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Recovery Fats and Oils from Agro-industrial Wastes and By-Products for Use in Industrial Applications

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Abstract: In the present study three agro-industrial residues were selected due to their different levels of reuse and relevance for México and some other developing countries, according to their physicochemical, nutritional and biological characteristics to exemplify the potential of agro-industrial wastes as sources of edible fats and oils. Rice (*Oryza sativa*) bran oil, mango (*Mangifera indica*) almond fat, and zapote mamey (*Pouteria sapota*) almond oil were studied. Results showed that in some countries, like México, the recycling of rice bran still requires some technological adaptations due to the small sizes of its rice processing plants. Some physicochemical characteristics of mango almond fat were found similar to those of industrial edible fats and zapote mamey almond fat showed relevant yields from almond extraction and an interesting fatty acid composition.

Key words: Agro-industrial wastes, fats and oils, mango almond fat, rice bran oil, zapote mamey almond oil

INTRODUCTION

The endogenous dimension of development and its sustainable scope have incorporated two determinant components for the future of the world: human well-being and world ecosystem protection. This opens to us - to the human race-the awareness of not being a foreign part of nature.

The agro-industry is a work process that integrates important aspects of the man's material and social reality: nature and human capacities, social capacities-of transformation. Nowadays a great part of the foods consumed by man are previously processed for solving problems like their inherent perishability and the requirements for their distribution; nevertheless, such processes also generate a lot of different agrondustral wastes that, because their origins and biological characteristics, frequently represent an ecological problem and simultaneously an enormous potentiality^[1].

The classification of any material as a residue or natural resource depends on our degree of knowledge about it and carries with it an historical and social determination on which the use of the material and its commercial value ultimately depend. The above mentioned characteristics can be modified through the

actions of science and technology; therefore, such classification should result from careful study and analysis of the material in question.

For example, raw materials generally have low use and exchange values compared with manufactured products. Wastes, on the other hand, have a very low level of use and exchange values; this is modifiable, however as we acquire knowledge about them that permits their subsequent transformation and use. For agro-industrial wastes there are many examples where scientific activity has demonstrated the benefits and practicality of their recycling.

The management of processed food wastes has different scopes: such as waste disposition (as a way of confining them in places far from population centers), waste treatment (as a result of legal frames in the struggle against environmental pollution), or waste recycling, which, under conditions of scarcity, in some places and countries, can became a true alternative for fighting environmental contamination and for helping to increase the supply of socially necessary goods, which could be in the form of food derived from agro-industrial residues.

Agro-industrial recycling includes solid and liquid phase materials and it may serve to increase the stocks of raw materials for food products. There are well-known

cases like sugar-cane wastes (paper, wood substitutes, ethanol, forage yeast, etc.) or dairy wastes (proteins, dehydrated and hydrolyzed whey, lactose, syrups, etc.). Nevertheless, the amount of recycled residues on the commercial scale is still smaller than those generated during the productive processes.

In specific cases of residue utilization, it becomes necessary to know the state of the art in the social context in order to fulfill the requirements of estimation, study and research; these may involve both theoretical and applied research, fundamental technological research, the development of products, processes and machinery, etc.

Fats and oils from non-conventional sources are constituted, principally, by wild plants, microorganisms, and some agro-industrial wastes.

Rice bran is an under-used or residual material in some parts of the world, but its economic and nutritional characteristics are important. It is known that rice is a cereal of basic and generalized consumption in the world. The chemical composition of rice bran has been widely investigated by several researchers^[2-6]. The rapid enzymatic deterioration of rice bran oil is an important factor that limits its suitable use as a raw material for making diverse foodstuffs for human consumption. The de-activation of lipolytic and oxidizing enzymes and the preservation of its nutritious properties have been the targets of several stabilization studies by means of diverse procedures^[7-11].

Rice (*Oryza sativa*) bran oil has edible quality and it is industrially produced in the major rice-producing countries; however, in other countries, like México, where rice mills are smaller and rice bran has to be transported and stored before extracting the oil, it is still an agro-industrial waste, in some places.

Mango (*Mangifera indica* L.) seeds are a residue of mango fruit processing. The almond fat is one of the most important components and it has been studied^[1,12-17]. In these studies the potentiality of the mango almond is emphasized because of some of its physicochemical characteristics; nevertheless, there are still very few studies about the consistency, polymorphism and other important phase properties of mango almond fat concerned with industrial applications.

The zapote mamey (one of the vernacular names given to the fruit of the *Pouteria sapota* plant in Mexico and Central America, whose culture and industrialization have spread widely through tropical regions of North America, Asia, and Africa) seed contains an almond that has been used in domestic applications in some ancient towns of Mesoamerica, alimentary, cosmetic, and pharmacological qualities having been attributed to it^[18,19].

The oil yield from the mamey almond fluctuates between 40 and 60%. This oil has been studied but little, hence the need to know more about its basic physical, chemical, nutritious, thermal and polymorphic characteristics in order to determine its industrial applications.

The present study exemplifies, with these three materials, the potential of agro-industrial solid wastes for fats and oils with interesting and useful properties.

MATERIALS AND METHODS

Three important residual materials from agro-industrial processing in Veracruz, Mexico, were selected, in order to evaluate their potentiality and further research needs for extraction of vegetable fats and oils extraction with special characteristics for use in the food industry, as part of a global project for recycling, in Mexico, industrial residues. The chosen materials were; rice (*Oryza sativa*) bran, mango (*Mangifera indica* L.) seed almond and Zapote mamey (*Pouteria sapota*) seed almond.

A review of the state of the art in the utilization of these residues was realized to delineate the level of investigation required for planning the corresponding studies.

Physicochemical characterization of residues: Samples of rice bran, mango and mamey almonds were chemically analyzed for proximal composition using official analysis techniques^[20-23].

Rice bran: Current knowledge about the rice production and industrialization of rice, particularly in Mexico, led to studies of applied research concerned with rice bran stabilization by means of several physicochemical treatments and economic studies of rice bran stabilization and oil extraction, considering the relatively small size and the regional dispersion of rice mills. The methodology used in that research is described elsewhere^[21,24].

Mango seed almond: The extraction, composition, and physicochemical properties of Mango Almond Fat (MAF) were analyzed; the methodology is delineated in previously published studies^[22]. The thermal behavior and polymorphism of MAF were studied by means of DSC and X-Ray diffraction; the techniques are described in the literature^[22-25]. The mixing compatibility of MAF with other vegetable fats from other origins was analyzed^[22,23].

Zapote mamey almond: The extraction, composition, and the physical and thermal properties of mamey almond oil were analyzed; the methodology presented by other researchers^[23,25,26].

RESULTS AND DISCUSSION

Table 1 shows the results of proximal analysis of the studied residues; there, the relatively high contents of oil from the mamey almond (44.1%) and rice bran (19.4%) can be observed. Mango almond fat showed a yield of 9.4%.

Rice bran oil: In the major rice-producing countries like the Asiatic ones (China, India and Indonesia produced 345 million tons, providing around 60% of world production in 2002), rice bran is an industrial source of edible oil. In small producers, as in the case of Mexico (which produces an average of 400 thousand tons/year), the dispersion of the small rice mills and the instability of rice bran during transport and storage have impeded the development of rice bran oil production at commercial level.

A literature review showed that the moist thermal treatment and some chemical treatments retard or stop lipase activity and prolong the shelf life of bran beyond the time needed for its transport and storage, thus allowing extraction on a profitable industrial scale.

Table 2 shows the results of the experimental essays, led by the authors, on rice bran stabilization. Treatments with water steam, HCl acid, dielectric heating and chemical plus dielectric heating for lipase de-activation, were evaluated as free fatty acid percentages produced at different storage periods.

Chemical and chemical + microwave treatments were more effective for stopping the free fatty acid production.

The investment project elaborated under these considerations for a rice bran oil extraction plant of 19.4 tons of oil/day, requires an investment of USD \$ 2.16 million. The project gives an equilibrium point of 32% in the fifth year of operation and a rate of return on investment of 88.6%.

Mango almond fat: Around 25 million tons and close to 500 varieties of mango are produced in the world^[27]; Mexico contributes with 5%, coming after India, the major producer with 60% of world production. In some Asiatic countries, mango almond seed is used as a raw material for making diverse domestic foodstuffs. In Mexico, however, where about 20 varieties are cultivated, with the Manila variety as predominating, the residual materials from of mango industrialization have not been used to advantage.

The results of this project showed that the extraction yield for MAF with hexane depended on the time of extraction, the weight/volume relations of the solid, and liquid phases and the particle size of the dehydrated and ground almond. In agreement with a previous study^[23] the

Table 1: Proximal analysis of rice bran, mango almond seed and zapote mamey almond seed

Composition (% d. b.)	Rice bran	Mango almond	Mamey almond
Moisture	10.5	19.8	36.4
Ash	5.7	2.1	3.9
Fat	19.4	9.4	44.1
Crude fiber	9.4	7.6	25.7
Protein	11.2	4.6	11.3

Table 2: Effect of stabilization treatment on rice bran free fatty acids developed at 50 days of storage

Treatments	Free fatty acids (%)
Without stabilization	47.28
Water steam	17.78
Chemical (HCl)	13.32
Dielectric heating	18.57
Chemical+Dielectric heating	7.46

MAF after purification had a refraction index of 1.466, 189.0 of saponification and 47.7 of iodine. In its fatty acids composition, stearic (between 39.0 and 42.6%), oleic (37.5 to 40.8%) and palmitic acid (9.2 to 9.9%) were predominant and in minor quantities, linoleic, araquidic, behenic and lignoceric acids, among others, with FA-saturated between 51.9 and 55.7% and FA-non-saturated between 43.9 and 47.5%^[22]. The melting and solidification curves of MAF showed it to be relatively simple, with temperature intervals of 50 and 40°C and transition enthalpies of 70.1 and 56.1 J g⁻¹ for melting and for crystallization, respectively, in samples without stabilization^[23].

The calorimetric analysis showed the existence of polymorphs α , β , β_1' and β_2' . The X-ray diffraction study showed that the evolution of form α to the β happens at 22°C in about 5 days. The X-ray spectra of stabilized samples showed the typical data of the β polymorph. Thus, the FA composition and the thermal and phase behavior of MAF were close to those presented for samples of cocoa butter (MC) prepared and analyzed in parallel in the same way.

Zapote mamey oil: In agreement with this investigation, *Pouteria sapota* is a vegetable species with great potential as a source of raw materials. Its fruit, the zapote mamey, is appreciated because of its organoleptic pulp characteristics. For some native cultures of Mesoamérica the almond seed was also a good versatile source of food as well as medicinal and cosmetic remedies.

The results showed that the fruit pulp is rich in carbohydrates, vitamins and minerals with valuable texture and flavor. The almond of the seed, which represents about 6% of the fruit, has a composition that may be of great interest to the food industry, notably for its protein (11.3%) and fiber (25.7%) contents and for its lipids (44.4%, d. b.) potential in the industry.

Even in premature fruits, before physiological ripeness, the oil yield was high, resembling that of most well-known oily seeds. Mamey almond oil has a relatively simple composition: principally palmitic, stearic, oleic and linoleic acids (with 8.71, 34.41, 47.06 and 5.12 g of FA/100 g of oil, respectively) and a thermal behavior with a profile like that of palm oil, with triacylglycerid fractions of high, middle and low melting points.

CONCLUSIONS

In accordance with this study, an alternative for the management of agro-industrial solid residues is their use as raw materials for the extraction of components having higher commercial value and intermediate or final use, such as fats and vegetable oils. According to its nature and the socioeconomic context where it is produced, every residue needs a different depth and scope of scientific or technological research to make its potential a reality.

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