EXTRUSION INFLUENCE ON NUTRITIONAL AND ENERGY VALUE OF FEED MATERIAL

Nerijus Ciganas[1], Romas Gružauskas[2], Rolandas Stankevičius[3], Gintarė Dovidaitienė[3], Ieva Kudlinskienė[2]

[1]Extruded products business manager, KG Group, Kaunas, Lithuania
[2]Institute of Animal Rearing Technologies, Faculty of Animal Husbandry Technology
Lithuanian University of Health Sciences, Veterinary Academy, Kaunas, Lithuania
[3]Department of Animal Breeding and Nutrition, Faculty of Animal Husbandry Technology
Lithuanian University of Health Sciences, Veterinary Academy, Kaunas, Lithuania

Corresponding author: Nerijus Ciganas
e-mail: n.ciganas@kggroup.eu; tel. +370 616 23809
Address: H. ir O. Minkovskių g. 63, LT - 46550 Kaunas

Abstract. There has been a huge interest recently in fabaceae crops and their usage possibilities in the diet of poultry, pigs and ruminants. Except soybeans, the most suitable fabaceae crops for this purpose are peas, lupines, faba beans and rapeseeds. Extrusion is a mechanical and thermal process of material processing. The word "extrusion" derives from the Latin language *exfrudere*, the word *ex* means out, and the word *frudere* means to thrust.

Nutritional value was studied using the following methods: dry matter determined by drying samples; crude protein examined by Kjeldahl method; crude fats counted after sample extrusion with ether; crude ash were counted by residue of organic material sample burnt at the temperature of 550°C; NFE = dry matter amount – crude protein amount – crude fats amount - crude fibre amount - crude ash amount; crude fibre determined as the residue of insoluble nitrogen free material in acid and alkali; NDF, ADF and ADL were determined using analyser ANKOM 200 Fibre Analyzer (Ankom Technology, Macedon, USA).

Studies have shown that extrusion influences nutritional value indicators of fabaceae and brassicaceae plants differently; however, most often the differences are detected within the tolerance range (P>0.05). In the future it would be useful to determine digestibility of extruded and non-extruded fabaceae and brassicaceae plants in order to determine processing impact on feed material uptake in organisms of livestock.

Keywords: extrusion, soybeans, rapeseeds, lupines, peas, faba beans

Introduction

In order to remain competitive in Lithuania, one should adapt to the imposed conditions and to reduce the price of production as much as possible. The cheapest protein feed materials are fabaceae crops and their products. They are rich with proteins, which contain almost all essential amino acids, fatty acids, vitamins and minerals. Peas, faba beans, vetches and lupines are the fabaceae crops that are most often grown in Lithuania. Fabaceae plants contain a lot of protein in seeds, and also in their vegetative parts. In some of the fabaceae plants protein content is between 20 and 40 %. These seeds may be valuable when producing complete feed on industrial scale and when adding them into compound feed produced in the farms. In the scientific literature thermal processing methods and the change of nutritional value after processing of the above mentioned fabaceae crops have not been analysed satisfactorily. The extrusion impact on the nutritional value of fabaceae crops has not been analysed, and for this reason extended research on nutritional value of these feed material (soybeans, rapeseeds, lupines, faba beans and peas) before and after extrusion has been carried out.

Extruder is a screw compression device. The material in the extruder is heated and compressed under the elevated pressure, and later forced through a die. During this process the temperature is very high and reaches up to 200ºC, however, the extrusion time is very short and takes only 5 to 10 seconds, so the extrusion is called HTST method since it involves short term exposure to high temperature (Harper, 1979). In the extrusion device under a high temperature, pressure and mechanical load, structural changes in the grains and their products take place, chain molecules of starch get shortened, therefore, amount of soluble material in water increases (M. Dehghan-Banadaky et al., 2007). When using extruded grain products, the output of extract increases, therefore, the cost price, labour and energy expenses are reduced. Extrusion is performed using grains that have insoluble fibre material between 4 and 20% calculated on the dry matter. These grains are mixed at 0–100ºC temperature, hydrated with water or water vapours until 15–50% humidity, extruded, and then the product of 100–180ºC temperature is pushed through a die which is between 3 and 5 mm in diameter. The extruded mixture has to contain between 20 to 100% whole grain or their mixture. Insoluble fibre material, preferably bran or grain husk, may be added additionally into grains, their products or their mixtures before hydration.

The efficiency of extruded fabaceae usage and brassicaceae plant seeds in livestock nutrition is determined by extrusion parameters such as exposure, temperature, steam supply flow and product composition (various data are provided in scientific literature), therefore, **the aim of this research** is to examine extrusion influence on nutritional and energy value of feed material, assessing nutritional value of soybeans, rapeseeds, lupines, faba beans and peas before and after extrusion process, in order to obtain the highest quality products for livestock nutrition.

Material and methods

Feed materials were extruded in the temperature ranging between 125 and 135°C under the humidity level of 17-20%.

The research on nutritional value of fabaceae crops was conducted in the University of Health Sciences, Institute of Animal Rearing Technologies, Laboratory of Animal Productivity, Institute of Animal Husbandry and Laboratory of Kauno Grudai AB.

Nutritional value was studied using the following methods: the dry matter was determined as the difference between wet and dry sample when drying it for 3 hours at the temperature of 105°C; crude protein was examined by Kjeldahl method when determining amount of nitrogen in the sample; crude fats counted after sample extrusion with ether; crude ash were counted by residue of organic material sample burnt at the temperature of 550°C; NFE = dry matter amount – crude protein amount – crude fats amount - crude fibre amount - crude ash amount; crude fibre determined as the residue of insoluble nitrogen free material in acid and alkali; NDF, ADF and ADL were determined using analyser ANKOM 200 Fibre Analyzer (Ankom Technology, Macedon, USA).

The quality of the laboratory research was determined in accordance to the differences between parallels depending on the concentration found in sample material being investigated. If the obtained results were above the allowable tolerance limits, the analysis was performed again. The differences of data obtained within the tolerance limits are statistically reliable $p<0,05$.

Results and discussion

Dry matter content of fabaceae and brassicaceae crops before processing was between 91.72 % and 94.01 %, after extrusion – 90.98 - 93.04 %, the highest DM content was found in extruded rapeseeds (94.50 %), and the lowest in the mixture of extruded rapeseeds (70 %) and faba beans (86.62 %).

Table 1. **Nutritional and energy value of raw and extruded fabaceae and brassicaceae plants**

Name of the feed	Dry matter, %	Crude protein, %	Crude fats, %	Crude ash, %	NFE, %	Calcium	Phosphorus	Metabolizable energy (ME), MJ/kg	Net energy for lactation (NEL), MJ/kg
Soybeans	93.78± 0.54	38.48± 0.47	18.30± 0.21	3.96 ±0.1	20.96	0.227	0.622	14.71	9.12
Extruded soybeans	93.04± 0.45	38.18± 0.37	19.18± 0.28	4.61 ±0.2	21.01	0.254	0.859	14.66	9.08
Lupines	91.72± 0.42	30.95± 0.23	15.71± 0.16	2.61 ±0.15	38.13	0.192	0.511	12.17	7.51
Extruded lupines	92.73± 0.62	27.53± 0.20	7.72 ±0.14	2.28 ±0.17	45.97	0.277	0.652	12.27	8.20
Faba beans	94.01± 0.49	26.73± 0.31	0.99 ±0.12	2.88 ±0.14	56.39	0.100	0.403	12.36	7.76
Extruded faba beans	90.98± 0.54	27.20± 0.36	1.21 ±0.14	2.97 ±0.08	53.38	0.164	0.479	12.13	7.61
Peas	92.33± 0.31	22.46± 0.56	1.61 ±0.18	2.52 ±0.11	61.21	0.102	0.411	12.82	8.18
Extruded peas	89.44± 0.84	23.14± 0.45	1.58 ±0.13	2.54 ±0.10	57.49	0.132	0.473	12.40	7.90
Rapes	93.83± 0.63	21.31± 0.34	39.66± 0.38	4.98 ±0.09	20.65	0.58	0.71	15.02	9.20
Extruded rapes	94.50± 0.37	20.05± 0.47	38.73± 0.46	2.13 ±0.08	31.03	0.44	0.78	14.93	9.15
Rapes 70 faba beans 30	92.65± 0.46	25.12± 0.28	19.58± 0.28	3.72 ±0.11	31.65	0.50	0.76	14.87	9.12
Rapes 50 faba beans 50	90.30± 0.47	23.44± 0.35	18.11± 0.23	8.35 ±0.16	38.16	0.28	0.63	14.81	9.09
Rapes 30 faba beans 70	86.62± 0.51	23.19± 0.24	10.66± 0.14	8.76 ±0.18	46.91	0.20	0.57	14.70	9.03

The highest amount of crude protein was determined in raw soybeans (38.48 %) and the amount changed insignificant after the extrusion (38.18 %). The lowest amount of crude protein was identified in raw rapeseeds (20.05 %) and after the extrusion the protein content in rapeseeds dropped by 1.3 %. The biggest influence of extrusion on protein content was when processing lupines; before the processing the quantity of proteins was found to be 30.95 %, and after the extrusion crude protein dropped by 3.42 % (27.20 %). It may be assumed that some of the protein could move into the concentration of nitrogen free extract, however, such hypothesis could be revised using more sophisticated methods.

The smallest amount of crude fats was found in raw and extruded faba beans, and the highest in raw and extruded rapeseeds. The greatest difference of crude fats, i.e. 7.99%, was measured among raw (15.71%) and processed lupines (7.72%). Similar differences of crude fats are presented in the research conducted by Bliznikas S. and co-authors (2011) who applied different processing methods of compound feed, however, these researchers failed to determine impact on other indicators of nutritional value. Our study findings obtained of crude ash, calcium and phosphorus confirm their results.

The amount of crude ash before and after processing changed insignificantly. The lowest amount was found in extruded lupines (2.28%), the highest in mixture which contained 30% of extruded rapeseeds and 70% of extruded faba beans.

The smallest amount of calcium and phosphorus was detected in feed faba beans, extruded full-fat soybeans.

Metabolizable energy amount in processed and non-processed lupines, faba beans and peas was very similar, approx. 12.3 - 12.82%, and the greatest metabolizable and net energy for lactation found in non-processed full-fat soybeans.

Also, extrusion did not have a significant impact on nutritional value of fabaceae crops (faba beans, peas) in the research carried out by other authors (Alonso et al., 2000a; Alonso et al., 2000b).

Table 2. **Fibre and its separate fraction amount in fabaceae and brassicaceae crops**

Name of the feed	Crude fibre, %	ADL, %	ADF, %	NDF, %
Soybeans	12.08±0.58	2.07±0.10	12.54±0.14	14.30±0.23
Extruded soybeans	11.56±0.52	2.20±0.11	14.49±0.16	17.36±0.24
Lupines	15.51±0.68	0.92±0.08	18.75±0.21	22.72±0.34
Extruded lupines	12.22±0.62	1.04±0.09	15.49±0.17	22.97±0.38
Faba beans	6.92±0.28	0.87±0.07	9.71±0.12	16.89±0.21
Extruded faba beans	6.22±0.32	0.73±0.07	53.38±0.64	9.10±0.14
Peas	4.53±0.22	0.39±0.06	6.69±0.21	15.06±0.35
Extruded peas	4.69±0.18	0.07±0.02	6.04±0.19	8.59±0.16
Rapes	10.53±0.42	17.02±0.38	12.48±0.17	3.95±0.08
Extruded rapes	9.32±0.37	18.79±0.43	11.91±0.09	5.08±0.07
Rapes 70 faba beans 30	6.55±0.11	12.57±0.37	8.96±0.08	2.96±0.08
Rapes 50 faba beans 50	7.98±0.14	13.79±0.32	12.25±0.10	3.44±0.05
Rapes 30 faba beans 70	6.36±0.09	10.45±0.29	8.43±0.04	1.9±0.03

The highest content of crude fibre was determined in raw lupine (15.51 %) and the lowest in raw peas (4.53 %). The crude fibre decreased even by 2.99 % after the extrusion, whereas the content of crude fibre in other fabaceae crops changed only slightly after extrusion.

The ADL fraction amount was determined in processed soybeans and the lowest in peas. ADL fraction amount in feed before and after processing changed insignificantly.

After the research it was found that the largest ADF fraction content was determined in extruded faba beans and the lowest in extruded peas. It shall be noticed that extrusion had a significant impact on ADF fraction changes in fabaceae crops. It was found that ADF fraction in faba beans after extrusion increased by 43.67%, in soybeans by 1.95%, but dropped in lupines by 3.36%.

The highest NDF determined in extruded lupines was 22.97%, the lowest in extruded rapeseed (30%) and faba bean (70%) mixture -1.9%. It shall be noticed that NDF fraction content in soybeans, faba beans and peas extrusion had a prominent influence, whereas NDF amount changes in lupines before and after extrusion were slight. After extrusion NDF fraction content in soybeans increased by 3.06%, in faba beans decreased by 7.79% as well as in peas by 6.47%.

Various testing was carried out with extruded soybeans: some authors claim that soybeans had a positive effect on dairy production and chemical composition (Grummer, 2000). Some authors argue that milk yield increased (Gatel., 1994).

Inclusion of soybeans into diet as the source of protein and fats is widely and often used on dairy farms. Comparing to other protein feed, extruded soybeans contain a lot of amino acids that are well digested in rumens of ruminants (Schwab, 1995).

It is very practical and cost effective to include soya and its by-products into the ruminant diet. A complete complex of amino acids is present in soybeans, therefore, it can be included into any diet composition. Depending on the processing method, soybeans are high quality and well digested proteins, fats, and are also rich in fibre. When soybeans are used in nutrition, they help to reduce or prevent ruminal acidosis, and decrease stomach pH. Soybean husks have a low amount of lignin and structural carbohydrates, but they are rich in fibre that is well digested in the rumen. It is stated that when including soybeans into diet, milk yield increases up to 4% (Solomon et al. 2000).

Davis, 2002 claims that if dairy cows are fed with extruded soybeans, protein digestibility In situ is prolonged by up to 15%/h. In addition, it improves milk yield, carbohydrate fermentation in the rumen and metabolism processes.

After extrusion, soybean oil is easily digested and absorbed in the rumen of cows.

Good quality milk has to contain as little palmitic, myristic and lauric acids in milk fats as possible. Studies have shown that when dairy cows are fed with extruded soybeans, the ratio of these acids in milk decreased to 5%. (Secchiari et al., 2003).

In recent 20 years there have been a number of experiments on feeding dairy cows with extruded, raw, heat-treated soybeans or soy meals (Chouinard et al., 2001). After so many years there are many different opinions and many experiments were performed with various results (Solomon et al., 2000).

Dhiman et al. 1999 argue that if dairy cows are fed with extruded soybeans, fat content of milk decreases and protein content increases.

Soybeans consist of 42% of crude proteins and 19-20% of crude fats and only 26% of proteins is digested in the rumens of ruminants (Faldet et al., 1992).

Forage lupine grains contain the highest amount of proteins considering all the leguminous cultures grown on farms. They may contain up to 20% of concentrated feed mixture intended for livestock. Widely used lupines are the sources of protein and energy in the nutrition of livestock. Their protein content makes them valuable feed for monogastric animals and ruminants since the price of lupines is competitive with other protein feed. Low level of starch and high level of carbohydrate fermentation of lupines make them especially valuable in cattle feeding due to low risk of acidosis. Relatively high amount of soluble and insoluble non-starch polysaccharides may have impact on absorption of other food substances; therefore, lupines have to be used strategically in order to optimise livestock production. Moreover, relatively low content of sulphur amino acids, methionine and cystine has impact on how the lupines will be used in livestock nutrition. However, low amount of methionine or lysine has no or only slight influence on ruminants because proteins are fermented when ruminating (Peterson et al, 1997).

70-80% digestible and 20-25% crude proteins are in the faba beans. They are not very delicious and easily digestible unless before feeding they are rolled or processed otherwise. Low digestibility of proteins is one of the main problems when feeding faba beans to livestock (Butolo, 2002). Dairy cows may be given 1 or 2 kg per day of forage faba beans together with other feed. 20% of faba beans may be added into concentrated feed mixtures (Kulpys, Stankevičius, 2010).

Peas are one of the four most important leguminous grains. Peas seeds are considered to be a valuable source of protein in livestock nutrition. The content of protein fluctuates between 22 to 24% (16-32% DM). They are rich in amino acids (lysine) and starch (48-54% DM). It is stated that if extruded peas are added into the nutrition of dairy cows, milk composition and quantity changes (Valentine et al., 1987); also, rates of starch degradation change in rumen. Starch resolves slower than in other grains (4–6%/h), therefore, the risk of acidosis is reduced. It is considered that inclusion of peas into the nutrition of dairy cows has a negative impact. Digestibility of crude proteins increases when peas are extruded (Goelema et al.,1999).

Peas as other legumes have extremely well and easily digestible proteins. Pea proteins are completely digested, but they are digested slower than proteins of soybeans by about 38%. Proteins in peas are digested at the rate of 1.6% per hour on average, whereas proteins of soya by 4.5%. Starch that is digested slowly helps to control pH level of ruminants. Proteins of extruded peas are digested slower by 50-75 %.

It is very useful to add rapeseeds into the nutrition of ruminants because they have 35% of crude protein and a well digestible amino acid complex.

Over the past twenty years EU, China, Canada and other world countries aimed at removing anti-nutritional factors such as glucosinolates and erucic acids present in rapeseeds, and as a consequence the rapeseed genotype that met biological value of soy flour was changed (Campbell et al 1999).

The cell size of rapeseeds is 30-50 microns. The cell of rapeseed consists of protein which diameter is 6-10 microns and lipids which diameter is 0.2-0.5 microns. Rapeseed fats inside the cells are well protected by cell walls.

Comparing to soybeans, the amount of crude fats in rapeseeds is more than double; however, the amount of crude proteins is almost 40% less. In rapeseeds there is almost no starch, however, they are rich in fibre.

Thermal processing of rapeseeds has a positive nutritional value (Burel et al 2000). Anti-nutritional substances are destroyed under the process of extrusion. In rapeseeds there are enzymes that release phosphorus combinations into oil. Rapeseed extrusion is carried out at 85–100°C temperature for less than 15 seconds (usually 5–6 seconds); in such short period of time enzymes do not free phosphorus compounds into oils so high-quality nutrients that affect good digestibility are retained. Rapeseed oil is known as a good source of energy, nutrients and calories, and it also may be cost-effective to use in cow feeding. In extruded rapeseed flour there is 7–15% higher oil content comparing to ordinary rapeseeds; in addition, digestibility of fats and amino acids also improve after the process of extrusion (Schumann W., 2005).

Conclusion

Studies have shown that extrusion influences nutritional value indicators of fabaceae and brassicaceae plants differently; however, most often the differences are detected within the tolerance range ($P>0,05$). In the future it would be useful to determine digestibility of extruded and non-extruded fabaceae and brassicaceae plants in order to determine processing impact on feed material uptake in organisms of livestock.

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