Effects of seeds drying prior the rapeseed crushing process. Potential benefits for energy consumption, meal quality and solvent emission

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1 Introduction

An important part of crushing activity in France is now involved in biodiesel production and consequently, some new constraints have been addressed to this industry. In particular, energy consumption by the process should be reduced to improve the energy balance of biodiesel production, compared to fossil fuel. Although the part of crushing activity is relatively weak (12%) (Price Waterhouse Coopers, 2007) in the global energy cost, research has to be conducted to optimize the current process.

By examining the various sources of energy losses, the heat of oil and meal exiting the production line was considered as difficult to valorize because of its low temperature, but also possible to be recovered through heat exchangers and used to preheat or pre-dry the seed prior to crushing. Drying seeds in crushing process (during cooking) allowed a more efficient work of expeller. Lower moisture content in seeds or flakes, decreased plasticity of the press cake that led to higher levels of compression and oil recovery (Singh *et al.*, 2002). Moreover, previous studies showed that a low content of residual oil in press cake was in favour of an efficient desolventisation of meal (Laisney, 1984). As seed drying could be beneficial for the two major energy-intense steps: cooking and desolventisation, which represented 2/3 of the global energy of crushing, we intended to study the effects of rapeseed seed drying prior flaking and cooking and to determine the effects on the performance of pressing, solvent extraction, desolventisation and quality of oil and meal.

2 Material and methods

The trial was carried out in the pilot crushing plant CREOL (Pessac-France) with continuous flow equipment at 150-400 kg/h.

Reference process :

- flaker (Damann Croes) had two smooth rolls of 500 mm in diameter and width.

- cooker (La Mecanique Moderne, France) composed of two superposed horizontal cylinders of 900 mm in diameter and 2000 mm in length heated by four resistances of 4 kW, the heat being transported by a thermal fluid circulating in a jacket. Inside the cooker, the flakes were mixed and moved by an helical ribbon. The flakes were dried in the bottom part of the cooker which was connected to a centrifuge ventilator

- press MBU75 (La Mecanique Moderne, France). The cake capacity was 360 kg/h and approximately 500 kg/h of flakes.

- solvent extraction was carried out on a continuous belt extractor (Desmet Ballestra, Belgium) fitted with a belt of 0.4 m in width, 4 m in length bearing a layer of 0.4 m of material to be extracted. The counter flow extraction was carried out by 6 loops of miscella recirculation. The miscella temperature was maintained in the range 50 and 55°C to maximize the deoiling.

- desolventizer-toaster (DT) Schumacher type (Desmet Ballestra, Belgium) using heat and counter-flow steam injection to remove hexane from the marc. The pressure of indirect steam can be adjusted from 0.1 to 1 MPa. The temperature of pre-desolventised meal at the top stage was around 70°C and the steam injected through the bottom tray condensed on the meal increasing its water content up to

25 %. In the lower stages, the meal dried while its temperature increased up to 105°C. At the bottom of desolventiser, a screw conveyor with variable speed carried the meal outwards where it was cooled down by air ventilation.

Preparation of experimental press cakes

Three press cakes batches were prepared according to the following processes (table 1), in order to obtain different moisture and oil contents.

- process A (pre-dried): by pre-drying the seeds, moderate cooking and hard pressing

- process B (not pre-dried control): by flaking, cooking, hard pressing to produce standard press cake used as control.

- process C (not pre-dried control): by industrial type process: flaking, cooking, moderate pressing to produce “prepress” type cake with a higher oil content (> 15%)

Table 1: Processes conditions and characteristics of the resulting press cakes

	Process A	Process B	Process C
Pre drying of seeds	Yes	No (control)	No (control)
Input flow press (kg/h)	400	408	550
Cooker ouput temperature (°C)	78,2	91,5	81,0
Press temperature (°C)	93,7	97,6	67,7
Moisture of material at press input (%)	2.8	3,7	6,55
Presse speed rotation (rpm)	14,0	19,0	15,8
Current (A)	24,8	16,8	15,0
Power (kW)	9,9	9,1	6,7
Cake water content (%)	4,2	5,8	7,8
Cake oil content (% dm)	9,2	10,2	18,0
Cake unextractible oil (%dm)	1,1	1,9	2,4
Cake oil content (%)	8,8	9,7	16,6

Extraction and desolventisation experiments

The three press cake batches were processed by continuous extraction with hexane at two flow rates (130 and 180 kg/h) and desolventised with steam injection at 4 and 10 kg/h and with a residence time of 60 and 80 min. A design experiment combining the different factors (drying, steam injection, residence time and flow rate) was applied with 12 runs to study the effects on oil and hexane content in meal and hexane content in marc.

3 Results and discussion

Preparation of experimental press cakes

Dried seeds could not be transformed like non-dried seeds. The flakes were too dry at the cooker output and the mechanical properties of press cake were non convenient for an efficient solvent extraction.

Several trials of process A were carried out to produce press cake with similar mechanical properties than standard press cake from process B. Convenient results were finally obtained by discarding the flaking operation and shortening the cooking time to 30 min. As the press cake from process A and B had low oil content, process C was applied to obtain press cake with higher oil content similar to industrial press cake. Press cakes from processes B and C were obtained without pre-drying and were considered as control to evaluate the press cake from process A.

Extraction

Residual oil in meal from C press cake was significantly higher and variable than for meals from A and B press cakes, suggesting that some problem have occurred during the solvent percolation (table 2). Residual oil and hexane contents could be related to press cake oil content.

The press cake C had also worth unextractable oil high enough (2.4% dm, Table 1) probably due to the presence of whole seeds not flaked. Despite the lack of flaking for its preparation, the press cake A did not contain whole grains because they were crushed during the pressing while batch C which was flaked presented high unextractable oil. The press was able to reach higher pressure with dried seeds and this pressure enhanced oil extractability. For the press cakes A and B, average oil content was lower in the case of dry seeds (1.7% vs. 2.6% respectively). This result was consistent with the values of unextractable oil (1.1% vs 1.9% respectively) measured on press cakes (table 1). The increased throughput of the extractor led logically to the increased oil content meal (2.2% vs. 2.0% respectively).

Table 2: Experimental design, factors, conditions and characteristics of resulting meal

Run	1	2	3	4	5	6	7	8	9	10	11	12
Seed pre-drying	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
Press cake preparation	B	B	B	B	A	A	A	A	C	C	C	C
Oil content (% dm)	10,2	10,2	10,2	10,2	9,2	9,2	9,2	9,2	18,0	18,0	18,0	18,0
Extraction - Desolventization												
Flow rate extractor (kg/h)	-	-	+	+	-	-	+	+	-	-	+	+
Steam flow rate (kg/h)	-	+	-	+	-	+	-	+	-	+	-	+
Residence time DT (h) [1]	-	+	+	-	-	+	+	-	-	+	+	++ [2]
Tray 6 temperature (°C) [1]	72	103	93	88	73	93	78	93	85	110	102	109
Tray 5 temperature (°C) [1]	-	-	-	-	99	102	96	87	96	98	73	106
Vent temperature (°C) [1]	66	84	65	79	54	67	56	59	49	54	52	55
Meal characteristics												
Hexane content of marc (%)	13,9	15,5	14,1	15,2	14,3	16,3	15,0	14,6	26,8	26,4	26,5	26,4
Oil content of meal (% dm)	2,5	2,5	2,8	2,5	1,4	1,7	1,7	2,0	7,2	5,0	5,8	5,9
Hexane content of meal (ppm)	96	74	51	48	128	228	178	28	17000	1710	7900	416
Protein solubility in soda (%)	60	51	54	51	81	78	82	75	70	58	68	47

1: in the desolventiser – toaster 2: residence time : 100 min.,

Desolventisation

Meal residual hexane content was in average, lower for press cakes B than for press cakes A (67 ppm vs. 144 ppm respectively). This result could be in contradiction with data from literature indicating that drying improved desolventisation, but these very low levels (<250 ppm) especially indicated that both treatments A and B were adapted for an effective subsequent desolventisation. Residual hexane levels in meal from press cake C were very high (7900 to 17 000 ppm) with a residence time of 60 and 80 min but dramatically decreased to 400 ppm at 100 min, despite high levels of oil residual meal (5,9%) and hexane in marc (26,4%).Protein solubility (measured in soda) of meal from press cake A was significantly higher (75-82%) than for the two other meals (51-60% for meal B and 47-70% for meal C).

Table 3 indicates the main effects determined with the only press cakes A and B by not taking into account the high effect of press cake oil content. The effect on oil content of the meal was mainly observed with drying. The effect on hexane residues in meal of the extractor flow rate was noticeable (-27) and due to the more or less high impregnation of press cake by the solvent due to the contact time.

Table 3: Contrasts calculated from the main effects for press cakes A and B (runs 1 to 8)

Effects	Average	Drying (1)	Extractor Flow rate (2)	DT Steam injection (3)	Residence time in DT (4)	Interactions
Hexane content of marc (%)	14,9	0,2	-0,13			
Oil content of meal (% dm)	2,14	-0,44	0,11			
Hexane content of meal (ppm)	104	37	-27	-9	-34	13-24
Protein solubility in soda (%)	66,3	12,6	-1,0	-2,7	-1,2	No

The effect of the residence time in the DT was important (-34) because of the kinetics of hexane desorption. The variation of steam injection showed no significant effect but an interaction was possible with extractor flow rate. The major effect was noted with the drying (+37) and confirmed the interest of this treatment.

The effect on protein solubility was observed with drying (+12,6) and confirmed that this pretreatment made easier the extraction and the desolventisation and avoided the use of drastic hydrothermal treatment in DT.

4 Conclusion

The trials showed that the seeds pre-drying allowed a performing deoiling and produced an expeller cake with low oil content (9.2 %) which led to reduce the impregnation of the cake by hexane and to facilitate the desolventisation step. Similar results were obtained with batch B in which the oil content is also low (10.2%). The protein solubility was preserved in batch A by the drying step since the heat treatments for cooking the seeds and desolventising the meal were reduced. These results indicated that pre-drying had beneficial effects on the quality of expeller cake which may lead to save energy by reducing amount of solvent required for extraction and to improve the meal protein quality. The hexane amount to be eliminated by the desolventizer could be strongly reduced and the level of hexane residue in meal, lowered.

The pre-drying step carried out in this experiment was somewhat excessive by comparison to the real possibility allowed by use of heat recovered from the processing but it emphasizes the importance of water for the expelling step and open new opportunities to take advantage of cheap heat in different places from oil-mill, using for example warm and dry air during summer to lower the water content of seeds.

Further experiment is needed to confirm these results and obtain data for comparing the energy balance of the new and the standard process. As very interesting results were observed on meal and protein quality, attention should be focused on the effects of drying treatment to the quality of oil and meal.

Key-words: seed drying, rapeseed, energy saving, protein solubility, solvent emission, crushing.

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