Impact of texturing/cooling by Instant controlled pressure drop DIC on pressing and/or solvent extraction of vegetal oil

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Abstract— *Instant controlled pressure drop process (DIC) was used as a texturing pretreatment in order to recover the highest part of oil content of various oleaginous materials such as jatrophacurcas, rapeseeds, camelina seeds and date seeds at 5% to 6% (dry basis) water content. Pressing and n-hexane 95% solvent extraction of oil from both DIC-textured and non-treated raw material RM seeds was achieved using separately ASE (Accelerated Solvent Extraction at high pressure and temperature,and short time) for quantifying the oil content, and conventional industrial solvent extraction of 2-hour Dynamic Maceration (DM) extraction at 68 °Cto establish extraction kinetics and practical yields. Whatever the extraction process and the oilseed species were, optimized DIC treatment allowed increasing oil yields and extraction kinetics whilst perfectly preserving oil quality. It was possible to perform comparative studies and to optimize DIC treatment based on oil extraction yields. DIC treatment performed at 0.63 MPa between 45 and 105 s depending on oleaginous varieties allowed getting much higher oil yields: 96.4% instead of 81%, 92.6% instead of 76%, 93.4%, instead of 86.3%, and 79% instead of 63% of oil contents from rapeseeds, camelina seeds, Jatropha and date seeds, respectively. Besides, in terms of fatty acid composition, instant cooling via DICenabled the preservation of the oil lipid profile.*

Keywords— Instant controlled pressures drop (DIC), Solvent extraction, Oil pressing, oil seeds, solvent extraction, Fatty acids.

I. INTRODUCTION

Rapeseed is one of the most important oil seeds, which contains an oil quantity between 40 and 55%% wt% wt. The composition is as follows: triglycerides 97-99%% wt% wt, fatty acids 0.5–2%% wt% wt and minor lipids 0.5–1%% wt% wt[1]. Rapeseed contains oil (fatty acids), proteins, water, cellulose and mineral elements. Rapeseed oil mainly contains unsaturated fatty acid. The main fatty acid composition of rapeseed oil is palmitic acid C16:0 (3.49%), stearic acid C18:0 (0.85%), oleic acid C18:1 (64.4%) and linoleic acid C18:2 (22.3%), linolenic acid C18:3 (8.23%) and other fatty acids (3%) [2].The production of rapeseed oil has been highly developed over many years for commercial use. Conventional processes employ both mechanical and/or solvent extraction methods. Indeed the most popular method is seed pressing followed by meal solvent extraction.

The ever-growing demand of vegetable oils has resulted in intensive work within the food industry, the oleo-chemistry industry, and regarding environmental concerns. Oils are the highest energy source between the three basic food compounds, carbohydrates, proteins, and fats. They also are good carriers of oil soluble vitamins and many fatty acids essential for health and that are not produced by the human body [3].

To find different lipid resources of vegetable oils, efforts have been focused on producing oil from annual plants, grown in relatively temperate climates and triggered from seeds. Oleaginous oil production is of great interest in terms of quality, titer, production rate and yield.

The world production of oilseeds is steadily increasing since 1970. In terms of the most prominent oils there was a production increase of 12% per year between 1979 and 2007, representing about 178 Mt/year of oil in 2015. This growth of oil production required an increase of seed harvested. Hence the production of oilseeds followed a meaningful progression

from 240 Mt in 1979 to 488 Mt in 1999 (+203 %), reaching 672 Mt in 2007, and about 530 Mt/year during the period of 2012/2015 [4].

Despite the vast range of vegetable oil sources, world consumption is dominated by palm, soybean, sunflower and rapeseed, oils with 38.1, 35.7, 18.2, and 17.8 million tons consumed per year, respectively [5].

The increase of seed cultivation being slightly lower than the increase in oil production illustrates an improvement of oil extraction processes. However, various methods for recovering seed oil keep including mechanical pressing and solvent extraction processes. These last ways use organic solvents such as hexane. Compared to hexane extraction, pressing has a lower efficiency and can recover only between 70 to 80% depending on the seed species. However, despite numerous thermal and mechanical pre-treatment operations such as cooking and flacking, conventional solvent extraction is highly time consuming and leads to yields not exceeding 95%.

The natural structure of oleaginous and the specific properties of cell walls are responsible of such low technological behavior regarding both pressing and hexane extraction processes. It is noted that cooking at about 80-100 ºC for 20-40 minutes implies an increase of yields and/or kinetics generated by thermal deterioration of cells.. However, because of the temperature level and heating time, such an operation similarly triggers oil degradation. Some mechanical treatments such as flacking and/or grinding recovery processes can also improve the technological aptitudes of oilseeds. Several cell wall degrading enzymes during aqueous extraction were studied at laboratory scale at ambient temperature..They manage to obtain a maximum yield of 86% of total oil content of the seed. Nevertheless, combinations of proteases with hemicellulases and/or cellulases did not further increase the extraction yield[6]. Thus, the enzyme-supported aqueous extraction offers a nontoxic alternative to common oil extraction methods with reasonable yields. Energy needed to remove water from residual meals is too high and since enzymatic reactions are time consuming, this operation of enzyme-supported aqueous extraction remains confined to laboratory scale.

At present, the industrial processes used for the extraction of seed oils typically involve steps of coking, flacking, grinding, solvent extraction (preferably hexane), desolventation of both oil and residual meal. In numerous industries, the combination of initial pressing step together with hexane solvent extraction of residual meal leads to the highest conventional yields reaching about 95%. Thus, industrial oil extraction from oleaginous seeds is commonly realized through mechanical pressing, which gives good-quality oils containing anthocyanins. The residual meal oil after press is usually extracted afterwards by solvent extraction; usually using hexane or supercritical fluid, with conventional Dynamic Maceration DM. It is worth noting that the other solvent extraction process of Accelerated Solvent Extraction ASE is usually only performed at laboratory scale in order to thoroughly determine the oil content of the concerned seeds.

Mechanical and thermal pre-treatments preceding these operations contribute to enhance their performances and can be identified as intensification ways in terms of process performances. Nevertheless, the oil quality is not preserved. Hence, consumer requirements usually imply the use of oil extraction by cold press, although its oil extraction yield is low, and its nutritional content is lower than what obtained with solvent extraction.

In the present study, to overcome these issues and in order to increase oil extraction yield of both cold pressing and solvent extraction while preserving the oil quality, we sought new texturing pretreatment way. We hence based our work on the swelling, which is a thermo-mechanical operation issued from the well-known process of Instant Controlled Pressure Drop DIC (Détente Instantanée Contrôlée) [7, 8]. It is performed by establishing saturated steam pressure up to 1 MPa for some dozens of seconds, and instantaneously dropping both pressure and temperature towards, a vacuum of 5 kPa and 30 ºC, respectively.

In these treatment conditions, four different oleaginous seeds were investigated; rapeseeds and camelina seeds, which interest is due to their high oil content with healthy properties, and *Jatropha Curcas* and date seeds, which were studied in order to generalize the main extraction ways and their intensification.

As a specific well-controlled thermo-mechanical treatment DIC technology has been established [9]defined, patented and developed by Allaf et al. (1993) [10]. This technique has been applied successfully for industrial drying intensification, texturing and decontamination of various biological products [11-14]. DIC was successfully applied for extraction of volatile compounds such as essential oils [15, 16]. It has been also used effectively for improving the extraction of bioactive compounds kinetics through the texturing impact [17].

II. MATERIAL AND METHODS

2.1 Raw materials

2.1.1 Rapeseeds

Rapeseed is a plant with large potentials and enormous economic applications that belong to the Brassicaceae or mustard family. It is one of the most important oilseeds which contain the oil quantity between 40 and 55%% wt% wt. The composition is as follows: triglycerides 97-99% wt% wt, fatty acids 0.5–2% wt% wt and minor lipids 0.5–1% wt% wt[1]. The production of oil from the rapeseeds has been highly developed. The total production of rapeseed plant all around the world was 46.2 Mt in 2005 [18]. Taking the 5th place among oilseed crop, the production of rapeseed oil in the world was 17.9 Mt in 2005 [19]. Its oil is classified as one of the healthiest vegetable oils because of its fatty acid composition: triglycerides 97-99% wt, fatty acids 0.5–2% wt and minor lipids 0.5–1% wt[1]. The main characteristics of this oil are its low level of saturated fatty acids (5–10%), high amounts of monounsaturated fatty acids (44–75%), linoleic acid (18–22%) and alpha-linolenic acid (9–13%). Therefore, the optimal ratio of omega-6 (linoleic acid) to omega-3 (linolenic acid) fatty acids (2:1) for human health natively exists in rapeseed oil [20].

2.1.2 Camelina Sativa (L.)

Camelina Sativa (L.) is an ancient oilseed crop that belongs to the Cruciferae family (Brassicaceae, Mustard) and it is considered to be native to northern Europe, the Mediterranean region, and Central Asia [21]. The revival of interest in Camelina seed is due to the high oil content together, which is about 400 g oil/kg dry matter basis (db), with healthy properties, [22, 23]. In accordance with the high amount of oil content and the healthy quality, Camelina seed oil is mostly extracted by mechanical pressing. Solvent extraction, possibly combined with initial pressing is done in the case of some studies. Most often this combination is adopted for economic reasons because of the significant amount of residual oil in the pressing oil cake/meal [24].

The main compounds of Camelina seed oil were reported in the literature. It shows highly unsaturated fatty acid up to 90%, depending on its origin. The main relative compounds of Camelina seed oil are oleic (C18:1n−9; 12–20%), linoleic (C18:2n−6; 14–24%), linolenic acid (C18:3n−3; 25–42%)

2.1.3 Jatropha Curcas

Jatropha is a genus of over 170 plants from the Euphorbiaceae family, Jatropha curcasoil is non-edible, native to the Central America, South-east Asia, India and Africa, in the tropical and commonly found and utilized across most of the tropical and subtropical regions of the world. Among the different species of Jatropha, Jatropha curcas has a wide range of uses and promises various significant benefits to human and industry. Extracts from this species have been shown to have anti-tumor activity, the seeds can be used in treatment of constipation and the sap was found effective in accelerating wound healing procedure[25]. Moreover, this plant can be used as an ornamental plant, raw material for dye, potential feed stock, pesticide, soil enrichment manure and more importantly as an alternative for biodiesel production [25]. Jatropha curcas a multipurpose plant, contains high amount of oil in its seeds, the seed yield is up to 5 tons/ha [26]. It has a yield per hectare of over four times as much as soybean and ten times as much as corn.

Jatropha seeds contain 37% oil which can be easily expressed for processing [27].

The proximate analysis of Jatropha seeds revealed the presence of water , crude fat and crude protein atabout 6%, 47% and 25%, respectively[27]. Jatropha seed oil has about 72% unsaturated fatty acids dominated by oleic acid C18:1 (34.3 – 45.8%) followed by lenoleic acid C18:2(29.0 – 44.2%), palmitic acid C16:0 (14.1 – 15.3%), and stearic acid C18:0 (3.7 – 9.8%).

Jatropha curcas seeds were purchased from the farmers in the South of Vietnam, while rapeseeds and Camelina Sativa seeds were boughtfromPoitiers and Sanctum méditérranée (France). Powder of date seeds was provided from Tunisia. Water content of all these products was about 6% wet basis (wb). All of them were stored at room temperature at laboratory before treated by DIC and extraction. The seeds were selected after cleaning and homogenization in terms of water content. Clean seeds were stored at room temperature before DIC treatment and pressing and/or solvent extraction processing. After DIC treatment, the samples were dried at room temperature until the initial moisture content was obtained. All of the DIC treated and untreated samples were ground before extraction with average particle size of 0.4 mm measured by a sieve machine (FRITSCH) with the amplitude 1.5 mm and 10 min of sieving time. The hexane used for extraction was purchased from

Carlo Erba (Val de Reuil, France). 1 ton of each sample was prepared for pressing, and solvent extraction by Dynamic Maceration DM was achieved on the meals.

2.2 Measurement of moisture content

Moisture content of ground seed was determined by using oven dry method. A 2-3 g of each sample was placed in a dish and was dried for 24 h at 105 °C with triplicates. An infrared moisture analyzer was also used (Mettler Toledo LP-16 Infrared Dryer/Moisture Analyzer with Mettler Toledo PE360 Balance - Bishop International Akron, OH – USA). Both obtained results were fairly consistent (± 0.5% wb). The initial water content of the ground seeds before extraction was 6%db.

2.3 DIC process

Since DIC treatment is a high temperature short time heating (HTST) (up to 160 °C, during some dozens of seconds) followed by an instant pressure drop towards a vacuum (about 5 kPa in 0.04-0.1 s), itcauses an autovaporization and an instant cooling of the product. The pressure drop induces a whole swelling and higher porosity of the product with a possible controlled destruction of cell walls. The thermodynamics of instantaneity can greatly contribute to a phenomenological model of phase separation.

2.3.1 Industrial DIC processing reactor

The Industrial DIC processing reactoris composed of three main elements as Figure 1:

- The processing reactor, where we loadthe productto be treated,
- The vacuum system, which consists of a vacuum tank (5) with a volume 100 times greater than the processing reactor, an adequate vacuum pump (6). The initial vacuum level is maintained at about 5 kPa in all the operation.
- A pneumatic instantaneous valve (4) that assures an instant connection between the vacuum tank and the processing reactor. This valve can be opened in the very short time (less than 0.2 s) in order to ensure the abrupt pressure drop ($\Delta P/\Delta t > 0.5$ MPa/s) within the reactor.

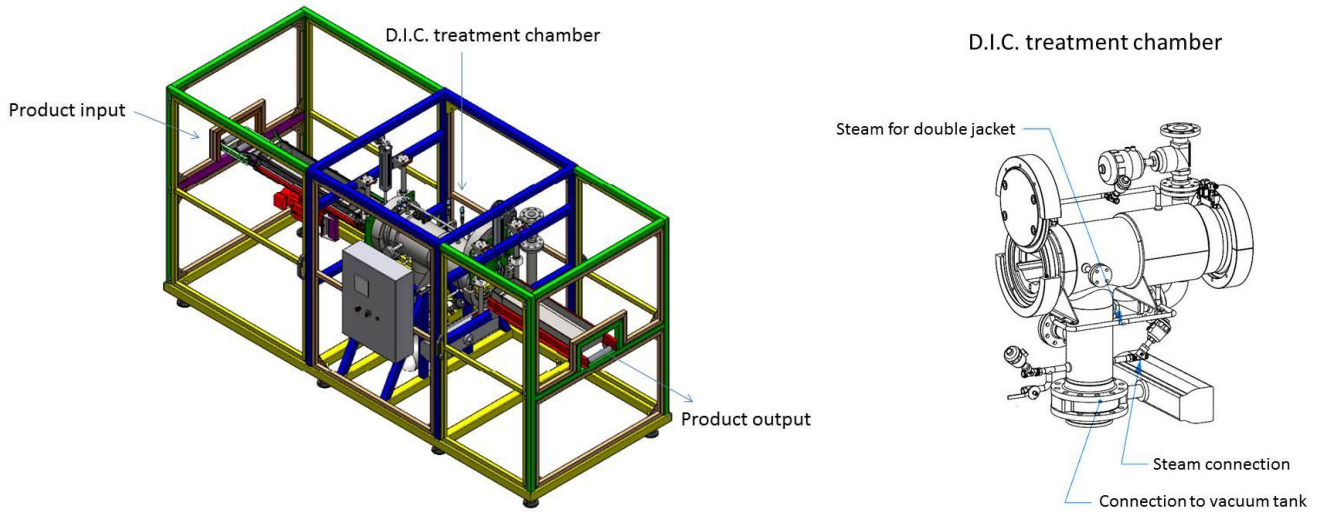

FIGURE 1: SCHEMATIC DIAGRAM OF THE INDUSTRIAL REACTOR DICL0.3-1.0 FOR TREATMENT PER BATCH BUT SEMI-CONTINUOUS FLOW: 30L OF TREATMENT CHAMBER; AUTOMATIC INPUT AND OUTPUT OF THE PRODUCT. TREATMENT OF ABOUT 500 KG/H. OF RAPESEED, JATROPHA SEEDS, CAMELINA AND DATE SEEDS

2.3.2 DIC treatment

The treatment is entirely automated, hence after the oilseeds are placed in the DIC treatment vessel a first vacuum stage is established in order to reduce the resistance between the exchange surface and the saturated steam. Afterwards a high-pressure steam is injected into the reactor and maintained during the treatment time (the pressure and treatment time are parameters that need to be defined beforehand). The thermal treatment is followed by an abrupt pressure drop towards a vacuum. This results in an instant autovaporization inducing an expansion and instant cooling of the solid material.

After DIC texturing, seeds were recovered and ready for extraction.

2.4 Solvent extraction

The study of the effect of texturing by DIC on oil extraction was performed by Accelerated Solvent Extraction (ASE) to determine the oil content, and Dynamic Maceration (DM) using n-hexane as solvent to measure kinetics and final yields.

Before extraction, oilseeds were ground by an industrial grinder at a rate of 4000 rpm for 10 s, and the average of particle size was 0.4 mm. Date seeds were ground in a heavy-duty grinder (National Institute of Arid Zone Degach, Tunisia) for 3 min and Particle sizes were ranged from 0.2 to 1.4 mm.

2.4.1 Accelerated Solvent Extraction (ASE)

In the present study, ASE was a Dionex ASE 350 system (Thermo Fisher scientifique, Sunnyvale, CA, USA). After preliminary tests, we defined the suitable ASE conditions. Once ASE was set, a 7-g sample mixed with 1 g of diatomaceous earth and introduced in a stainless-cell. Usually, solvent quantity correspond to 60% of the cell volume.

ASE operation begins with a 5-min heating step. The cell should reach a high level of pressure (10.4 MPa) to keep the solvent (hexane) in liquid phase despite its high temperature. ASE process was performed for 5 cycles of 10 min each, using 30–40 mL of solvent quantity depending on the particle size.

Then, cell content was purged by nitrogen for 150 s. The solvent was removed in a rotary vacuum evaporator at 40 °C, and oil were drained under a stream of nitrogen and weighted afterwards by analytical balance to finally be stored in a freezer (4 °C) for subsequent chemical analyses. The average oilyields were expressed in g oil/kg wb ±0.05 g/kg wb (wet basis).

2.4.2 Dynamic Maceration (DM)

A quantity of 200 kg of concerned powder was added to 2 m^3 of n-Hexane. The Dynamic Maceration DM was performed in an extraction batch with stirring. An adequate stirring at 400 rpm assured the homogeneity and the external intensification of the operation. The extraction ratios were measured at different interval times to establish the kinetics.

2.5 Press extraction

The screw press machine ("OMEGA 20" type "Taby Orebro", Germany) was first run for 15 min without seed material but with heating via an electrical resistance-heating ring attached around the press. Then DIC-textured and non-textured samples (300 g) were introduced into the hopper that gravimetrically feeds the single Screw Press machine. The screw pushes the seeds to a die located at the end of the cage. Under the effect of compression, a part of the seed oil is separated from the residual solid material and leaves in the back through the perforated sleeve. Rapeseed meal outflows at the press end. The performance of the press depends on the design of the screw and the size of the filter. The flow pressure is strongly determined by the diameter of outlet of the die (in our case, it was 8 mm). Fine particles in the expressed oil were separated by filtration and the filtrate and the cake were collected, weighed and stored at 4 °C. The oil content was gravimetrically determined and expressed as weight percentage on wet basis (%, w.). The pressed meals were immediately repackaged in zipper seal polyethylene bags stored at 4 °C until use.

2.6 Gas chromatography analysis

A quantity of 30 to 40 mg of oil was prepared to be converted to methyl esters. The fatty acid composition was determined as contents of methyl esters.

GC-MS analyses were performed using Agilent 19091S-433 gas chromatography (Kyoto, Japan). The instrument was equipped as follow: a capillary column HP-5MS (5% Phenyl Methyl Siloxane) (30 m x 350 µm x 0.25 µm). The oven temperature increased from 70 to 200 °C at a rate of 5 °C/min, and then it was programmed to rise up from 200 to 260 °C at a rate of 2 °C/min, to be set at 325 °C for 50 min. The carrier gas was helium and the velocity average was at 37 cm s-1. Injection of 1 µl of the various samples was carried out with a split mode (ratio 1:20) and the injector temperature was held at 270 °C. The ionization mode was electron impact (EI) at 70 eV. The identification of common fatty acids was based on using the NIST'98 [US National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA] mass spectral database.

III. RESULTS

Many studies at laboratory scale were established to identify and quantify the impact of DIC parameters on the extraction oil yield in the cases of various seeds. DIC operating conditions were optimized to obtain the maximum of yields in different considered seeds of rapeseeds, camelina seeds, jatropha and date seeds [17, 28,29].

These optimized processing parameters were used on the industrial scale DIC equipment.. The saturated steam pressure P (between 0.6 and 0.8 MPa) and the heating treatment time t between 35 and 105 s, were performed depending on the seeds, as shown in the Table 1. Treatment capacity of this industrial scale DIC reactor was established to be about 8 tons/hour.

TABLE 1
OPTIMIZED DIC CONDITIONS ADOPTED FOR INDUSTRIAL TREATMENT

Seeds	DIC treatment	
	P (MPa)	t (s)
Jatropha	0.7	70
Colza1	0.63	77
Colza2	0.63	105
Camelina	0.63	105
Date seeds	0.8	38

3.1 Comparative oil contents

The use of ASE Accelerated Solvent Extraction aimed at determining the oil content of each product. The ASE values were systematically ranged from 19 to 21%,thehighest for DIC textured oilseeds compared to untreated seeds. This fact should be attributed to higher availability of oil within the expanded seeds with ruptured cell walls. Thus, we could establish a comparison between the oil content reported in the literature and our results issued from DIC textured date seeds, jatropha seeds, rapeseeds, and Camelina seeds, summarized in Table 2.

TABLE 2
COMPARISON OF OIL YIELDS (%, W.B.) BETWEEN PRESENT EXPERIMENTS AND LITERATURE

Seeds	Oil content (% wet basis wb)			
	In this research		In literature	Authors
	DIC treatment	Untreated RM		
(**1**). Date seeds	12.3	9.21	8-10	[30]
(**2**). Jatropha seeds	38	31.74	30-40	[27, 31]
(**3**). Rapeseeds	37.8	31.7	31-34	[1, 17]
(4). Camelina seeds	36.3	29.8	27.58	[22, 23]

DIC pretreatment, in case of date seeds allowed the smallest particle size powder to get 12.3 % wb as ASE yield which was higher than that published byBesbes, Blecker [30], who reported it at 8-10% wb. In the case of Jatropha seeds oil yield, DIC treatment allowed to get oil yield extraction 38% wb , which is the same range than that reported by Parawira [27]. In case of rapeseeds and Camelina seeds treated with DIC, oil yields were higher than that reported in literature.

3.2 Comparative Industrial Yields

By using a mass input of 1 ton seeds of each sample, it was possible to perform a comparative study of various extraction operations; pressing of untextured RM and DIC-textured seeds; 2-h-DM (Dynamic Maceration) of powdered DIC-textured and untextured raw material, combining pressing of oilseeds followed by 2-h-DM of pressing-cake (meal) for untextured and DIC-textured raw material. The oil yields issued from extraction by solvent, pressing, and combining both are presented in **Error! Reference source not found.**. The following tables (Table 4, Table 5, and Table 6) present the oil composition.

By inserting optimized DIC texturing pre-treatment, we could increase yields of both solvent extraction (here for 2 hours of dynamic maceration DM and for 2 hours of soxhlet extraction) and pressing. In the case of pressing followed by DM of meal, DIC treatment performed at 0.63 MPa for 105 s allowed getting a total extraction of 96.42%, instead of 80.86% for oil colza2, and a total extraction of 92.60%, instead of 76% for camelina seeds.

We could also increase yields of solvent extraction (here for 2 hours of dynamic maceration DM and for 2 hours of soxhlet extraction) in the case of date seeds, colza1 and jatropha.

TABLE 3
COMPARATIVE INDUSTRIAL YIELDS OF VARIOUS EXTRACTION OPERATIONS IN 1000 KG RAW MATERIAL

Wet basis RM=1000 kg	Oil content (kg)*	Untextured raw material RM		DIC textured seeds	
		Pressing	DM Solvent	Pressing	DM solvent
(1). Date seeds	123 kg	/	77 kg	/	97 kg
Residual oil content in final meal			46 kg		26 kg
(2). Jatropha seeds	350 kg	/	302 kg	/	327 kg
Residual oil content in final meal			48 kg		23 kg
(3). Rapeseeds 1	392 kg	/	206 kg	/	315 kg
Residual oil content in final meal			86 kg		77 kg
(4). Rapeseeds 2:	392 kg	/	202 kg	/	305 kg
Seed pressing		285 kg	/	311 kg	/
Solvent extraction from meals		/	32 kg	/	67 kg
Total extracted oil [a]		317 kg		378 kg	
Residual oil content in final meal		75 kg		14 kg	
(5). Camelina:	370 kg	/	171 kg	/	278 kg
Seed pressing		267 kg	/	293 kg	/
Solvent extraction frommeals		/	31 kg	/	70 kg
Total extracted oil[a]		298 kg		363 kg	
Residual oil content in final meal		102 kg		7 kg	

Total a: Pressing of DIC-textured seeds + solvent extraction of meal (cake issued from pressing).

DIC treatment performed at 0.63 MPa for 77 s and at 0.7 MPa for 70 s, allowed getting a total extraction of 80.35% instead of 52.55% of colza1oil, and a total extraction of 93.42%, instead of 86.28% for jatropha seeds, successively.

For date seeds, DIC performed at 0.8 MPa for 38 s, allowed getting a total extraction of 78.86%, instead of 62.60% for non-treated material. DIC treatment triggered higher yields and lower solvent extraction time without any quality degradation of oil. This is worth to be highlighted because of its huge industrial and economic impacts.

3.3 Oil extraction kinetics

To identify the kinetics of Solvent Dynamic Maceration DM extraction of oil in date seeds powder, rapeseeds, Camelina seeds and jatropha seeds powder, the points were carried out between 5 min and 120 min. The quantity of extracted oil was identified based on the total weight of the material. DM was used with different particle sizes (0.2–1.4 mm) of powder from raw material and DIC textured samples.

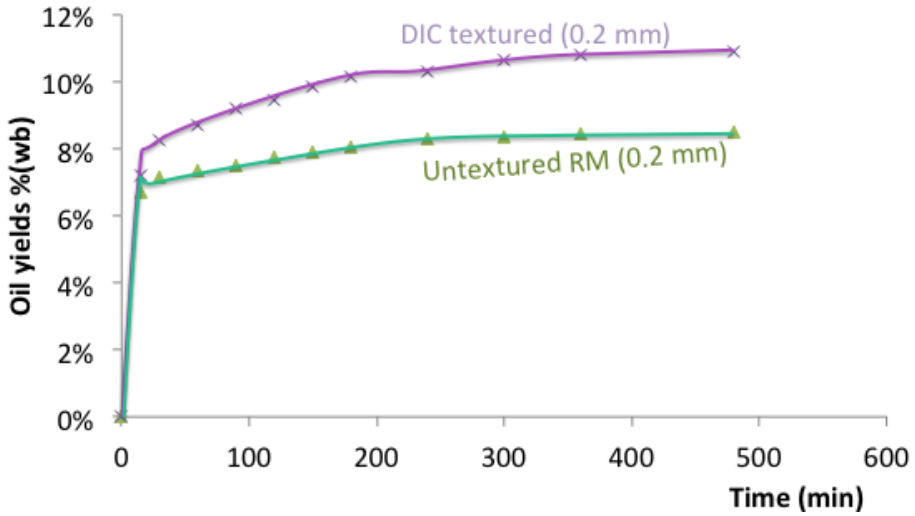

FIGURE 2.EXTRACTION KINETICS OF UNTEXTURED AND DIC-TEXTURED DATE SEED OIL.

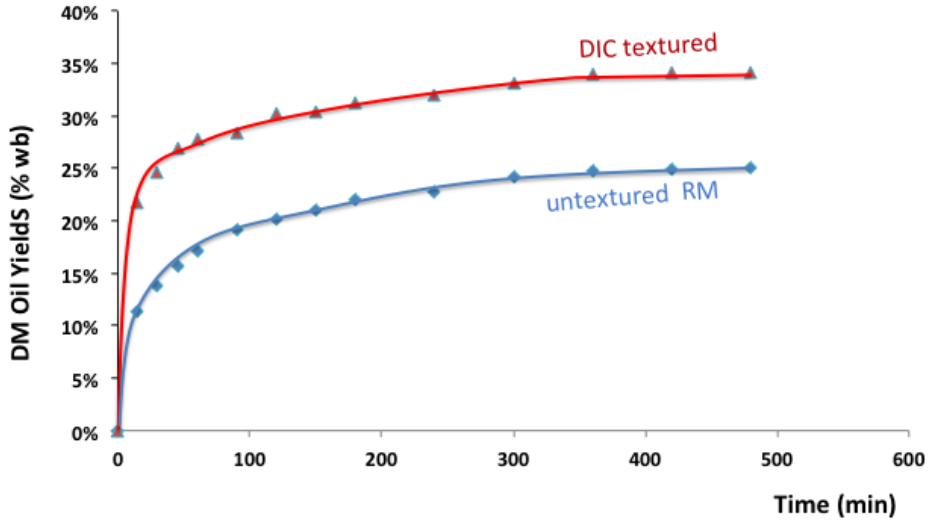

FIGURE 3.EXTRACTION KINETICS OF UNTEXTURED AND DIC-TEXTURED RAPESEEDS OIL.

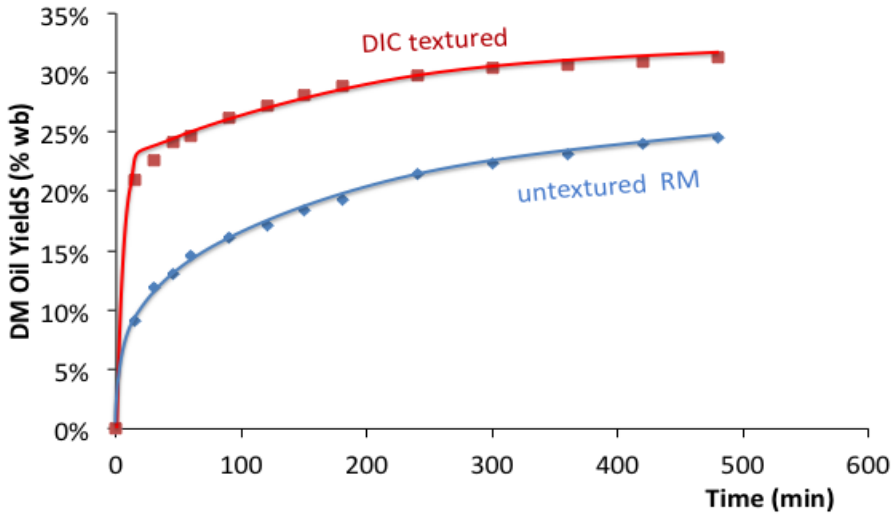

FIGURE 4 EXTRACTION KINETICS OF UNTEXTURED AND DIC-TEXTURED CAMELINA SEEDS OIL YIELD.

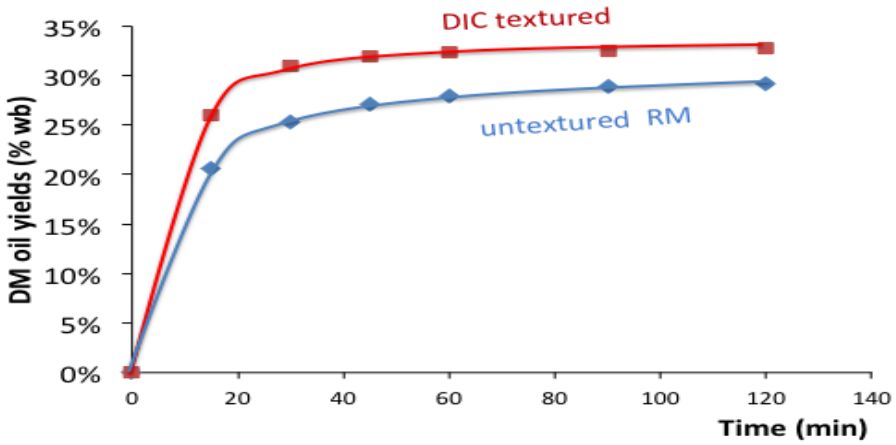

FIGURE 5 EXTRACTION KINETICS OF UNTEXTURED AND DIC-TEXTURED JATROPHA SEEDS OIL YIELD.

3.4 Fatty acid composition

The fatty acid methyl ester FAMEs composition of rapeseeds oils, camelina seed oil and their meals is shown in Table 4, Table 4 and Table 6. The most abundant fatty acids of oilseeds, meal and date seeds oil were oleic (C18:1), linoleic (C18:2), linolenic (C18:3), palmitic (C16:0), myristic (C14:0), and lauric (C12:0) acids which together composed about 90-95% of the total fatty acids.

TABLE 4
COMPOSITION OF FATTY ACID PROFILE (RELATIVE %) OBTAINED VIA GAS CHROMATOGRAPHY GC FROM RAPESEEDS AND CAMELINA SEEDS (SFA: SATURATED FATTY ACIDS; MUFA: MONO-UNSATURATED FATTY ACIDS; PUFA: POLY-UNSATURATED FATTY ACIDS)

	Pressing oil from rapeseeds		Pressing oil from camelina seeds	
	RM	DIC	RM	DIC
C12:0	-	0.62	0.5	0.62
C14:0	0.05	0.34	0.075	0.3
C16:0	5.09	6.94	5.19	6.90
C16:1	0.08	-	0.08	0.8
C18:0	1.86	2.27	1.8	2.2
C18:1	55.97	62.39	17.1	18.5
C18:2	18.18	18.79	18.76	18.89
C18:3	-	-	31.2	32.4
C20:0	1.02	1.00	1.5	1.2
C20:1	13.80	7.31	13.8%	13.9
C20:2	0.87	0.34	-	-
C22:0	0.23	-	-	-
C22:1	2.21	-	2.88	1.44
C24:0	0.13	-	2.21%	-
C24:1	0.51	-	0.13%	-
SFA	10.24	11.17	11.275	11.22
MUFA	72.57	69.7	33.99	34.64
PUFA	19.05	19.13	49.96	51.29

TABLE 5

FATTY ACID PROFILE (RELATIVE %) OBTAINED VIA GAS CHROMATOGRAPHY FROM DM RAPESEEDS AND CAMELINA MEALS (SFA: SATURATED FATTY ACIDS; MUFA: MONO-UNSATURATED FATTY ACIDS; PUFA: POLY-UNSATURATED FATTY ACIDS)

	Colza Meal solvent extracted oil		Camelina Meal solvent extracted oil	
	RM	**DIC**	**RM**	**DIC**
C12:0 lauric acid	0.08	0.08	0.26%	-
C14:0 myristic acid	-	0.08	0.16%	-
C16:0palmitic acid	3.21	4.99	4.28%	4.02%
C16:1 palmitoleic acid	1.19	0.26	0.23%	-
C18:0stearic acid,	1.08	1.57	1.30%	1.22%
C18:1oleic acid	78.48	80.10	74.89%	75.49%
C18:2linoleic acid	15.31	12.24	16.64%	18.33%
C18:3linolenic acid	0.41	0.39	-	-
C20:0arachidic	-	-	0.47%	-
C20:1gondoic acid	-	-	1.54%	-
C20:2 Eicosadienoic acid	0.24	0.22	-	-
C22:0behenic acid	-	-	0.23%	-
C22:1erucic acid	-	0.07	-	0.94%
C24:0lignoceric acid	-	-	-	-
C24:1 tetracosenoic acid	5.02	7.4	-	-
SFA	82.88	80.36	7.01%	5.24%
MUFA	15.31	12.24	76.66%	76.71%
PUFA	0.08	0.08	16.64%	18.33%

TABLE 6

FATTY ACID PROFILE (RELATIVE %) OBTAINED VIA GAS CHROMATOGRAPHY FROM DM EXTRACTED OIL OF DATE SEEDS (SFA: SATURATED FATTY ACIDS; MUFA: MONO-UNSATURATED FATTY ACIDS; PUFA: POLY-UNSATURATED FATTY ACIDS)

	Fatty acid profile (relative %) of seeds date	
%	**RM (F)**	**DIC (F)**
C8:0	-	0.30
C10:0	-	0.37
C12:0	15.64	23.84
C14:0	7.36	8.78
C16:0	9.65	8.13
C16:1	0.27	-
C18:0	3.29	2.56
C18:1	53.14	47.81
C18:2	10.28	7.69
C20:0	0.36	0.31
C22:0	-	0.21
SFA	36.22	44.5
MUFA)	53.41	47.81
PUFA	10.28	7.69

The major fatty acids found in those cultivars for DIC treated and untreated samples were similar with various relative ratios. This similarity in fatty acid profiles of oils issued from RM untreated and DIC textured treated rapeseed and meals powders should reflect the absence of any significant degradation trigged by DIC. Indeed, since DIC is a high-temperature short-time process with an abrupt pressure drop towards a vacuum resulting in instant cooling, optimized DIC treatment avoids any discernible thermal degradation.

IV. CONCLUSION

The industrial scale of intensification of oil extraction from various oleaginous was carried out using Instant controlled pressure drop (DIC) texturing. This technology had the capacity of increasing yields of oil obtained from both pressing (more than 10%) and Dynamic Maceration with hexane (about 12% more). The coupled operation of DIC, pressing and solvent extraction of meals shows a great impact and defined the most adequate intensification technology with total oil extraction of DIC textured seeds as 378 instead of 317 and 363 instead of 298 kg/ton of raw material for rapeseeds and Camelina, respectively. The higher availability and better kinetics of solvent extraction triggered by DIC were proved by the highest extraction yields obtained with ASE for DIC textured seeds. All these quantitative aspects were systematically coupled with a consequent preservation of the product quality defined through the profiles of fatty acids. Finally, compared with cooking and flacking, DIC needs about 1 min treatment time and much lower energy consumption.

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