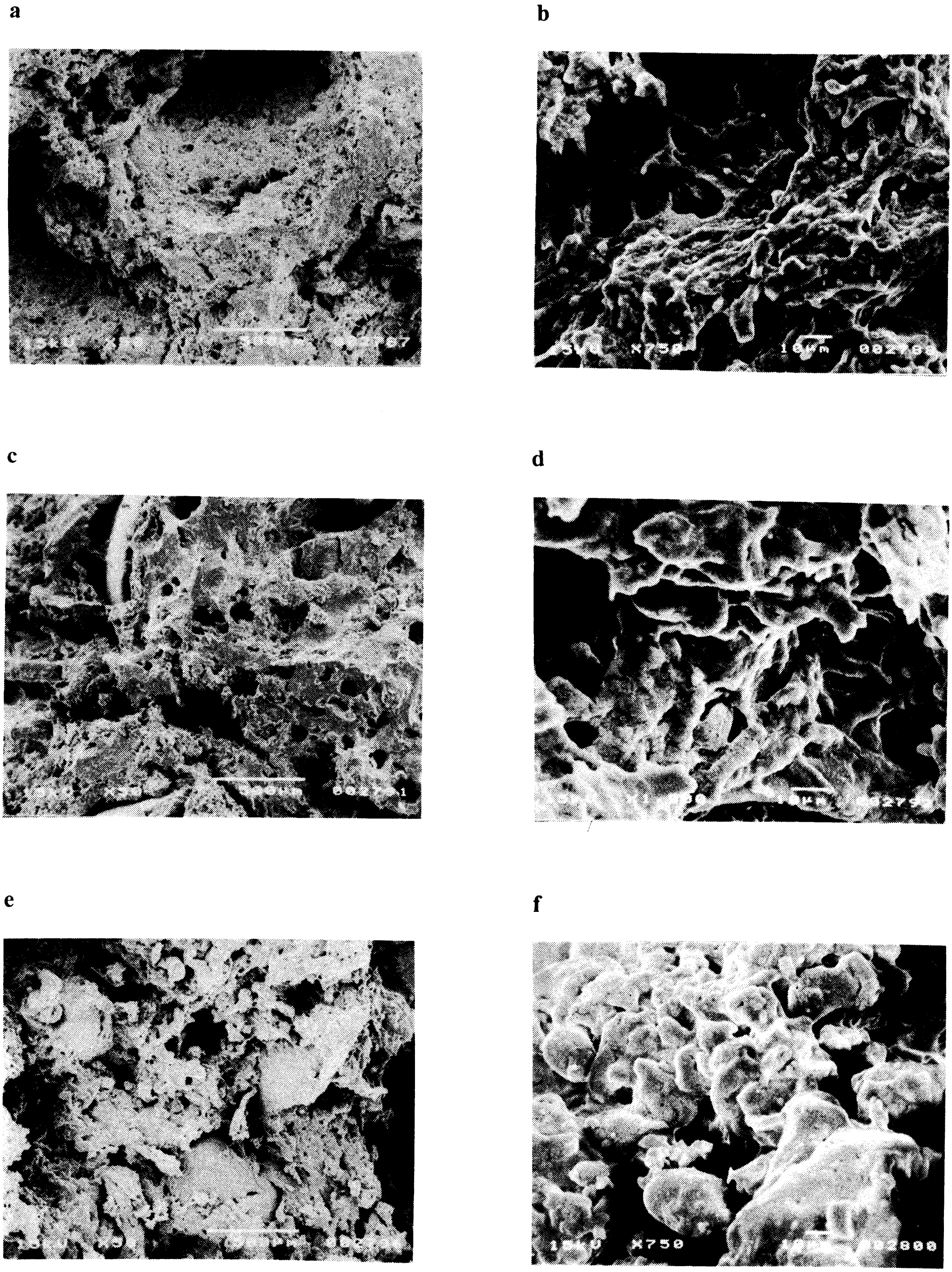

Photo 3. Macro- and microstructure of lupine extrudate. Extrusion temperature of 100/130/160/150/120°C. Raw material moisture content: a,b – 15%, c,d – 19.5%, e,f – 25%.

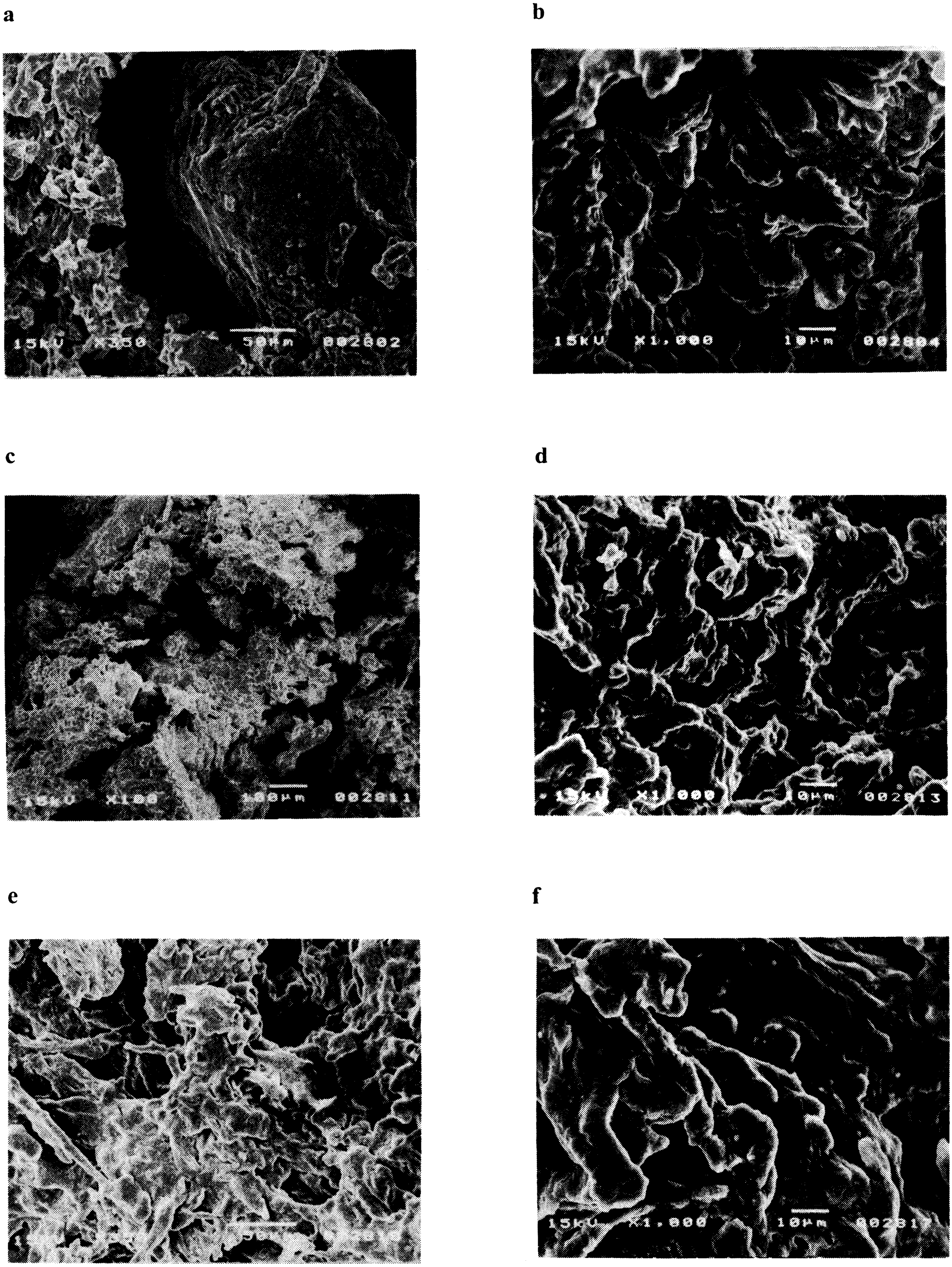

Photo 4. Macro- and microstructure of lupine extrudate. Extrusion temperature of 110/160/200/180/140°C. Raw material moisture content: a,b – 15%, c,d – 19.5%, e,f – 25%.

Table 2. Chemical composition of yellow lupine var. Iryd. (%)

Crude ash	Crude protein	Crude fat	Crude fibre	Nitrogen free exstract
4.58	45.37	4.07	15.04	30.94

is bound in the complexes with protein and carbohydrates, whereas some of its part, that is extractable by non-polar solvent, must be "locked" in the protein-carbohydrate mass. Gwiazda *et al.* [2] observed fat in the form of clear-shaped drops both in the full-fat soya extrudates as well as in the soya flour extrudates with an addition of 5, 10, and 15% fat. He obtained extrudates using a twin-screw extruder at a temperature of 180°C. Formation of a fibrous structure was more difficult only when oil content was over 15%. The same phenomenon appeared in the case of lupine when fat content was 4%.

CONCLUSIONS

1. The phenomenon of seaming lipid disappearance during the process of extrusion as a result of their binding allowed for the formation of more favourable conditions for the processing of raw materials with increased fat content.

2. In the conditions of increased lipid binding it was possible to obtain lupine extrudate with a compact, porous structure, and a fibrous microstructure.

3. The microstructure of the lupine extrudate was also conditioned by the transformations in the structural components.

4. Modification of the process temperature and raw material moisture level allowed us to obtain extrudate produce with very differentiated microstructures.

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