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Oil extraction from coriander fruits by extrusion and comparison with solvent extraction processes

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ABSTRACT

The aim of this work was to optimise a single-screw extruder dedicated to coriander production and to investigate the effects of screw configuration, nozzle diameter and nozzle/screw distance. On the other hand, the coriander fruit was extracted using soxhlet methods, the results were compared with mechanical screw press methods.

Maximum yield was obtained with single screw extruder for a configuration allowing the strongest oil expression (nozzle/screw distance: 3 mm, nozzle diameter: 9 mm).

Comparing with mechanical press, the maximum yield was obtained by the soxhlet extraction with 21.25%.

The effect of the operating parameters on oil quality was not important. In all the experiments tested, the oil quality was very good. The acid value was below 1.8 mg of KOH/g of oil and iodine values were tolerable (44 mg of iodine/100 g of oil).

Nine fatty acids were identified, with petroselinic acid accounting for 74–77% of the total fatty acids, followed by linoleic, oleic and palmitic acids, accounting for 12–13%, 4–6% and 3%, respectively, of the total fatty acids.

β-Sitosterol was the major sterol in all oils with 28% of total sterols of all oils. The next major sterols in all oils were stigmasterol (24–27% of total sterols) and Δ^7-stigmasterol (14–18% of total sterols).

1. Introduction

Industrial extraction of edible oil from oilseeds or other rich materials can be carried out through two traditional processes which are mechanical expression and solvent extraction. For seeds with high oil content, such as sunflower seeds, groundnuts, palm kernels or rapeseed, both steps are usually involved, whereas materials of lower oil content, such as soybeans, can be directly solvent-extracted (Ward, 1984; Lusas, 1985).

In the last 30 years, extrusion cooking has been developed as a continuous process for food production. In the food industry, high temperature – short time extrusion cooking is used to produce direct expanded products such as snacks, breakfast cereals and pet foods (Miller, 1990; Moore, 1994; Rokey, 1994).

Typically, extrusion studies examine only two or three primary extrusion variables, but many factors such as barrel temperature, die geometry, extruder type, feed composition, feed moisture, feed particle size, feed rate, screw configuration and screw speed can influence product quality. Ingredient composition and extrusion conditions affect the final product quality through their influence on the extruder response, or secondary variables (motor torque, pressure, product temperature and shear) (Phillips, 1989).

The continuous oil extraction of oilseeds is widely carried out in a single-screw press. This type of machine consists of a single-screw of variable pitch and channel depth, slowly rotating in a cage type barrel (Isobe et al., 1992). Transport of material in a single-screw press depends mainly on friction between the material and the barrel's inner surface and screw surface during screw rotation. Thus, a solid core component is often necessary to produce the friction. This causes excess frictional heat, large energy consumption and oil deterioration.

Commercial production of vegetable oils is based on mechanical pressing and extraction. The mechanical expression of oil from oilseeds is one of the methods mostly used in the removal of oil from oil-bearing materials. This method which offers the possibility of using the cake residue has relatively low initial and operational costs and produces uncontaminated oil (Fasina and Ajibola, 1989). However, mechanical oil expression equipment and processes presently available are not considered adequate for this purpose, as their oil extraction efficiency is quite low (<70% oil

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extraction) (Bargale et al., 1999; Willems et al., 2008). For this reason, the yield obtained by mechanical pressing is usually lower than those obtained by extraction with solvents such as hexane and pentane. It is only in the last century that solvent extraction has been used in this field. The advantage of solvent extraction is the high yield that can be obtained economically with this method, but this is at the expense of a reduced oil quality. In particular for high value added oils this quality reduction is unacceptable, limiting the production process to mechanical expression (Venter et al., 2007; Willems et al., 2008).

During the last decades, in addition to oleaginous species, many new plant species have been investigated as potential sources of vegetable oils due to nutritional, industrial and pharmaceutical interests. Species of interest include the coriander (*Coriandrum sativum*) which is widely distributed in the Mediterranean area. This plant is an oilseed crop belonging to the Umbelliferae family. The interest in this crop is due to the high level of unsaturated fatty acid in the oil. The fatty acid profile is a main determinant of the oil quality in coriander fruit mainly with percentage of oleic (5–7%), linoleic (13–16%) and petroselinic acids (65–76%) (Ramadan and Mörsel, 2002; Sriti et al., 2009).

This latter can be oxidatively cleaved to produce a mixture of lauric acid and useful compound in the production of detergents, and adipic acid a C_6 dicarboxylic acid which can be used in nylon polymer synthesis (Murphy, 1991).

Lipid components in fruits, though occurring in minor amounts, are presumed to contribute to the development of characteristic aromas and flavours during ripening as they are considered as precursors for various volatile odorous principles of fruits (Gholap and Bandyopadhyay, 1980). Supran (1978) reported that lipids contribute to the industrial and nutritional value as well as characteristic aromas and flavours.

This study is set out to evaluate the effects of screw configuration and operating parameters such as nozzle diameter and nozzle/screw distance on oil extraction from coriander fruits. The characterization of extraction performance was observed by determinations of oil extraction yield and oil quality.

2. Materials and methods

2.1. Plant material

All trials were carried out using a single batch of coriander fruits obtained from Korba area (North East of Tunisia). The moisture content of the fruits was 8.41 ± 0.03% and the lipid content was 21.25 ± 3.6% on the basis of dry matter weight (Table 1).

All solvent and chemicals were analytical grades that were obtained from Sigma–Aldrich, Fluka, Prolabo and ICS (France).

In this study, the oil extraction was carried out with soxhlet and mechanic pressing, without solvent extraction for the cake.

2.2. Dry matter, protein and mineral content

Dry matter was determined gravimetrically after drying at 105 °C for 24 h (NF V03-908).

Table 1
Chemical composition of the coriander fruit from the batch used for experimental (% of dry matter).

	Fruit
Moisture content (%)	8.41 ± 0.03
Oil yield (%)	21.25 ± 3.60
Proteins (%)	16.45 ± 0.22
Mineral (%)	9.73 ± 0.12

Data are expressed as mean ± SD of three replicates.

Protein content was determined by Kjedhal method according to the French Standard NF V18-100 consisting of mineralization of organic nitrogen content in the sample to mineral nitrogen. By convention, the protein content of the sample was then obtained by multiplying the total nitrogen content by a conversion factor empirically (6.25).

The mineral content was determined according to standard French NF V 03-322. The sample underwent calcination in an oven at 550 °C until constant weight. All experiments were done in triplicates.

2.3. Single-screw extruder

Extrusion was done by a single screw extruder (Model OMEGA 20, France) with a motor (0.75 kW of puissance, 230 V of maximal tension, 5.1 of maximal intensity), a screw length was 18 cm, a pitch screws of 1.8 cm, internal diameter was 1.4 cm and 0.5 cm deep channel and a sleeve of 2.5 cm of internal diameter equipped with a filter pierced outlet of liquid at the end the screw and a surface of nozzles. The filter section was 2 mm in diameter to separate extracted oil. The feed rate and the screw rotation speed maintained constant to 15 g/min (0.9 kg/h) and 40 rpm, respectively. Six nozzles of different diameters (5, 6, 7, 8, 9 and 10 mm) were used in pressing the coriander seed. The screw press was first run for 15 min without seed material but with heating via an electrical resistance-heating ring attached around the press barrel, to raise the screw-press barrel temperature to the desired temperature. Running temperature was adjusted with a thermocouple.

2.4. Oil extraction and fatty acid methylation

Fruits from coriander were extracted with OMEGA 20 extruder. The filtrate was centrifuged at 8000 × *g* for 20 min in order to separate the foot from the liquid oil and the oil content was determined. Then, 20 mg of total extracted oil rendered soluble in 1 mL ter-butyl-methyl ether (TBME). Before analysis by gas chromatography, fatty acids were transformed into their corresponding methyl esters according to the procedure reported by norm NF of ISO 5508 using 50 μL trimethylsulfonium hydroxide (TMSH) in methanol (Müller et al., 1990). The sample was analyzed in three replications.

2.5. Unsaponifiable and sterol extraction

Five mg of dihydrocholesterol (internal standard) was added to 140 mg of oil. Then, 3 mL of 1 M KOH in ethanol was added and the mixture was maintained at 75 °C for 30 min. After cooling at the ambient temperature, 1 mL of distilled water and 6 mL of isohexane were added to the mixtures. The isohexane phase was allowed to isolate unsaponifiable fraction which was analyzed by GC. Before GC analysis, samples were silylated by the addition of 1 mL *N*-methyl-*N*-trimethylethylsilylheptafluorobutyramide (MSHFBA) mixed with 50 μL of 1-imidazol methyl and heated for 5 min at 103 °C. All experiments were done in triplicate.

2.6. Gas chromatography

The fatty acid methyl esters were analyzed by GC, using a Varian 3900 gas chromatography (Grenoble, FR) flame ionization gas chromatograph, with a fused silica capillary column, CP Select CB (50 m, 0.25 mm i.d., 0.25 μm film thickness; Grenoble, FR). The carrier gas was helium with a flow rate of 1.2 mL/min; split ratio was 1:100. The initial oven temperature was held at 185 °C for 40 min, increased at a rate of 15 °C/min to 250 °C and then held there for