FEED-A-GENE

Adapting the feed, the animal and the feeding techniques to improve the efficiency and sustainability of monogastric livestock production systems

Deliverable D1.1

New parameters for use of soybean and rapeseed products in feed production

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Public - PU	**X**
Confidential, only for members of the consortium (including Commission Services) - CO	
Classified, as referred to in Commission Decision 2001/844/EC - Cl	

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1. Summary

Objectives

The objective of this document is to provide a description of the production of novel feed protein products from rapeseeds or soybeans grown in Europe. This work was undertaken to investigate the potential of alternative European feedstuffs to increase their production in quantity and quality in Europe, thereby helping Europe to reduce its dependency on imported protein sources. The present deliverable is based in activities in WP1 task 1.1 but has strong links with the activities in task 1.3 to task 1.6.

Rationale:

Task 1.1 focuses on the processing of European grown rapeseeds and soybeans to obtain products with high protein content and/or suitable for the feed market. A process employing extrusion-pressing or flaking-pressing cooking was used to produce expeller soybean meals from European cultivated soybeans. The impact on the quality of the soybean product of the initial dehulling of beans was evaluated and the different steps in the process were followed.

Besides that, innovative and improved process stages of solvent extraction of rapeseed oil have been investigated. The classical process of rapeseed cake involves defatting with hexane, treatment with aqueous ethanol under vacuum to eliminate soluble carbohydrates, and drying with ethanol. New successive steps of oil extraction using hydro-ethanol / ethanol / hexane were investigated. The goals were to concentrate the protein content, limit the energy of desolvation to that of hexane, and ensure a good removal of anti-nutritional factors.

Lastly, an upgrading of conventional rapeseed meal was undertaken by a biological method. The goals were to increase the protein content of the meal and to control the contents for the anti-nutritional factors (i.e. glucosinolates).

Teams involved:

IFIP

TERRES INOVIA (previously named CETIOM)

HAMLET PROTEIN

DLO

Species and production systems considered: all animal species and countries in Europe

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2. Introduction

During months 1 to 36 of Feed-a-Gene project, a study determined the influence of different processes on the nutritional quality of expeller soybean meals. A 2 x 2 factorial design based on extrusion or cooking processes in combination with dehulling and pressing was used to produce four partly defatted soybean meals with low residual trypsin inhibitor activity. The effects of process factors (preparation, temperature) and variations of flow rate/speed and specific mechanical energy were monitored.

Previous authors have highlighted the effect of operating parameters (screw rotation speed, temperature, and back pressure) and raw material (seed species, variety, water content, and pre-treatment) on process performance (oil yield and press capacity). For a given bean or seed origin, the main factors influencing the process are pressure, temperature, and moisture content.

Industrial pressing of oilseeds is realized using continuous screw presses. The presses are fed with crude or pre-treated seeds. Types of pre-treatments (thermal pre-treatment, size reduction, mechanical sieving, etc.) differ for various seed species (Carr, 1997). Each type of seed pre-treatment provides its own advantages. Dehulling is used to separate the oil-rich almond from hulls containing limited amount of oil and to eliminate antinutritional factors negative to animal feeding. Crushing and flaking promote solvent extraction step by changing the cake permeability. Cooking provides several advantages: moisture conditioning of seeds, oil viscosity reduction, increasing plasticity of seed, breaking of cell walls, protein clotting by denaturation, sterilization and deactivation of thermosensitive enzymes, and destruction of thermolabile toxic components (Dunford, 2012; Laisney 1992).

During the same period, a laboratory study of the successive steps of oil extraction with hydro-ethanol / ethanol / hexane has also been initiated. The main goals of this work were to verify that the hydro-alcoholic solvent solubilizes in hexane in order to carry out a succession of ethanol-water then hexane extraction with aims to concentrate the protein in the meal (with the objective of protein content of at least 60%) while limiting the energy of desolvation to that of hexane. For this, the work will focus on the study of partitioning components (lipids, non-lipid dry matter, volatile components) between the cake and the miscella during successive washes and depending on the chosen solvent combination.

It is important that the heat treatment of rapeseed meal is not too powerful in order not to degrade protein solubility and lysine content. However, the disadvantage of such a mild process could be an insufficient removal of glucosinolates. This could be obtain by the use of a biological treatment of the meals. While the technology has been proven for soybean meal, such a novel process has to be developed to improve the value of rapeseed protein.

3. Results

3.1 Evaluation of the effects of dehulling and thermal treatments for production of expeller soybean meal

An experimental work was conducted at the OLEAD 'Oilseed–protein crops technology platform' (Pessac, France) on the production of expeller soybean meal (SBM) using different processes.

Origin of beans

The non-GMO soya (var. Ecudor, Euralis Semences, Lescar, France) was grown near Toulouse, France in accordance with industry specifications (CC Sojadoc vs 19) and yielded around 3000 kg /ha. It was harvested in September 2015. A batch (4200 kg) was bought by Cetiom and Ifip and received in two deliveries in November 2015 and January 2016 (N°585/SO/P15 and 585-2/SO/P15).

Characteristics are detailed in following Table 1 and Figure 1. The oil content had a regular value, whereas the protein content (44 %) was rather high compared to the mean result for the 2015 harvest (40.7%, Terres Inovia, 2015) or the Table values in the animal feed data base (39.6%; feedipedia.org). This high protein content was in relation with the high thousand-kernel-weight and the high yield resulting from good grain filling conditions at the end of the crop. Additionally, trypsin inhibitor value was only 25 units/mg.

Table 1 Chemical composition (% of DM) of European soybeans

	Source	Crude Fiber	Water	Oil	Proteins	KOH sol. Proteins	Solubility, %	Trypsin In TIU /mg.
Experimental batch	Analysis[1]	5.6	13.4	20.5	44.3	42.1	95.0	25
France 2015,	Survey[2] (n= 92)		13.2	21.4	40.7			
Feedipedia	Tables[3]	6.2 (n=3753)	11.3 (n=7315)	21.4 (n=3466)	39.6 (n=7125)			

1. Results were obtained from analysis by Terres Inovia Laboratory in Ardon (France) using NF V03-040 (Crude Fiber), NF EN ISO 665 (Water), NF V03-908 (Oil), NF EN ISO 5983-2 (Proteins), internal method adapted from ISO 14244 (KOH sol. Proteins), and by InVivo Labs in St-Nolff (France) using AOCS Ba 12-75 – SN (trypsin inhibitors). 2. Results from a survey by Terres Inovia on soybeans produced in 2015 and intended for the feed industry. http://www.terresunivia.fr/decouvrir-terres-univia/actualites/qualite-des-graines-soja-destination-de-l-alimentation-animale. 3. Composition and nutritive values for raw and processed whole soybeans of Feedipedia, an open access information system on animal feed resources. https://www.feedipedia.org/node/42 Last updated on July 4, 2017, 10:37

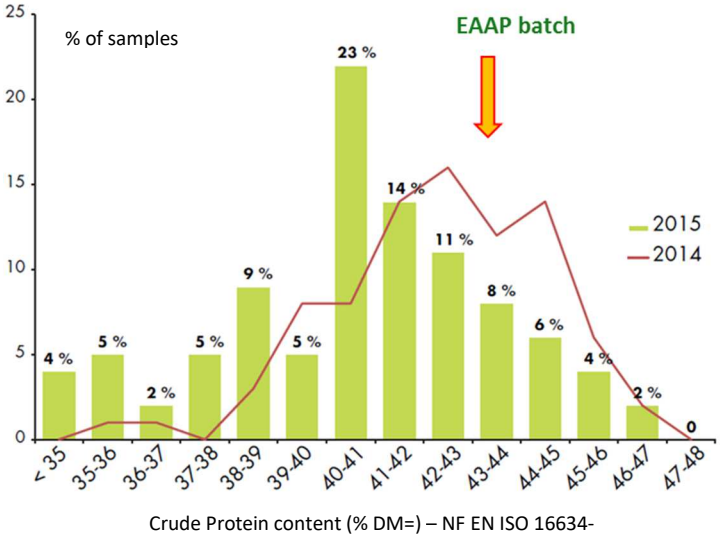

Figure 1 Distribution in protein content of samples of French soybeans for animal use harvested in 2014 (n=88) and 2015 (n=97).

Source : Enquête Soja à destination de l'alimentation animale – Récolte 2015 (Terres Inovia)
http://www.terresunivia.fr/decouvrir-terres-univia/actualites/qualite-des-graines-soja-destination-de-l-alimentation-animale

Methods for process

The schematic diagram of the processes is showed in Figure 2.

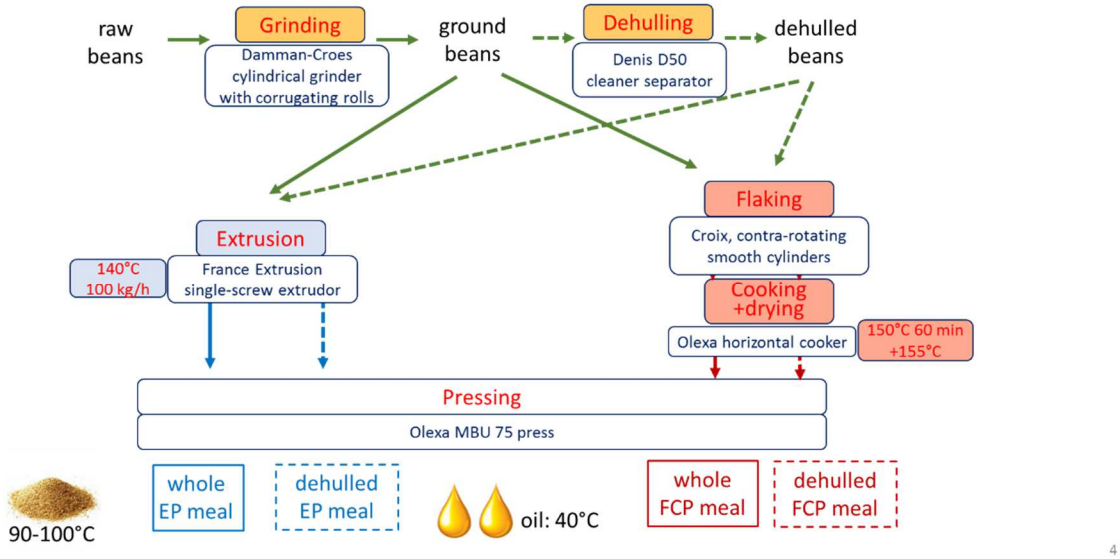

Figure 2 Schematic diagram of the soybean process.

Grinding/Dehulling

At first, soybeans (4.2 T) were ground in a cylindrical grinder with corrugating rolls (Damman-Croes, Roeselare, Belgium) with a setting of the nip between the rollers as for kernels. Around

55 % of the ground product (2.3 T) was then dehulled with a cleaner separator (D50, Ets Denis, Brou, France). Soybean almonds rich in oil were separated from hulls and shells. The quantity balance of the dehulling is detailed in Table 2.

Table 2 Material balance of the dehulling operation

Initial quantity, kg	Seed almonds, kg	Hulls, kg	Losses, kg
2300	1899	384	17

Flaking-Cooking (FCP)

Flaking was used for both products (dehulled or not) in order to increase the surface area. The gap of the contra-rotating smooth cylinders (Croix) were set to obtain flakes without almond residue. Then the flakes were cooked (horizontal cooker, Olexa, Arras, France) at 150°C during 60 minutes.

Extrusion (EP)

The two products (dehulled or not) were extruded using single-screw extrusion (FEX1 France extrusion) at 140°C at around 100 kg/h.

Press operation

All beans were then pressed using a single screw press (MBU 75, Olexa, arras, France) with a barrel diameter of 180 mm and a theoretical capacity of 400 kg/h for cold-pressed rapeseed. The half-compressing arrangement was chosen (least compressing arrangement with addition of two ring-cones in the exudation zone to slow the progression of the cake.

Nutritional composition analysis

Raw beans and SBM products were analyzed at COFRAC accredited laboratory of Terres Innovia (Ardon, France) for moisture (ISO 665 for beans and 771 for meals, respectively), crude protein (ISO 5983-2), crude fat (NF V03-908 for beans and ISO 22630 for meals), crude fibre (NF V03-040) and KOH protein solubility (NF ISO 14244). Trypsin inhibitor contents [1 TIU/mg = 1.9 trypsin inhibitor activity (TIA) mg/g] (TIU/mg) were analysed at a COFRAC accredited commercial laboratory (InVivo Labs, France) using the AOCS Ba 12-75 SN method.

Table 3 Chemical composition of the raw soybeans and of processed expeller soybean meals

	Dry Matter (%)	*Oil (%)*	*Oil % DM)*	*Protein (%)*	*Protein (% de-oiled DM)*	*Protein solubility KOH (%)*	*Crude Fiber (%)*	*Trypsin inhibitors (UTI/mg)*
Raw soybeans	86.6	17.8	20.5	38.4	55.7	95.0	4.8	25
EP-dehulled	93.9	4.8	5.2	52.3	58.8	75.9	2.9	3.5
EP-whole seeds	94.2	4.6	4.9	50.1	56.0	70.2	5.5	2.6
FCP-dehulled	92.3	5.9	6.4	50.5	58.4	88.8	3.2	7.6
FCP-whole seeds	91.3	7.8	8.6	46.6	55.8	82.0	5.1	3.6

As showed in Table 3, extrusion allowed a higher oil extraction than cooking (residual oil: 4.9 vs 8.6 g/100 g of dried matter (DM) in whole EP and FCP meals and 5.2 vs 6.4 g/100 g of DM in dehulled EP and FCP meals, respectively).

The dehulling step resulted in an increase of almost 3 g/100 g of the protein content (58.8 and 58.4 g/100 g for dehulled EP and FCP meals, respectively, and 56.0 and 55.8 g/100 g for whole EP and FCP meals, respectively, on a fat free DM basis).

The KOH protein solubility was increased by dehulling for EP (70 vs. 76%) and FCP processes (82 vs. 89%, for whole and dehulled meals, respectively). Trypsin inhibitor (TI) values were 2.6, 3.5, 3.6 and 7.6 TIU/mg for whole and dehulled EP and FCP meals, respectively. The lower dryer outlet temperature measured for the dehulled beans compared to whole beans (90 vs. 97°C) may explain the lower TI inactivation for the dehulled FCP meal *(See in Annex the Cooking table for Product 1: Dehulled FCP meal).*

Quality of protein

The protein relative digestibility of the products was determined by Wageningen University as the rate and maximum hydrolysis of peptide bonds using the effect of hydrolysis on the pH of the solution.

The degree of hydrolysis of the intact raw soybeans and the four oil extracted meals is presented in Figure 3. The curve characteristics and the initial pH of the solution (before pH was brought to pH 8.0) is provided in following two Tables with and without the raw soybeans included in the analysis.

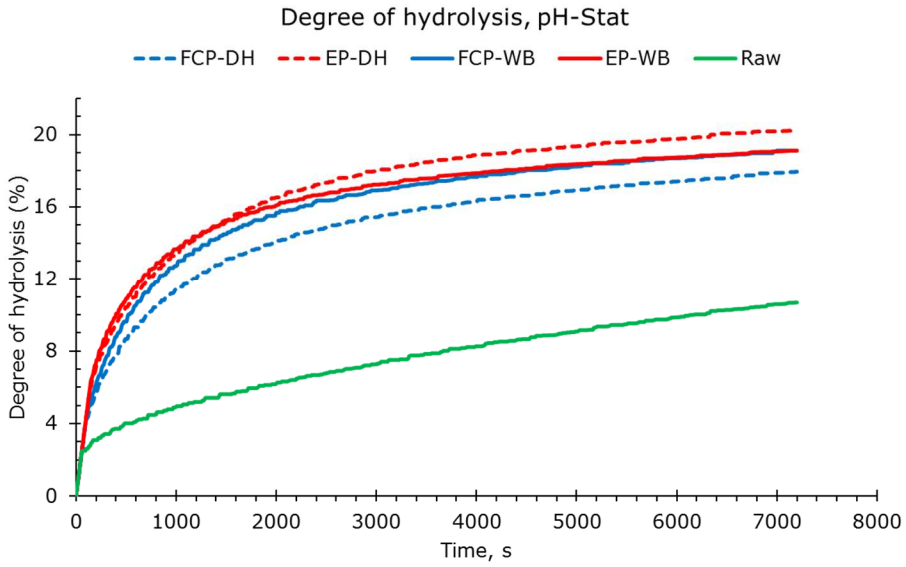

Figure 3 Rate of in vitro hydrolysis of raw soybean and extracted soybean meal extruded (E) or flaked (FC) or dehulled (D) or whole (W)

Table 4 Parameters describing the degree of hydrolysis of raw soybean and extracted soybean meals.

	Soybean	FCP-DH	EP-DH	FCP-WB	EP-WB	SEM	P treatment
Rate k ($\times 10^{-6}$)	46.1^{a}	80.0^{b}	82.0^{b}	87.1^{b}	115.9^{c}	0.290	<0.001
DH max.	12.38^{a}	19.10^{b}	21.52^{d}	20.29^{c}	19.90^{bc}	0.319	<0.001
Initial pH	5.99^{a}	6.84^{b}	7.00^{b}	6.97^{b}	7.06^{b}	0.093	<0.001

FCP-DH = flaking-cooking process of dehulled beans; EP-DH = expanding process of dehulled beans; FCP-WB = flaking-cooking process of whole beans; EP-DH = expanding process of whole beans

Table 5 Parameters describing the degree of hydrolysis of extracted soybean meals.

	FCP-DH	EP-DH	FCP-WB	EP-WB	SEM	Process	Dehulling	P x DH
Rate k ($\times 10^{-6}$)	80.0^{a}	82.0^{a}	87.1^{a}	115.9^{b}	0.316	0.001	<0.001	0.003
DH max.	19.10^{a}	21.52^{c}	20.29^{b}	19.90^{ab}	0.274	0.006	0.455	<0.001
Initial pH	6.84	7.00	6.97	7.06	0.069	0.114	0.198	0.605

FCP-DH = flaking-cooking process of dehulled beans; EP-DH = expanding process of dehulled beans; FCP-WB = flaking-cooking process of whole beans; EP-DH = expanding process of whole beans

The results in Figure 3 and Table 4 demonstrate a lower rate and maximum degree of hydrolysis of intact raw soybeans compared to all four oil extracted meals. This effect may be related by the much higher trypsin inhibitor activity in the raw soybeans (25 TIU/mg) compared to the extracted meals (2.6-7.6 TIU/mg).

The results in Figure 3 and Table 5 demonstrate an interaction between processing and dehulling on the rate and maximum degree of hydrolysis. The rate of hydrolysis (k) was higher for the meal from extrusion processing of whole beans compared to the other products and not different among the other three products. The maximum degree of hydrolysis was higher in meal from extrusion processing than from flaking cooking when soybeans were dehulled prior to processing, but not when whole soybeans were processed. Dehulling increased the maximum degree of hydrolysis in meal from extrusion processing, but decreased the degree of hydrolysis in meal from flaking cooking. It can be speculated that the latter was related to the higher trypsine inhibitor activity in FCP-DH (7.6 TIU/mg) compared to FCP-WB (3.6 TUI/mg), but it is not clear whether trypsine inhibitor activity plays a role at these low levels. On the other hand, dehulling may increase the maximum degree of hydrolysis if we assume that the protein in hulls is less digestible than protein in beans.

3.2 Experimental work on the processing of RSM

Olead and Terres Inovia have initiated a work on improving technological methods to extract oil from rape seeds and process rapeseed meals.

Conventional protein concentrates are made by two successive steps, the first one in hexane for oil, the second one in aqueous ethanol to extract the sugars while keeping the protein in the insoluble state. This protocol is likely to be less efficient with rapeseed than with soybean as rapeseed protein is more heat sensitive than soybean protein. The goal of the study was to

propose a new combination of polar (ethanol) and apolar (hexane) solvents in order to extract both fats and sugars of the dehulled rapeseed without intermediate desolventization.

The starting material was ground dehulled rapeseed cake with a oil content of 17%, which was extracted with either 79 % ethanol followed by 96% ethanol and finished by hexane (OP2), or with a simplified succession of 79 % ethanol and hexane (OP1; Figure 4). It was only with OP2 that it was possible to obtain the lowest oil content.

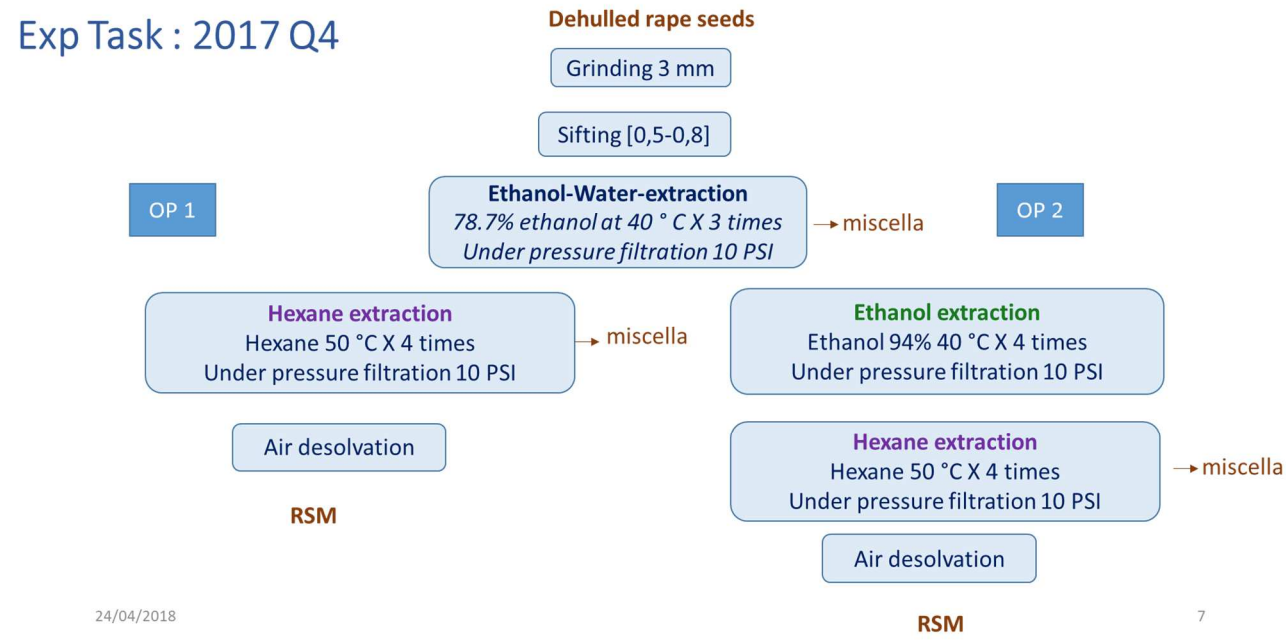

Figure 4 Desolvation processes tested for the rapeseed meal production

Table 6 Composition of RSM obtained in the Lab study *(na: non analyzed)*

	Product	DM (%)	Oil (% DM)	CP (% DM)	GLS (µmol/g MS)	Quantity (g)
Dehulled rapeseeds	31.OP1 Int	92.4	17.0	36.5	35.0	300 g/test
	31.OP1 Int bis	91.8	17.0	37.1	39.3	
RSM OP1	90.OP1	84.5	0.8	51.2	7.5	185
	90.OP1 bis	86.8	0.6	53.4	11.3	156
RSM OP2	90.OP2	95.1	0.3	53.5	na	175
	90.OP2 bis	88.6	0.1	55.8	17.3	202

DM, dry matter; CP, crude protein; GLS, glucosinolates.

The experiments was repeated twice and the data were analysed statistically (ANOVA, in Excel) with $p<0.05$. The composition results showed that both methods finally reached a similar oil yield ($p=0.656$) (Table 6). The final protein content of the RSM of 51-56% was lower than the target of 60% protein, partly because of a low initial protein content; 44% on de-oiled dry matter. Thus, the protein content was increased by 8-11 points of proteins in comparison to a rapeseed meal theoretically extracted by hexane. However, the final protein contents of both methods were not significantly different ($p=0.299$). The methods extracted 72-90% of the initial glucosinolate mass. However, the glucosinolate extraction can still be considered as unsufficient. Lastly, this step 1 of the work did not allow to experimentally evaluate the level of entrainment of ethanol by hexane.

3.3 Biological improvement of RSM

Ifip selected three rapeseed meals processed at the beginning of 2016 from European grown and non-GMO rape seeds by three big size oilseed mills of Saipol-April group.

These samples were analysed by the COFRAC accredited Terres Innovia Laboratory (Ardon, France). The methods and results are displayed in Table 7. Samples duplicates were sent to Hamlet Protein for laboratory scale experiments on upgrading the nutritional value of the different European rapeseed meal sources.

The Sète origin was chosen by Hamlet Protein for the further step of pilot scale production which is consistent with the high protein solubility and middle high glucosinolate content of this RSM, indicating that the anti-nutritional factors were not totally removed in this mill.

Table 7 Chemical composition of the RSM samples before selection (Winter 2016)

Origin	**Water**	**Oil**	**Proteins**	**Protein KOH solubility %**		**GSL**	**Oil**	**Proteins**	**GSL**
method	Etuvage	Soxlhet	Kjeldahl	Kjeldahl		HPLC	Soxlhet	Kjeldahl	HPLC
reference	ISO 771	ISO 22630	NF EN ISO 5983-2	Adapted from ISO 14244		NF ISO 10633-1	ISO 22630	NF EN ISO 5983-2	NF ISO 10633-1
	% on crude	%/DM	%/DM	%/DM	% Protéines totales	µmol/g MS	(% crude)	(% crude)	µmol/g on crude
Sète	11.1	3.1	36.8	21.7	58.9	16.1	2.8	32.7	14.3
Le Mériot	11.7	2.8	36.3	16.3	45.0	10.4	2.5	32.1	9.2
Grand-Couronne	10.6	2.0	37.3	15.1	40.6	4.6	1.8	33.3	4.1

Results were obtained from analysis by Terres Inovia Laboratory in Ardon (France)

A 3.3 ton batch of RSM processed by the Sète oil mill in October 2016 with European non GMO seeds was bought by Ifip. Samples were analysed by NIR (Solevia Laboratory, Villefranche-de-Rouergue, France) and chemical composition (InVivo Laboratory, Chateau-Thierry, France). Composition values of the October batch from the Sète Oil mill (Table 8) are in good agreement with the values of the January batch (Table 7) except for protein solubility. The GSL content was as expected.

Table 8 Chemical composition of the selected RSM (October 2016)

Lab	Water	Oil	Proteins	Ash	Crude Fiber	% KOH solubility of N	GSL	Total Lysine	NDF	ADF	ADL	Tanins	GMO
Invivo Labs	CE152/2000	Internal MGRA-H 15/02	NF EN ISO 16634	CE152/2000	Internal, CellF 13/02	Internal NSOUDE-H ; SOLN02CV01	Internal, glucenzy 01-06	CE152/2000	NF V18-122	NF V18-122	NF V18-122	SPM	PCR ISO 24276,
	12.7	3.0	33.9	6.4	12.1	38.1	13.7	17.9	26.0	18.7	8.2	0.33	< 0.9%
Solevial	IR		IR		IR								
	12.2		32.6		14.1								

SPM : spectrophotometry

A successful pilot scale upgrading of rapeseed meal was conducted by Hamlet Protein and the product used for a feeding trial at IRTA (Table 9). The protein content was increased by 4 absolute % points. For glucosinolates in the RSM prepared by Hamlet Protein a total content of 16.9 µmol per g DM (ie 15.9 on a crude basis) was found with HPLC method by Terres Inovia laboratory. The value initially determined in the unprocessed RSM was 13.7 ± 2.7 µmol g on crude basis by In Vivo Lab with an enzymatic method. Since two different laboratories and methods were involved, it cannot be concluded that the values are different or not.

Table 9 Chemical and nutritional composition of commercial RSM before and after biological treatment

	Dry Matter (%)	*Crude Fat (% crude)*	*Protein (% crude)*	*Protein (% DM)*	*Ash (% crude)*	*Crude Fiber (% crude)*	*GSL (µmol/ g crude)*
Basal RSM	87.8	1.8	34.1	38.8	6.4	12.0	13.7
Improved RSM	94.4	1.4	40.3	42.7	7.3		15.9

The basal RSM batch was sampled both by Ifip and by IRTA. Chemical composition values of the basal RSM are means of the analysis results obtained by InVivo Laboratory (Chateau-Thierry, France; see Table 8) and by IRTA Laboratory (Reus, Spain) excepted for crude fat (determined only by IRTA Laboratory) and GSL content (determined only by In Vivo Laboratory). The improved RSM batch was sampled both by Hamlet Protein and by IRTA. Chemical composition values of this improved RSM are means of the analysis results obtained by Hamlet Protein Laboratory (Horsens, Danmark) and by IRTA Laboratory (Reus, Spain) excepted for crude fat and ash contents (determined only by IRTA Laboratory). The GSL content of the improved RSM was determined by Terres Inovia (Ardon, France).

4. Conclusions

It can be concluded that all four processes base on either extrusion or cooking or dehulling or not are robusts and may produce good quality expeller soybean meals with 46-52 g/100 g crude protein, 4-7 g/100 g residual oil, reduced trypsin inhibitor content, resulting in high *in vitro* protein digestibility and expected amino acids digestibility (Quinsac et al, 2012a). In the present study, the difference in temperature during drying for one of the soybean batches can be considered as an occasional event that easily can be controlled and avoided. However, the event shows that the processing temperature of soy products is crucial for the protein quality and level of antinutritional factors (Webster, 2003; Quinsac et al, 2005, 2012b; Karr-Lilienthal et al, 2006). Our results further show that extruded-expelled SBM could be produced in medium-sized crushing plants from local and GMO-free soybean crops in the future. Such products could have interesting nutritional and economic values thus contributing to a further development of soybean production in Europe (Le Cadre et al, 2015; Quinsac et al, 2015; Recknagel, 2015).

The goals of the first experiment on improved rapeseed meal were not fully achieved, as the protein concentration was too low and the glucosinolates insufficiently extracted. Future lab experiments will test the effect of the last hexane extraction on the facility of desolvation and will enable new extractions trials to improve the glucosinolates removal by using aqueous solvent. Beside the experimental work, time will be dedicated to a model of prediction of the energy cost of aqueous ethanol extraction coupled with pure ethanol finishing and / or hexane hexane finishing and to the production of small batches for in vitro or in vivo evaluation

5. Appendix

Monitoring results of experimental production of expeller soybean meals

Product 1: Dehulled FCP meal (17-11-2016)

Cooking

Time h/mn	Cooker exit temperature (°C)	Steam flow (kg/h)	Cooker set temperature (°C)	Dryer set temperature (°C)	Dryer exit temperature (°C)
9 :00	82.0	10.0	155.0	155.0	91.0
10 :05	87.0	9.5	145.0	150.0	89.0
11 :35	89.0	9.5	145.0	150.0	91.0

Press operation

Time h/mn	Oil flow (kg/h)	Oil temperature (°C)	Cake flow (kg/h)	Cake temperature (°C)	Rotation speed (rpm)	Motor power (Kw)	Barrel temperature (°C)
8 :55	29.5	35.0	185.0	99.0	15	9.5	-
10 :00	24.0	42.0	184.0	93.0	15	6.3	-
11 :30	23.0	44.0	182.0	103.0	13.5	6.0	-

Product 2 : Whole FCP meal (17-11-2016)

Cooking

Time h/mn	Cooker exit temperature (°C)	Steam flow (kg/h)	Cooker set temperature (°C)	Dryer set temperature (°C)	Dryer exit temperature (°C)
13 :20	90.5	9.5	148.0	155.0	96.1
14 :20	89.8	9.5	148.0	155.0	97.2
16 :10	90.2	9.5	148.0	155.0	97.4
17 :10	92.6	9.5	148.0	155.0	97.6

Press operation

Time h/mn	Oil flow (kg/h)	Oil temperature (°C)	Cake flow (kg/h)	Cake temperature (°C)	Rotation speed (rpm)	Motor power (Kw)	Barrel temperature (°C)
13 :35	20.0	40.1	163.0	86.3	13.5	5.3	98.6
14 :20	19.5	39.8	150.5	86.1	13.5	5.3	105.2
16 :10	18.5	39.9	156.0	88.1	13.5	5.3	103.2
17 :10	18.0	39.7	132.0	89.0	13.5	5.3	107.3

Product 3 : Whole EP meal (18-11-2016)

Extrusion

Time h/mn	Flow rate (kg/h)	Flow rate index	Rotation speed (rpm)	Motor power (Kw)	Cake temperature (°C)	Last zone temperature (°C)
12 :10	96.8	1275	9	19.7	150.8	138.0
13 :40	-	1305	9	19.3	149.7	137.0
15 :00	-	1328	9	20.5	150.1	138.0
16 :30	-	1328	9	20.8	151.4	139.0

17 :00	-	1328	9	19.5	-	141.0
18 :15	-	1328	9	18.4	-	139.0
19 :00	-	1328	9	18.6	-	137.0

Press operation

Time h/mn	Oil flow (kg/h)	Oil temperature (°C)	Cake flow (kg/h)	Cake temperature (°C)	Rotation speed (rpm)	Motor power (Kw)	Barrel temperature (°C)
12 :20	13.0	34.3	73.0	100.1	15	7.2	110.9
15 :30	14.0	34.8	75.5	99.8	15	5.3	114.4
17 :20	13.5	33.5	78.0	103.8	15	5.1	114.0

Product 4 : Dehulled EP meal (21-11-2016)

Extrusion

Time h/mn	Flow rate (kg/h)	Flow rate index	Rotation speed (rpm)	Motor power (Kw)	Cake temperature (°C)	Last zone temperature (°C)
10 :20	115	1375	9	25.7	152.8	141.0
11 :10	-	1375	9	25.7	152.6	140.0
12 :00	-	1375	9	25.0	-	141.0
13 :00	-	1375	9	24.8	-	142.0
14 :00	-	1375	9	23.7	-	142.0
15 :00	-	1375	9	-	-	141.0
16 :45	-	1375	9	-	-	139.0
17 :50	-	1375	9	-	-	141.0

Press operation

Time h/mn	Oil flow (kg/h)	Oil temperature (°C)	Cake flow (kg/h)	Cake temperature (°C)	Rotation speed (rpm)	Motor power (Kw)	Barrel temperature (°C)
10 :15	16.5	31.6	98.5	77.4	15	5.0	77.9
11 :20	17.0	37.3	96.5	85.6	15	5.0	98.5
12 :20	22.5	41.0	96.0	85.0	15	5.0	105.6
14 :00	18.5	42.0	101.0	86.0	15	4.0	109.0

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