A Wet Process Technology Applied to Jojoba Seed to Obtain Oil and Detoxified Protein Meal

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An industrial wet process to obtain oil and meal from jojoba was set up. The process sequence consists of breaking the seeds, homogenizing with water of suitable pH and temperature, and centrifuging to accomplish separation into oil, process water and wet meal. Oil is obtained with a yield of 70–75% and requires no supplementary refining treatment for the industrial purposes for which it is destined. The meal obtained is devoid of the toxic components simmondsin and simmondsin-2′ ferulate, and the protein content may be considered unchanged. The procedure contemplates a drying treatment for the meal with a view to using it as animal feed. This system is simple, economical and flexible in use.

KEY WORDS: Centrifugation, jojoba meal, jojoba oil, jojoba seed, wet process.

The current demand for products to replace spermaceti oils in cosmetics and pharmaceuticals, as well as for lubricants serving as alternatives to those of fossil origin, has had a considerable influence on the development of jojoba oil production. The seed contains approximately 50% of a colorless, odorless oil, which is structurally similar to whale oil, and consists essentially of a mixture of C-40 to C-44 monoesters containing C-20 to C-22 long-chain unbranched monoenoic fatty acids and alcohols. After separating the oil from the seed by conventional extraction processes the resultant meal, of high protein content, represents a potential ingredient for animal feed. However, before it may be used for such purposes it requires a detoxification treatment to eliminate the natural components of simmondsin, simmondsin 2′-ferulate and some of their cyanomethylenecyclohexyl glucosides (1).

As some of the authors had previously set up an industrial process for wet extraction to obtain fatty substances and protein meal from various seeds and fruit crops (2–14), the aim of this research was to verify the applicability of this innovative technology to jojoba seed.

The practical interest in this technology is explained by the following advantages: i) Oil is obtained without using solvents by a simple, economical system that is flexible in use. This is important when we consider the particular agronomic culture that does not permit conventional extraction plants to be used. ii) Detoxified meal is obtained from the extractive action of water in the working conditions adopted.

EXPERIMENTAL PROCEDURES

Materials. Whole jojoba seed came from California and had the composition illustrated in Table 1.

TABLE 1

Composition of Jojoba Seed

Oil (hexane extr.)	48.0
Protein (N × 6.25)	15.9
Crude fiber (Weende)	22.0
Ash	1.6
Simmondsin	2.3
Simmondsin 2′-ferulate	0.7
Moisture	3.1
Difference from 100%	6.4
NDF	18.8
ADF	18.6

Description of technology. Jojoba seeds were crushed and rolled, and then kneaded under preset conditions of dilution, pH, temperature and operational times. A centrifugal decantation was carried out, separating the bulk into three phases—oily, aqueous and solid. The oily phase was clarified by centrifuging to obtain jojoba oil. The aqueous phase was obtained by recovering the residual oil through a centrifuging operation similar to the primary centrifugal decantation process. The solid phase was subsequently submitted to squeezing and drying to obtain the separation of the meal, which is potentially suitable for animal feed. Partial recycling of the aqueous phase at the end to reduce the volume of water used is optional.

Technological operations. Crushing was carried out in a hammer mill (grid with 9 mm diameter holes). Rolling was carried out in a rolling mill with a single pair of ribbed rolls of 1 m diameter (slot width, 2 mm). Kneading was carried out in vats with hot water jackets. The outer side of these were insulated to prevent heat dispersion. This operation keeps the bulk, essentially composed of husk and kernel, in motion. The time, temperature, stirring speed and pH value of the oily paste were the determining parameters for efficiency and successful operation. In this operation recycled water was integrated with preheated fresh water. After correcting the pH value by adding acids suitable for use in food (*e.g.*, 36% pure hydrochloric acid), the bulk was kneaded until the first oil was expelled, which usually occurred in 10–15 min.

Centrifugal separation was carried out in a horizontal Nuova Maip-Pieralisi centrifuge (Jesi (AN), Italy). The oily kneaded paste was introduced to obtain the separation of the oily liquid, an aqueous liquid and a solid phase. The operation was facilitated by dosing the decanter inlet flow with hot water to improve separation efficiency. A continuous-flow centrifugal decanter was used to feed the vertical centrifuges, which were adapted for the recovery and the clarification of the oil and to obtain the solid phase from which the meal was derived.

Centrifugal clarification permits the finishing of the oil by its centrifugal separation from both the oily and aqueous phases leaving the decanter. The operation was

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conducted by two similar Nuova Maip-Pieralisi vertical centrifuges, which received the two liquid flows leaving the decanter. Finished oil and process water both flow from the outlets of the vertical centrifuges. Pressing eliminates part of the water present in the semi-solid phase leaving the decanter. A Nuova Maip-Pieralisi discontinuous hydraulic press was used for this purpose. The press works at a hydraulic pressure of 400 bars. The semi-solid bulk was pressed at the decanter outlet at a temperature of approximately 55°C. Drying was carried out in a dehydrator built by Società Italiana Essiccatoi (Milano, Italy). This was a continuous operation apparatus in which air was heated by hot gases from a burner using low commercial cost fuel.

Analytical methods. Determination of proteins was carried out according to the method set out in NGD (*Norme Grassi e Derivati*) B 5-1976 (15). Determination of lipids was carried out according to the method set out in NGD B 4-1976 (15). Fiber content was determined according to the method set out in NGD B 6-1976, and ash content was evaluated according to the method set out in NGD B 3-1976 (15). The total residual substances was calculated as a difference between 100% and the sum: lipids + proteins + fiber + ash.

The composition in amino acids was analyzed according to Spackman *et al.* (16). Determination of NDF (neutral detergent fiber) and ADF (acid detergent fiber) were carried out as described by Heredia Moreno and Fernandez Diez (17). Simmondsin and derivatives were evaluated by thin-layer chromatography, high-performance liquid chromatography and infrared analysis as described by Verbiscar *et al.* (18).

RESULTS AND DISCUSSION

The fundamental parameters of the process, for the purpose of improving oil yields, were the degree of crushing of the seeds and the kneading conditions with particular reference to pH, temperature and contact time. The most suitable form of the seeds for processing is that of maximum disruption, which is obtained by consecutive passing through the hammer mill and the rolling mill.

Where a seed-to-water ratio of 1:2 was adopted throughout kneading, the optimum pH is 4.5, as is shown in Table 2 as derived from a series of laboratory tests performed with the other parameters remaining unchanged.

The influence of the temperature was assessed in a similar way and it is shown that an increase in temperature causes an increase in yield (Table 3). A similar appraisal performed on the influence of kneading time (Table 4) indicates that the optimum time is about 45 min. We were able to assemble the optimum conditions shown in the diagram and material balance of Scheme 1, which shows the wet extraction process for jojoba seed-mass balance.

TABLE 2

Influence of pH on Extracted Oil Yields

pH	Yield with reference to total seed (%)	Yield with reference to total oil (extractable with hexane) (%)
3.5	12.2	25.4
4.0	11.6	24.3
4.5	19.9	41.5
5.0	19.0	39.6
5.5	8.0	16.6

TABLE 3

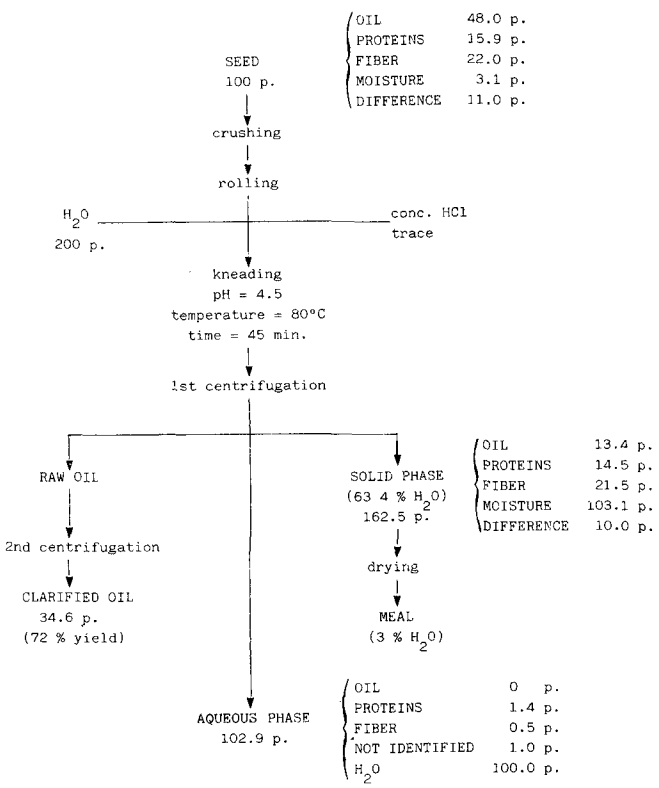
Influence of Temperature on Extracted Oil Yields

Temp. (°C)	Yield with reference to total seed (%)	Yield with reference to total oil (extractable with hexane) (%)
25	7.5	15.9
35	0	0
50	0	0
60	0	0
70	19.9	39.6
80	23.3	48.5

TABLE 4

Influence of Kneading Time on Extracted Oil Yields

Time (min)	Yield with reference to total seed (%)	Yield with reference to total oil (extractable with hexane) (%)
15	16.1	33.5
30	20.3	42.4
45	28.8	60.1
105	18.0	37.4



SCHEME 1

TABLE 5

Amino Acid Composition of Means

	Amino acid content (g/16 g N)		
	Meal extracted by hexane	Meal obtained by wet process	Meal obtained by wet process (Scheme 1) following treatment with boiling water
Aspartic acid	7.41	7.55	7.35
Treonine	5.87	5.99	5.81
Serine	4.90	4.89	4.85
Glutamic acid	11.45	11.35	11.45
Proline	5.65	5.73	5.81
Glycine	9.13	9.03	9.13
Alanine	5.45	5.31	5.41
Valine	10.10	10.08	10.10
Methionine	1.25	1.14	1.25
Iso-leucine	4.45	4.38	4.45
Leucine	8.50	8.60	8.75
Thyrosine	5.21	5.19	5.25
Phenylalanine	6.75	4.64	4.75
NH_3	1.35	1.94	1.85
Lysine	4.65	4.55	4.55
Histidine	2.35	2.23	2.35
Arginine	7.25	7.25	7.15
Cisteic acid	5.13	5.02	5.00
Tryptophane	1.74	1.64	1.60

The correction of the natural pH, which is approximately 5.5, to the optimum value of 4.5 is achieved by addition of concentrated hydrochloric acid. That correction is essential for the purpose of improving the oil yield, as already demonstrated in previous research (2–14), when the isoelectric point of the proteins is reached, it minimizes the emulsifying effect of these proteins with fatty substances. The washing action of the water ensures that the oil is devoid of undesirable water-soluble components, such as the simmondsin toxins.

After the second centrifugation, the oil is presented as a clear, colorless liquid, which is odorless, and no further refining is required.

Although the yield of 72% is not high, it is a far more economical process than the conventional solvent extraction method, and its practicality and flexibility permit *in loco* production. The following additional treatment, set up with the specific aim of meal detoxification, was demonstrated as suitable to increase yields.

The elimination of simmondsin and simmondsin 2′-ferulate, as stated by some authors (18), is possible by water extraction. At the same time, a brief boiling treatment reduces operating times and promotes the coagulation of the proteins, thereby facilitating centrifugation. This treatment was proposed as an alternative to the addition of hydrochloric acid, previously described, and also proved to be effective for the purpose of detoxication.

An operating step has therefore been added to the scheme shown in Scheme 1, following rolling, and allows the batch of seeds to dwell continuously immersed in boiling water (seed/water ratio, 1:2) for 15 min, during which time it is stirred efficiently. After the operation, the bulk is transferred to the kneading section, where the addition of water and hydrochloric acid is no longer necessary. From this point, the treatment continues as shown in Scheme 1.

After this treatment the meal is notably detoxified—98.4% of simmondsin is extracted, and the corresponding ferulate is reduced by 94.7%. The amount of protein extracted during the treatment with boiling water is around 9%. The amino acid content is not substantially altered with respect to the initial values, as shown in Table 5. The oil yield is also raised to 79%.

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