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Compositional evaluation of hot-pressed rapeseed cake for the purpose of bioplastic production

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Abstract. Rapeseed is widely cultivated for biodiesel or food-grade oil production. As the oil production process generates huge amounts of wastes and by-products (e.g. oil press cake and meal) that have relatively high crude protein content, valorisation as input material for protein-based bioplastics has a lot of potential. There is a limited number of studies undertaken on using rapeseed cake directly (without prior protein extraction) for biomaterial production, but the initial results have been very promising. As rape and turnip rapeseeds are also some of the most harvested crops in Estonia, the rapeseed oil press cake as a by-product is also available from local food-grade rapeseed oil production. In this regard, we investigated locally available rapeseed oil press cake for chemical composition and explored suitability for bioplastic production. The results indicate suitability for direct biomaterial production, meaning properties for biomaterial formation could be further explored.

Key words: biomaterial, bioplastic, by-product, rapeseed cake, valorisation.

INTRODUCTION

According to European Bioplastics market development update for 2020, currently bioplastics represent only 1% of all the globally produced plastic materials (European Bioplastics, 2020). As concerns on plastic pollution are rising, demand for alternative materials for conventional petrochemical plastics is growing. Increasing the market share of bioplastics would support the circular economy concept by reducing also dependency on fossil resources (Geueke et al., 2018; Imre et al., 2019). Currently the industrial expenses to produce bioplastics are still higher than for petroleum-derived plastics (Raza et al., 2018). One option to reduce dependency on fossil resources and manufacturing costs of bioplastics would be to use wastes and by-products as input materials (Saharan & Sharma, 2012), and in this way the amount of wastes is reduced and new value-added products can be produced (Pagliaccia et al., 2019; Tsang et al., 2019).

Rapeseed is the second largest oilseed crop cultivated globally (Woźniak et al., 2019). In addition, rapeseed production in Baltic countries (Lithuania, Latvia, Estonia) is growing gradually (Carre & Pouzet, 2014) (Fig. 1), meaning there is a proportional growth in the generation of wastes and by-products (Delgado et al., 2018). Rapeseed is mainly used for producing food-grade oil or biodiesel due to high oil content in the seeds (Hu et al., 2017). The oil production process from rapeseed produces huge amounts of wastes and by-products like press cake and meal (Delgado et al., 2018). These wastes and by-products are comparably high in protein content (up to 50% on dry basis) (Aider & Barbara, 2011). However, their direct usage for food and feed applications has limitations due to presence of undesirable components (Li et al., 2017; Zhang et al., 2018; Paciorek-Sadowska et al., 2019). Nevertheless their usage as valuable material for bioplastic production holds a lot of potential (Wanasundra, 2011).

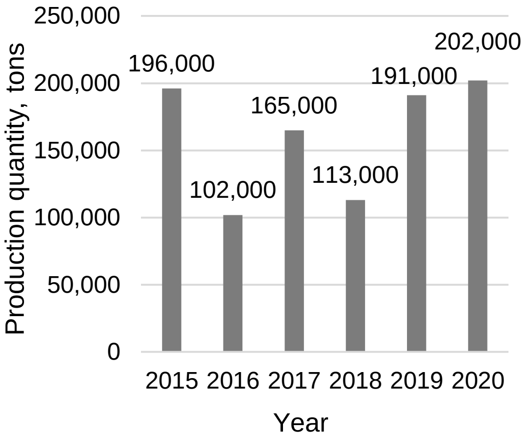

Figure 1. Rape and turnip rapeseed production quantities (tons) in Estonia, 2015–2020 (Source: Statistics Estonia, 2020).

Rapeseed meal mainly consists of cruciferin and napin that function as storage proteins, oleosin, which has structural properties (Aider & Barbara, 2011) and other trivial proteins such as trypsin inhibitors and thionins (Nioi et al., 2012). Cruciferin is a high molecular (300–310 kDa) 12S globulin that has gelling, emulsifying and binding properties in its native form (Aider & Barbara, 2011; Akbari & Wu, 2015). Napin is a low molecular (12.5–14.5 kDa) 2S albumin that has foaming properties (Schmidt et al., 2004; Li et al., 2017). The amino acid composition includes high content of leucine, aspartic acid and glutamic acid, but lower values of methionine, histidine and cysteine (Shi & Dumont, 2014). The protein constitution of rapeseed cake should be well balanced for protein-based film generation- napin functions as plasticizer that increases technological workability and cruciferin enables better mechanical properties (Li et al., 2017).

The chemical composition of rapeseed cake may be influenced by several factors such as processing parameters and technology (Leming & Lember, 2005). The objective of this study is to evaluate composition of hot-pressed rapeseed cake from Estonian food-grade oil producer and to evaluate its suitability for biomaterial production based on formerly conducted studies.

MATERIALS AND METHODS

To evaluate locally available hot-pressed rapeseed cakes potential as low cost raw material for bioplastic production, proximate analysis of chemical composition were performed and compared with data from related research papers and literature.

Hot-pressed rapeseed cake was obtained in 2020 from Scanola Baltic (Jõgeva vald, Estonia) which produces food-grade rapeseed oil.

The proximate analysis of rapeseed cake included analysis of crude protein, ash, fiber, fat content, moisture and volatile matter. Crude protein content (N×6.25) analysis were performed according to Kjeldahl method ASN 3402- *The determination of nitrogen according to Kjeldahl in rapeseed meal* with Foss Kjeltec 2300. Moisture and volatile matter content was determined by ISO 665:2020- (*Determination of moisture and volatile matter content in oilseeds)* and crude ash after ignition at 550 °C for 18 hours. Crude fat determination was done by Soxhlet extraction (Soxtec 2043) with petroleum ether. Crude fiber was determined according to ISO 6865:2000 *Animal feeding stuffs-determination of crude fibre content*. Nitrogen free extractives (NFE) were calculated as follows: NFE (%) = dry matter – (crude ash + crude protein + crude fat + crude fibre). Gross energy (GE) content was calculated by colorimetric coefficients of different nutrients as follows (Leming & Lember, 2005):

$$GE\ (MJ\ kg^{-1}) = (T_1 23.9 + T_2 39.8 + T_3 20.1 + T_4 17.5)/100,$$

where T_1 – crude protein (%); T_2 – crude fat (%); T_3 – crude fibre (%); T_4 – nitrogen free extractives (%).

The analysis were conducted in Food Technology Laboratory, Chair of Food Science and Technology of the Estonian University of Life Sciences and in Feed and Metabolism Research Laboratory (FMRL) of the Department of Animal Nutrition of Estonian University of Life Sciences. The study was carried out in Estonian University of Life Sciences under ERA- Chair for Food (By-) Products Valorisation Technologies.

RESULTS AND DISCUSSION

Results of rapeseed cakes proximate analysis are summarised in Table 1. This result is also compatible with quality characteristics of rapeseed cake set by the rapeseed oil producer- e.g. crude protein 34.0–40.0%; crude oil/fat < 11.8% and crude fiber < 16.0% (Scanola Baltic, 2020).

Value of nitrogen free extractives based on FMRL results is 29.3% and gross energy 20.3 MJ kg^{-1}.

In order to compare obtained results with formerly conducted studies, available research data of rapeseed cake or meal characterisation, composition and possible applications for usage in material generation are summarised in Table 2.

Table 1. Results of proximate analysis from the same rapeseed cake sample by Food Technology Laboratory (FTL) and Feed and Metabolism Research Laboratory (FMRL) (mean *n* = 3 ± s.d)

	FTL	FMRL
Crude protein, %	36.0 ± 0.1	36.9
Crude ash, %	6.40 ± 0.0	6.70
Crude fiber, %		13.7
Crude fat, %	8.70 ± 0.1	9.10
Dry matter, %	97.9 ± 0.0	95.7

The examples of characterised by-products include rapeseed cake/meal, cold-pressed rapeseed cake/meal, prepressed rapeseed cake/meal, milled pelletized rapeseed cake/meal, milled sieved pelletized rapeseed cake/meal and defatted rapeseed cake/meal.

Table 2. Overview of formerly conducted studies about rapeseed processing by-products (rapeseed meal/cake)- results of proximate analysis and usage outcomes in biomaterial production

	Dry matter	Moisture	Protein	Ash	Fiber	Fat/ Oil	Outcome- production of biomaterials	Source
Cold-pressed rapeseed meal	92.0%	-	40.6%	7.3%		2.8%	Rapeseed protein concentrates (RPC) were prepared by different extraction methods from cold-pressed rapeseed meal and prepressed rapeseed meal. All RPCs had good film-forming properties.	Fetzer et al., 2019
Prepressed rapeseed meal	94.2%	-	34.4%	7.2%		2.3%		
Rapeseed cake	93.13%	-	38%	-	12.6%	15.48%	Milled rapeseed cake was successfully used in preparation of rigid polyurethane-polyisocyanurate foams.	Paciorek-Sadowska et al., 2019
Rapeseed meal, milled pelletized rapeseed meal, milled sieved pelletized rapeseed meal	-	-	~41%.	-	-	-	Rapeseed meal in different forms was used with plasticizer (glycerol) in injection moulding process. Combination with polycaprolactone was also tested. The results indicated suitability for biomaterial production.	Delgado et al., 2018
Canola meal	-	9.8%	36.5%	7.3%	11.7%	4.1%	Protein-based films from canola protein isolates (CPI) were generated by wet cast and heat compression processing method. It was verified that protein cross-linking took place in CPI matrix.	Li et al., 2017
Defatted rapeseed cake	-	9.58%	45.68%	5.3%	11.05%	1.59%	Rapeseed protein isolates were used to form biomaterial in combination with polyvinyl alcohol and glycerol. The results indicated suitability for making disposable food contact articles.	Patel et al., 2016
Defatted canola meal	-	10.8%	40.6 %	6.6%	21.7%	2.1%	Protein isolates (cruciferin, napin) from defatted canola meal demonstrated good foaming and emulsifying properties.	Akbari & Wu, 2015

Acknowledging the fact that all these by-products may originate from very different production processes, including possible exposure to high temperature and different pre- and after-treatments (such as defatting), the values of reported composition have been compiled in Table 3. This illustrates that rapeseed cake available from Estonian oil production has similar compositional characteristics with those of previously published research data.

Table 3. Summarised data of rapeseed by-products compositional values from Table 2

	Min	Max	Mean
Protein, %	34.4	45.7	39.5
Ash, %	5.3	7.3	6.7
Fiber, %	11.1	21.7	14.3
Fat/oil, %	1.6	15.5	4.7
Dry matter, %	92.0	94.2	93.1
Moisture, %	9.6	10.8	10.1

When considering rapeseed cake suitability as input material for bioplastic or biomaterial generation, only one of the reviewed studies (Delgado et al., 2018) indicated the use of rapeseed cake directly (without prior protein extraction and isolation) in bioplastic production. The results from Delgado et al. (2018) indicated that relatively high protein content and low price, combined with good techno-functional properties can make rapeseed cake a considerable alternative for bioplastic production. But obviously there is a research gap on available data of using rapeseed cake directly for bioplastic generation and additional studies on that matter should be conducted. Previously conducted studies included protein isolation or concentration as pretreatment to material formation, resulting in relatively good film forming properties.Our results on the composition of rapeseed cake are comparable to previously conducted studies on rapeseed cakes suitability for material production, meaning direct usage in injection moulding or compression-moulding process could be considered. In addition, isolating proteins from rapeseed cake prior to material formation could be considered for protein based film generation.

CONCLUSIONS

Hot-pressed rapeseed cake from the Estonian oil production industry has comparable compositional qualities and this can be compared with previously reported works on rapeseed by-products. This indication holds high promise to be suitable for bioplastic production. As there is only one article available on the direct usage of rapeseed cake (without prior extraction of proteins) in biomaterial generation, more research activities should be directed to cover this research gap in Estonia.

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