Application of the process of extrusion and micronisation and their influence on nutritive value of feedstuffs

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Abstract

Deficit of food for population that grows every year significantly makes the food production a very important problem in the world and in Serbia. The solution to increase the feed and food production is in the usage of new technologies, technologies in biotechnology, actually in bioindustry. The most important feedstuffs that are used in animal nutrition like cereals and other grain-soybean, rapeseed, corn, barley and sorghum, beside nutritive substances contain certain antinutritive substances, that represent limiting factor of their usage. Removal, actually inactivation of antinutritive substances and increase of digestibility are a great challenge for feed industry. Many antinutritive substances can be eliminated or significantly reduced with the usage of adequate heat treatments. With the application of the latest heat treatments, such as micronization and extrusion, it comes to destruction of antinutritive substances and improvement of nutritive, hygienic, physical-chemical and other feed properties. The usage of processing technology such as extrusion and micronization is certainly one of the most important alternatives for feed and food production which by its high nutritive values can fulfill high demands of modern nutrition.

Key words: feed, heat treatments, micronization, extrusion, animal nutrition.

Introduction

Processing of food is a very important activity both in developed and non-developed countries. Due to rapid global population growth, severe food shortages could be faced. To prevent this, food and feed production must be increased through application of new technologies in biotechnology, that is, bioindustry (Lazarević et al., 2005). Numerous technological processes aimed at improving nutritional value of food and feed products intended for human and animal consumption and efficiently utilization of primary and processed agricultural and food by-products have been developed worldwide.

Nowdays, various heat treatment processes are used worldwide for cereals and other grain processing, such as toasting, extrusion, micronization, microwave heat treatment (Van der Poel, 1997; Sakač et al., 2002; Marsman et al., 1998; Puvača, 2011), however, according to the practical experience and literature data (Sakač et al., 2003; Sakač et al., 2006; Sakač et al., 2005; Puvača et al., 2012), extrusion and hydrothermal treatments are most commonly used processes in Serbia.
Properly applied heat treatment process has been shown to reduce anti-nutritional factors to an acceptable level, enhance digestibility of some nutrients (protein, oil, carbohydrate), and improve sensory properties and microbiological quality of final product (Jansen, 1991; Zhou and Erdman, 1995). Along with the antinutrient content reduction, thermolabile nutritive components must be preserved, therefore, process need to compromise these two demands.

Micronisation

Grain can be heated by a variety of processes that use emissions of the waves, which differ in part of the electromagnetic spectrum that is used.

Micronisation is a specific heat treatment in which the layer of grain on the conveyor belt is continuously carried under ceramic radiators emitting radiation with wavelength in the near infrared region ranging from 1.8 to 3.4 mcm. The emitted rays, which are directed to a product, cause the frequencies from 80 to 170 million mega beets per second inside the grain, which leads to rapid heating, increased stress of water vapour and rapid water evaporation. Micronisation decreases the moisture content of grain by 30-40%. The intensity of infrared rays' translation into heat and its effect depends on the type of material to be treated (Bekrić et al., 1996; Sakač et al., 1996; Puvača, 2011).

The conveyor belt within the microniser can oscillate in order to tumble the grain and expose well all its surfaces to wave's effect. The most important parameters of this treatment are the speed of the conveyor belt, thickness of product layer, space between the product and the radiation source and certainly the achieved temperature (Bekrić et al., 1996).

Extrusion

Extrusion is the process in which the feedstuff or mixture is pushed through the barrel by means of screws of different configurations and pressed through the die at the end of barrel. The basic concept of extrusion process is high temperature, short time, whereby the high temperature is a direct result of friction, or pre-conditioning and steam injection, or a combination of both. The humidity of treated material in dry extrusion is about 30% while it is up to 80% in wet extrusion. Extruders can be classified as those with one or two screws, and the latter may have screws that are rotating in the same or in opposite directions, and screws can also narrow in a conical shape. Extrusion is the process in which the material is exposed to high temperatures, up to 200°C, for 1-2 minutes or more precisely the material temperature increases progressively within the last 15 to 20 seconds up to the optimum one to achieve the desired effects (Puvača, 2011). Therefore, this process is classified as heat treatment with high temperatures and short period of its action. At the same time, the material for extrusion is also exposed to relatively high pressure, which can range up to 25 MPa. Thanks to extrusion, it is possible to achieve a range of effects on the treated material, such as grinding, hydration, cutting, homogenisation, mixing, dispersion, compression, heat treatment, and inactivation of antinutritional substances, compression, and expansion, binding of particles, formation of porous structure and partial dehydration and sterilisation. The type and intensity of induced changes depend on the added energy in relation to time and quantity of product, design of screws (spiral shape, segments for slowing down, type and length of individual segments, the ratio between the length and diameter), type and structure of the material to be treated, humidity and fat content, capacity, additional heating and cooling of each barrel section, and die geometry (Bekrić et al., 1997; Jansen, 1991; Jovanović et al., 2006; Jovanović et al., 2009; Kirchner, 2009; Puvača, 2011; Stanače et al., 2011; Stanače et al., 2012). Extrusion is a complex and complicated technological process, but it is very flexible and provides the possibility for processing of a range of different raw materials such as: oilseeds (soybean, sunflower, rapeseed, cotton seed, peanuts, etc.), cereals (wheat, corn, barley, rice, oats, etc.), legumes (beans, peas and field pea), raw materials with high moisture content (fresh fruits and
vegetables, animal, fish and milk proteins), combinations of raw materials (different portions of some of the above raw materials which are mutually complementary in nutrient content), by-products and wastes from the food industry (e.g. rendering plant products, meat and meat and bone meal, waste from fish processing industry, by-products of dairy industry, breweries, sugar refineries, etc.), complete animal feed mixtures (balanced meals for piglets, calves, poultry, dairy cows and horses, fish feed, pet food, etc.), (Puvača, 2011; Stanačev et al., 2011).

Extrusion is the technological treatment that modifies the most the internal structure of material. After treatment, the product is often quite different, from nutritional point of view, compared to the raw material from which it is composed. The material that has been properly extruded is much better, according to its nutritional and physical properties than the pelleted material. Animal feed components undergo a whole range of changes during extrusion. These are primarily changes in starch and protein components. Friction and shear of the product during the extrusion provide an additional effect caused by the splitting of oil cells, and cell walls. Given that this is the treatment with high temperature and short duration, the loss of useful substances is minimised. However, it should be noted that irregular extrusion might result in negative effects (Bekrić et al., 1997; Lević et al., 1999).

**Application of micronisation and extrusion processes**

The most significant changes in cereal grain thermally treated occur in starch as starch makes two thirds of a grain weight that as fresh has no palatability and edibility. It is known that starch macromolecules that succumb many processes of transformation under thermal and mechanic effects result in different physical structures and properties (Jane, 2004; Whistler and BeMiller, 2009). Depending on needs of different consumers, types and categories of animals, the task is to produce food by combining different raw materials that biologically supplement and their nutritive values by the application of appropriate technological processing treatments. In conventionally processed, starch is cooked and gelatinised in the presence of a great amount of water. Grain is hydrated from the surface towards inner parts, although often many starch granules remain unchanged. During the process of extrusion the grain content is exposed to cutting, mixing, compression, heating and to passing through openings under high pressure. Starch granules exposed to these conditions gelatinise and form homogenous mass. A short time that the material is in the extruder is not optimum for total gelatinisation of all starch granules. In the process of micronisation, grains absorb infrared rays and gelatinisation is done from the centre to the periphery of the starch granule. Due to these reasons, combining processes of micronisation and extrusion in practice give good results. Performed studies encompassed numerous experiments with grains of maize of different physical traits and various chemical compositions. These studies point out to the possibility of making a new assortment of biologically valuable food and feed.

Under *in vitro* conditions, the effect of a high micronisation temperature and extrusion on digestibility of dry matter of corn grain was determined, as well as, changes in other very important nutritive components of corn grain (Terzić et al., 2005). Obtained results are presented in Table 1 (Radosavljević et al., 2010; Živančev et al., 2010).

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<th>Table 1. Digestibility and nutritive quality of corn grain</th>
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<td>Oil (%)</td>
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<td>Digestibility (%)</td>
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According to obtained results it can be concluded that the application of the micronisation process and extrusion in corn grain led to the increase of the digestibility coefficient in relation to digestibility of dry matter of fresh grain. The changes in the content of soluble carbohydrates and the reduction in the content of starch and crude fibres under effects of high temperatures caused the increase in digestibility of corn flakes. The same studies encompassed the determination of effects of high temperatures on in vitro digestibility of dry matter of soya bean grain in Figure 1 (Radosavljević et al., 2010).

![Figure 1. Effects of high temperatures on digestibility of soybean products](image)

It was concluded that the extrusion process more significantly affected the increase in digestibility of soya bean grain dry matter. On the other hand, the micronisation process had a completely opposite effect on soya bean grain digestibility. Depending on needs of different types and categories of animals, the task is to produce feed by combining raw materials that biologically supplement and their nutritive values by the application of appropriate technological processing treatments. Therefore, the aim of these studies is to observe the effect of high temperatures during the micronisation processes on changes in biochemical contents of grain of different cereals and legumes. In addition to maize and soya bean grain, wheat, barley and field pea grains were micronised at the temperature of 145°C. The basic chemical content (starch, proteins, oil, crude fibres and ash) and the content of soluble proteins, trypsin inhibitor, urease, resistant starch and dry matter digestibility were analysed in fresh grain and flakes obtained after the treatment with infrared rays. Changes in the basic chemical content in flakes of cereals and legumes cannot be attributed to effects of high temperatures during the micronisation process. High temperatures affect the decrease in the content of water soluble proteins in cereal and legume grains, as well as, the decrease of the content and activities of observed antinutritional substances. Digestibility of legume grains was decreased under high temperatures by approximately 3%, while digestibility of corn and wheat grains was increased. High micronisation temperatures did not affect enzymatic hydrolysis of cereal starch, while a significant effect on the decrease of the content of resistant starch was observed in field pea (Terzić et al., 2007).

**Conclusion**

Extrusion of grains intended for human and animal consumption is one of heat treatment processes, used to improve its nutritional, hygienic and physico-chemical properties, that is, to inactivate thermo-labile antinutrients, upgrade sensory properties and ensure product safety. Upon extrusion of corn, quality feed of improved nutritional value is obtained, with increased total and reducing sugar content due to changes in starch structure (gelatinization process), and resultingly, improved organoleptic properties of extrudate. Due to reduction of microbial counts during extrusion, these products
are hygienically safe to be used for feeding all animal species and age groups and can be stored safely for longer periods. The implementation of such projects within the field of the development of a new assortment of food and feed by the application of modern technical and technological procedures of field crop processing is very important and of great significance for today and future generations. Therefore, this implementation should continue in future.

**Acknowledgements**

This paper is a result of the research within the project III 046012, financed by the Ministry of Science and Technological Development, Republic of Serbia.

**References**


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