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ASSESSING TRANSPORT SUSCEPTIBILITY OF RAPESEED MEAL FRACTIONATION PRODUCTS

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ABSTRACT. **Background:** Having considered increasing production of liquid and solid biofuels from rapeseed and bearing in mind its stable and unquestionable position in the food and animal feed industries, a rational approach towards technologically and logistically efficient utilization of by-products from rapeseed processing is required. The aim of the research presented in the article is to assess the transport susceptibility of rapeseed meal fractions, varying according to particle size and chemical composition.

Methods: Resistance to changes stimulating self-heating has been assumed as the main criterion of transport susceptibility. The following diagnostic variables have been experimentally determined: total protein, crude fat and crude fiber content, porosity, and water activity in the fraction of examined meal. In order to organize a set of particles and to indicate their optimal applications according to criteria chosen with regard to both utilization and transportation, two aggregate indicators have been calculated.

Results: It has been proved that medium-sized particle fractions (0.075-0.4 mm) exhibit the lowest transport susceptibility, whereas the those with the largest granulations (>3 mm) -have the highest. One significant relationship is the decline of feeding value and concurrent increase in the transport susceptibility of meal fractions, which in practice means that those fractions least-favoured by the animal feed industry can be least cumbersome to transport.

Conclusions: It has been suggested that there should be a division of rapeseed meal into two products with different applications and different transport susceptibility. The fractioning of meal can bring numerous, measurable benefits for the meal industry and logistics processes for solid biofuels, where storage and transport properties have considerable importance, alongside commodity price and transport costs.

Key words: self-heating, transport of biomass, sustainable energy logistics, solid biofuels, utilization of rapeseed.

INTRODUCTION

Over the last three decades, there has been a steady increase in the volume of agri-bulk cargoes carried by sea [Maritime Knowledge Centre, 2012]. Those loose materials of plant origin that due to the scale of production are traded in bulk consist mainly of unprocessed grains, oil-seeds, legumes, as well as various products resulting from their processing, such as cake and meal, which are the protein source in the production of compound feed. One of these cargoes which is transported by land and sea in increasing volumes in the EU is rapeseed meal of double-low varieties (RM 00) which is a byproduct of de-oiling rape, currently used alternatively as feedstuff or solid biofuel in green energy production [Ucar and Ozkan 2008, Leśmian-Kordas and Bojanowska 2010]. In 2013 domestic rapeseed production amounted to 1.28 million tons, which was the highest level for over ten years and double that of 2004, according to data published by Fediol [2015]. Poland is currently the third largest producer of rapeseed in Europe by volume, after Germany and France and is a major supplier to the EU internal market. About 50% of rapeseed meal produced in Poland is exported to the countries of

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Western and Northern Europe, predominantly by sea.

Natural cargo transport susceptibility is defined as the resistance of cargoes to changes in their properties affected by the conditions and duration of transport processes resulting from chemical, physical and biological properties of the cargoes. Loads of perishables, dangerous and hygroscopic properties as well as those sensitive to mechanical damage possess the lowest natural transport susceptibility. One of the properties of rapeseed meal is its propensity to self-heating, which is the basis for listing this cargo (under common name Seed Cake) in international transport rules in class 4.2. of dangerous goods [IMDG 2014, IMSBC 2013]. In the case of oilseed meal, self-heating processes are preceded and then accompanied by a series of changes resulting from fermentation, decomposition of compounds, oxidation of fatty acids, microbial growth, gradual evaporation of water and further thermal decomposition of organic matter [Becker 1996, Sturaro et al. 2003]. The oxidation of unsaturated fatty acids with heat, water and carbon dioxide release and increased microbial activity in the initial stage of the process (35ºC-70ºC) are considered to be direct causes of self-heating, taking place in seed cake containing residual fat, with a water content above the critical level [Bowes 1984, Becker 1996, Ramirez-Gómez et al. 2009].

Fractionation of rapeseed meal, which improves its nutritional value considerably through the removal of larger particles with a lower protein content and a higher anti-nutritional dietary fiber content [Mińkowski 2002], has not so far been applied on an industrial scale, mainly due to the problems with the utilization of fractions with a lower feeding value. However, there is a possibility of using coarse fractions of rapeseed meal as a renewable source of energy, mainly lumped parts of seed pulp and the plant's coats . The consequence of dividing rapeseed meal into fractions with different functional properties and alternative applications is that products with different technological and transport characteristics, including a propensity to self-heating processes, can be obtained.

The present work aims at diagnosing the susceptibility of chemically different rapeseed meal fractions to self-heating processes, using multiple comparative analysis methods: linear ordering of multivariate objects [Sokołowski 2009].

MATERIAL AND METHODS

The research material was post-extraction rapeseed meal produced in "ADM Szamotuły" Sp. o.o. Fractionation of the rapeseed meal by sieving was performed in accordance with PN-ISO 2591-1: 2000, using a set of Multiserw Morek control sieves. The equivalent diameter of each fraction was calculated as the geometric mean of marginal particle sizes in accordance with PN-89/R-64798. The content of the basic chemical components of rapeseed meal and its fractions (moisture, crude protein, crude fiber, crude fat) was determined by the near infrared spectroscopy (NIRS) method, on a spectrometric FT-NIR MPA- Multi Purpose Analyzer, Bruker. The camera was equipped with a rotating integrating sphere for loose, heterogeneous products. Quantitative results related to the selected chemicals, corresponding to the absorbance spectra obtained, were calculated on the basis established by the camera manufacturer's calibration model for rapeseed meal, using the OPUS 6.0 program. The results were expressed as grams of the component per 100 g of dry matter ($g \cdot 100g^{1}$ d.m.). The water activity was determined by the static method, involving measurements of sorption of water vapor at t = 25°C and at a relative humidity of 60%, 75% and 90%. Samples of 5 g were kept in Petri dishes in a climatic chamber type 60 U Mytron, until its constant weight was achieved. The change in the weight of each sample was monitored every day to an accuracy of 0.0001 g. The porosity of the meal and its fractions was determined by the following formula:

$$\varepsilon = \frac{\rho_{rz} - \rho_n}{\rho_{rz}} 100\% \qquad (1)$$

where:
ε - porosity (%);
ρ_{rz}- true density ($g \cdot cm^{-3}$);
ρ_n- bulk density ($g \cdot cm^{-3}$).

The true density was determined by the Erdmenger - Mann method by measuring the volume of a sample of a known mass through the progressive replenishment of the flask with a liquid (ethyl alcohol). Bulk density measurements for natural meal and its fractions, except the smallest, were carried out according to PN-EN 1236:1999. Bulk density of dust with a particle size of less than 0.075 mm was determined in accordance with PN-EN 50281-2-1:2002. All measurements were made in duplicates of six.

THEORY AND CALCULATIONS

A synthetic approach to selected properties of rapeseed meal fractions was used to order particle collections with different dimensions, according to their transport susceptibility and, furthermore, to indicate the most favorable application of fractions due to the criteria adopted: usability value as a feed component and transportation properties. Linear ordering of rapeseed meal fractions was done according to the level of resistance to unfavorable chemical changes, initiating self-heating and the level of feeding value. The aggregate indexes <0;1>, as a point measure, were calculated using the following formula:

$$W_i = \frac{1}{m} \sum_{j=1}^{m} \alpha_j \, x'_{ij} \qquad (2)$$

W_i - aggregate index,
m –number of selected properties,
α_j – weight of j-variable,
x'_{ij} – normalized values of individual attributes (feature values converted to mutual comparability).

The normalized values of variables were calculated by the unitarization method, in which the interval of a particular value to the observed extreme value (the "worst" in terms of the kind of analysis) is divided by the differential between the maximum and minimum values of the j-variable. The diagnostic variables are qualified as stimulants or destimulants, according to whether their high levels are desirable (S) or undesirable (D) from the point of view of the phenomenon concerned. The following diagnostic variables were selected for calculating the "level of resistance to changes initiating self-heating" (RL) index:

X_1: fat content (% d.m.) - a destimulant - high fat content favors exothermic oxidation processes [Bowes 1984];

X_2: protein content (% d.m.) - a destimulant - high protein content favors microbial growth, especially at water activity above 0.7 [Sikorski 2001];

X_3: water activity at temperature of 25°C and at moisture content (m.c.) of samples equal to 12.5% (The maximum permissible moisture content for extracted oil seed meals according to Polish Standard PN-80/R-64773) – a destimulant - higher water activity enables the microbial activity [White and Jayas, 1989];

X_4: porosity (%) - a stimulant - higher porosity facilitates removal of pointwise cumulated heat [Horabik 2001].

In the case of the "level of feeding value" (FL) index, the following diagnostic measures were used:

X_5: protein content (% d.m.) - a stimulant – a high protein content enhances feeding value, also as a result of an increase in the amino acid concentration [Messerschmidt et al. 2014];

X_6: fat content (% d.m.) - a stimulant - a high fat content increases energy value, as well as essential fatty acid concentrations [Smulikowska and Nguyen 2003];

X_7: fiber content (% d.m.) - a destimulant – a high fiber content decreases feed digestion and metabolic energy [Smulikowska and Nguyen 2003];

X_3: water activity at a temperature of 25ºC and at m.c. of samples of 12.5% - destimulant - higher water activity, particularly above 0.7 may increase the degree of protein and amino acid degradation, which lowers feed quality [Pastuszewska and Raj 2003];

X_8: particle size (mm), expressed as the equivalent diameter of the particles - stimulant - excessive fragmentation of the feed is not desirable because of the possibility of respiratory diseases developing and excessive blowing during feed intake by animals.

Due to the fact that experts in the literature have not established weights for the features selected, as well as the lack of a universally accepted formal statistical method for weighing features, in the analysis it was assumed that attributes are equally important from the point of view of the phenomena under consideration and their coefficients of validity are $\alpha j = 1$.

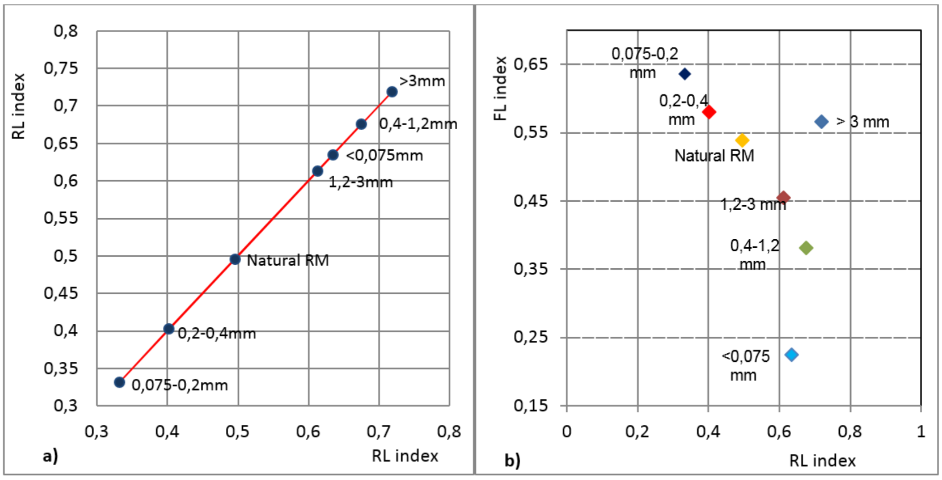
RESULTS AND DISCUSSION

The results obtained using multivariate linear ordering of objects in the form of RL and FL indexes are presented in table 1. The higher the aggregate index, the more the values of the selected diagnostic variables are similar to the state of the most desirable (index value of 1). The mutual distances of the points for each fraction on the axis of linear hierarchy are a measure of their similarity, due to the properties analyzed (Fig.1a).

Table 1. Aggregate indexes of the level of resistance to changes initiating self-heating (RL) and the level of the feeding value (FL) for rapeseed meal and its fractions
Tabela 1. Wskaźniki agregatowe poziomu odporności śruty rzepakowej i jej frakcji na przemiany stymulujące samozagrzewanie (RL) oraz poziomu wartości paszowej (FL)

Fraction (mm)	**Mass (%)**	**Level of resistance to changes initiating self-heating (RL) index**	**Level of feeding value (FL) index**
> 3	12.0	0.7190	0.5657
1.2-3	6.3	0.6127	0.4549
0.4-1.2	56.9	0.6754	0.3810
0.2-0.4	18.9	0.4023	0.5802
0.075-0.2	5.8	0.3320	0.6360
<0.075	0.1	0.6343	0.2248
Natural RM	100	0.4956	0.5394

Source: Own studies



Source: Own studies

Fig. 1. a) "Level of resistance to changes initiating self-heating" (RL) index
b) Correlation between the level of resistance to changes initiating self-heating (RL index) and the level of feeding value (FL index) for rapeseed meal (RM) and its fractions
Rys. 1. a) Wskaźnik poziomu odporności na przemiany stymulujące samozagrzewanie
b) Zależność między poziomem odporności na przemiany stymulujące samozagrzewanie a wartością paszową śruty rzepakowej i jej frakcji

Dust fractions (0.075-0.2 mm and 0.2-0.4 mm) have the greatest potential susceptibility to the development of adverse changes, while fractions with a particle size greater than 3 mm have the lowest (w> 3 = 0.7190). The lowest RL indexes values of particles with a size between 0.2-0.4 mm and 0.075-0.2 mm are the result of cumulative, disadvantageous effects: low porosity, a relatively large concentration of protein (40.6% d.m. and 43.4% d.m.) and a relatively high content of residual fat, of 5.6% d.m. and 5.1% d.m., respectively (Table 2). Dust with a particle size of less than 0.075 mm is characterized by lower propensity to self-heating than coarser dust fractions, due to their lower fat content (3.3% d.m.) and higher porosity (64.2%) (Table 2).

A high level of the RL index for fractions with a particle size above 3 mm is caused primarily by relatively low water activity (0.77) at the moisture content of the material (12.5%) and the relatively low fat content (3.6% d.m.). The lower propensity to negative changes in the case of fractions in the particle size range 0.4-1.2 mm compared to powdery fractions is in turn associated with a lower protein content (34.2% d.m.) and greater porosity, which allows for the dissipation of heat, being locally accumulated during self-heating processes.

In practice, an important role in the self-heating intensification is attributed to dust fractions, especially at higher temperatures, due to the release rate of various volatile compounds from powdery particles [Bowes 1984, Ramirez-Gómez et al. 2010]. The studies conducted showed that dust fractions may also enhance these changes at lower temperatures due to different chemical composition and higher water activity relative to unfractionated meal. An important observation is the fact that fractions which are the most desirable as animal feed (Figure 1b) may be simultaneously the most burdensome in transport. Potential resistance to chemical and biochemical deterioration stimulating self-heating decreases, with an increase in the feeding value, except for the two marginal fractions i.e. with a particle size greater than 3 mm and less than 0.075 mm.

Table 2. The values of diagnostic variables for rapeseed meal and its fractions
Tabela 2. Wartości zmiennych diagnostycznych śruty rzepakowej i jej frakcji

Fraction (mm)	**Crude protein ($g\cdot 100\ g^{-1}$ d.m.)**	**Crude fiber ($g\cdot 100\ g^{-1}$ d. m.)**	**Crude fat ($g\cdot 100\ g^{-1}$ d. m.)**	**Water activity**	**Porosity (%)**
> 3	37.7	11.5	3.6	0.77	59.9
1.2-3	38.2	11.8	4.8	0.79	60.3
0.4-1.2	34.2	13.7	7.4	0.80	63.7
0.2-0.4	40.6	9.4	5.6	0.79	58.0
0.075-0.2	43.4	7.9	5.1	0.81	58.1
<0.075	38.5	9.8	3.3	0.92	64.2
Natural RM	37.0	11.8	6.3	0.77	58.4

Source: Own studies

Fine and coarse dust (0.075-0.2 mm and 0.2-0.4 mm) containing a high concentration of protein and low percentages of anti-nutritional fiber have the highest value for the feeding industry. A fraction of particle size greater than 3 mm is also highly suitable for utilization in animal feeding. This is caused mainly by the degree of fragmentation and the hygroscopic properties of this fraction. The permissible water content of meal, accepted in trade at the level of 12.5%, corresponds to this fraction with water activity aw = 0.77, while in the finest fraction of dust, at the same water content, water activity is 0.92. The finest dust has a very low FL index, which is associated with the high water activity compared to the other fractions at the same water content, low fat content and high degree of fineness. The low feeding usefulness of the fraction with a particle size of 0.4-1.2 mm is, on the other hand, determined by the relatively low protein content and high crude fiber content.

Sorting rapeseed meal fractions according to their tendency to unfavorable changes (Figure 1a) reflects the characteristics of each set of particles, where all the analyzed attributes are equally important. Assuming that oxidation of meal's residual fat is the main process which initiates heat accumulating and giving a higher coefficient of validity to the diagnostic variable "fat content", fraction positions would have been changed. Studies on the processes of self-heating taking place in oilseed meals [Bowes 1984, Becker 1996, Sturaro 2003] indicate that the assumption of the biochemical character of heating processes in post-extraction meals and of its equally important role compared to the chemical oxidation of polyunsaturated fatty acids seems appropriate. The German Insurance Association qualifies toasted oilseed meals as materials which are biotic active and which undergo microbiological processes leading to changes in the quality and stimulating exothermic reactions [Container Handbook, 2015]. The author's own studies (unpublished) showed that the growth of microflora on the surface of rapeseed meal samples stored at different temperatures and at a relative humidity of 80% is dependent mainly on protein content. However, according to transport regulations (IMSBC, IMDG Codes), the residual fat content and further moisture content in meals are the only criteria to assign cargo to one of four groups, including three dangerous ones (Seed Cake: UN 1386 a, 1386 b UN or UN 2217).

Table 3 shows the classification of fractions of rapeseed meal with a given moisture content and residual oil based on the criteria contained in the IMSBC Code. According to these criteria, only two fractions, i.e. one with a particle size above 3 mm and the other below 0.075 mm with a certain moisture and oil content could be classified as safe in transport in terms of self-heating. Other collections of particles, as well as unfractionated rapeseed meal, meet the requirements for the classification set of seed cakes prone to self-heating (class 4.2. of dangerous goods, UN 1386 (b)).

Table 3. The classification of fractions of rapeseed meal according to IMSBC Code
Tabela 3. Klasyfikacja badanych frakcji śruty rzepakowej wg Kodeksu IMSBC

Fraction (mm)	Moisture content (M) (%)	Residual oil content (O) (% d.m.)	Moisture + residual oil content (%)	Dangerous cargo class 4.2/group B UN 1386 (b)*	Cargo classified as non -hazardous**
>3	10.9	3.6	14.5		•
1.2-3	9.5	4.8	14.3	•	
0.4-1.2	10	7.4	17.4	•	
0.2-0.4	9.2	5.6	14.8	•	
0.075-0.2	7.7	5.1	12.8	•	
<0.075	7.8	3.3	11.1		•
Natural RM	10.9	6.3	17.2	•	

*Classification criteria: O (residual oil) <10% and when M (moisture content) > 10% then M+O <20%
** Classification criteria: O (residual oil) <4% and O+M<15%

The comparison of results obtained by multivariate analysis with the data presented in table 3 shows that aggregate indexes (RL) for each fraction mostly coincide with the classification states (dangerous/safe), according to marine transport regulations. Resistance-level indexes of fractions classified as safe in transport were high (w> 3 = 0.7190 and w <0.075 = 0.6343). For the remaining fraction, which are classified as dangerous goods according to the IMSBC Code, these indicators were correspondingly lower, with the exception of fractions with a particle size in the range of 0.4-1.2 mm (w0.4-1.2 = 0.6754). The reason for this discrepancy is the oil content of this fraction, which exceeds 4% d.m. and thus prejudges qualifying this group of particles to class 4.2 of dangerous goods. Simultaneously, this fraction has the lowest protein concentration and the highest porosity, which contributes to its higher position in the hierarchy of collections of particles by increasing the level of resistance to unfavorable changes initiating self-heating.

CONCLUSIONS

It can be concluded that it is beneficial to divide rapeseed meal into two fractions in terms of both the utility of meal as well as its transportation properties: finer meal, which might be used exclusively for the domestic animal feeding industry and a thicker one, used as a biofuel to be utilized locally and due to greater resistance to quality changes, exported in bulk by sea, in the case of production oversupply . With each ton of rapeseed meal, about 250 kg of fine fraction meal (d <0.4 mm) is obtained, with a protein content of more than 40% d.m. and structural polysaccharide content reduced to the level of 7.9-9.4% d.m. (vs 11.8% in the natural meal). However, this fraction has very low transport susceptibility (the influence of the fraction with a particle size less than 0.075 mm on the transport susceptibility of mixed dust fractions can be omitted because of its weight participation of only 0.1%). During long journeys by sea, the benefits of fractionating the natural meal may be reduced by the quality of such a product dropping quickly, especially with unmodified, averaged standards for permissible moisture content. In transport processes, such a product will be more susceptible to self-heating than natural meal and will pose a real risk of explosion [Bojanowska and Leśmian-Kordas 2009]. It would therefore be useful to use transport packaging for domestic carriages of fractionation meal products intended for the fodder industry.

Fractions with a particle size above 0.4 mm, obtained in amounts of about 750 kg per ton of meal, could instead be used as a renewable energy source. We can assume with a high probability that such a product, as compared to unfractionated meal, would be characterized by greater transport susceptibility, and also would pose a much smaller risk of explosion in technological and transportation processes. The experience with agro-biomass in the green energy sector, including rapeseed meal, has shown that the delivery logistics as well as transportation attributes of solid fuels, such as hygroscopic properties, explosiveness of dust or susceptibility to self-heating, are as important as their functional characteristics (elemental composition, heating value, emission of gases and particles etc.). It has not been ruled out that the fractionation of meal may also bring benefits for the combustion processes, because of the lower protein content in coarser fractions (and thereby probably lower emissions of nitrogen oxides NO_x), which together with the transport susceptibility presented in this paper, can inspire experimental research on the effect of the fractionation on the properties of solid biofuels originating from rape seed.

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OCENA PODATNOŚCI TRANSPORTOWEJ PRODUKTÓW FRAKCJONOWANIA ŚRUTY RZEPAKOWEJ

STRESZCZENIE. **Wstęp:** Wzrastająca produkcja biopaliw płynnych i stałych z nasion rzepaku, przy stałym znaczeniu tej rośliny w przemyśle spożywczym i paszowym, wymaga racjonalnego, a zwłaszcza efektywnego technologicznie i logistycznie zagospodarowania produktów ubocznych technologii przerobu rzepaku. Celem badań przedstawionych w artykule była ocena podatności transportowej zróżnicowanych ze względu na wielkość cząstek oraz skład chemiczny frakcji śruty rzepakowej.

Metody: Jako kryterium podatności transportowej przyjęto odporność frakcji śruty na przemiany stymulujące samozagrzewanie. Wytypowano i oznaczono doświadczalnie następujące zmienne diagnostyczne: zawartość białka ogólnego, tłuszczu surowego oraz włókna surowego, porowatość, a także aktywność wody w poszczególnych frakcjach śruty. W celu uporządkowania zbiorów cząstek, a następnie wytypowania najkorzystniejszych ich zastosowań ze względu na przyjęte kryteria - cechy użytkowe i technologiczno-transportowe, obliczono dwa wskaźniki agregatowe.

Wyniki: Stwierdzono, iż najmniejszą podatność transportową wykazują średnie frakcje pyłowe (0,075-0,4 mm), największą zaś frakcja o największej granulacji (d> 3 mm). Istotną zależnością jest spadek wartości paszowej frakcji śruty wraz ze wzrostem podatności transportowej, co oznacza w praktyce, że frakcje najmniej pożądane w przemyśle paszowym, mogą być najmniej uciążliwe w transporcie.

Wnioski: Zaproponowano podział śruty rzepakowej na dwa produkty, różniące się przeznaczeniem oraz podatnością transportową. Frakcjonowanie śruty może przynieść wymierne korzyści zarówno dla przemysłu paszowego, jak i w sferze logistyki dostaw biopaliw stałych, w której obok kosztów surowca i jego transportu, istotną rolę w wykorzystaniu biomasowych źródeł energii odgrywają cechy przechowalniczo-transportowe.

Słowa kluczowe: samozagrzewanie, transport biomasy, logistyka energii odnawialnej, biopaliwa stałe, wykorzystanie rzepaku.

DIE BEWERTUNG DER TRANSPORTEIGNUNG VON FRAKTIONS-PRODUKTEN DES RAPSSCHROTES

ZUSAMMENFASSUNG. **Einführung**: Die ständig wachsende Produktion von flüssigen und festen Biokraftstoffen aus Rapssamenkörnern erfordert angesichts der kontinuierlichen Bedeutung dieser Pflanze in der Lebensmittel- und Futterindustrie eine rationelle und vor allem technologisch und logistisch effiziente Bewirtschaftung von technologisch bedingten Nebenprodukten, die bei der Rapsverarbeitung entstehen. Die Bewertung der Transporteignung der wegen der Größe differenzierten Partikeln und die chemische Zusammensetzung der Rapsschrotfraktion waren der Zweck der im Artikel präsentierten Forschungen.

Methoden: Als Transporteignungskriterium wurde die Abhärtung der Schrotfraktion gegen die Wandlungen, die Selbstaufheizung deren stimulieren, angenommen. Man hat experimentell folgende Variablen wie: den Inhalt des Proteins, des Rohfettes und des Rohfadens, die Porosität als auch die Wasseraktivität in den einzelnen Schrotfraktionen markiert. Um die Partikeln-Mengen einzuordnen und anschließend ihre günstigsten Anwendungen angesichts der angenommenen Kriterien wie Nutz-, Technologie- und Transporteigenschaften auszuwählen, hat man zwei Sammel-Indizes berechnet.

Ergebnisse: Es wurde festgestellt, dass die mittlere Staubfraktion (0,075-0,4mm) die niedrigste Transporteignung aufweist, dagegen die höchste die Fraktion mit der größten Granulation (d> 3mm). Als eine wesentliche Abhängigkeit gilt der Wertrückgang der Schrotfutterfraktion samt dem Transporteignungsanstieg, was in der Praxis bedeutet, dass die in der Futterindustrie am wenigsten erwünschten Fraktionen für den Transport aber am meisten geeignet sein können.

Fazit: Man hat die Aufteilung des Rapsschrotes in zwei Produkte, die sich bezüglich der Bestimmung und der Transporteignung unterscheiden, vorgeschlagen. Das Fraktionieren des Schrotes kann messbare Nutzen sowohl für die Futterindustrie als auch im Bereich der Biokraftstofflieferung bringen, in dem, neben den Rohstoff- und Transportkosten, die Lager- und Transporteigenschaften die Hauptrolle bei der Inanspruchnahme von Biomassenenergiequellen spielen.

Codewörter: Selbsterhitzung, Transport von Biomasse, Logistik für erneuerbare Energien, biogene Festbrennstoffe, Inanspruchnahme von Raps

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