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ECO-DESIGN OF INTEGRATE SYSTEM OF DRYING AND SEPARATING OF OLIVE RESIDUES IN OLIVE OIL INDUSTRY

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Abstract
The objective of this research is optimizing a process of recycling residues called olive cake (stones) for renewable energy use and Pomace for animal feed industry use. This study includes a drying and separation of solid residues from pulp and store final product for an expedition to recommended user. Drying will proceed continuously in parallel with the existing production process of olive oil.

Introduction
The olive tree has been present in the Mediterranean since the last glaciations. The first traces of the oleastre date from 6000 years ago. The domestication of the olive tree dates from 5500 BC to the south of Haifa (Near East). Morocco has been producing for over 2000 years. In 1970 about 230,000 Hectares of olive grove. Since 1986 a massive program of planting by the Kingdom to increase production. Today more than 400 000 hectares with more than 400 000 tons of olives. This plantation has a serious environmental implication for the future at the national level.

The olive oil industry generates a significant amount of residues that impact not only the country but the entire planet by mainly polluting the soil. Their recycling is still partial for technical and economic reasons.

However, in the majority of cases, the cost factor limits the use of these resources. Public pressure and environmental constraints are pushing governments to strike a balance between financial constraints and social pressure. In order to optimize costs it is important to implement a logistics system for an efficient collection; Which can be managed by a local contractor or a power conversion operator.

On the other hand, residues with a high humidity of 45 to 55% can not be stored indefinitely or converted into energy without drying. This dehumidification requires a high energy consumption to reach levels between 10 and 15% to be a source of renewable energy.

The existence of technical constraints relating to high humidity and economic limitations related to logistics and energy consumption in order to make the residues usable leads us to consider a study of an integrated economic process to respond to this issue.

The objective of this research is the eco-design of an economic system to recover the residues of the olive oil "olive cake" in view of their reuse in the energy supply for the case of the pomace and in industry for pulp. The design includes the separation of pomace and pulp before storage for shipment to the recommended uses. This separation will be carried out in continuous mode in parallel with the existing production process.

Historic

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Introduction To Last Results

The "OC" olive cake at 8-12% moisture is widely used for bio-fuel and energy production. On the other hand, the decay of the market demands for olive cake following its quality (two-phase system) in addition to the transport problem. This leads to a decrease in the biomass extraction units.

The main techniques of drying residues coming from the process of extraction of olive oil are: dehumidification by centrifugation, drying by natural gas and by solar energy.

Dehumidification by centrifugation involves carrying samples at high rotational speed to create a pressure to separate the liquid, mainly water with traces of residual oil, solid particles. Tests at a rotational speed of determined over a predefined time period to evaluate separation performance by centrifugation.

Based on the findings, the available moisture level remains high so that residues can be economically reused for energy recovery. In addition, the energy consumed for dehumidification remains an important indicator for the reuse of residues after prior drying.

Finally, solar technology offers a drying alternative with a reduced direct operating cost excepting investment and maintenance costs. This renewable energy technology can participate in reducing the costs of drying.

Optimization of the process of drying and separation of residues of olive oil, take into consideration the areas of solar energy, physical separation and other areas related to heating.

Production Of Olive Oil

World production of olive oil is in the order of 3,270,500 for the year 2013-2014 (International Olive Oil Council, November 2014). Spain remains the world's largest producer at a rate of about 1,780,000 for the agricultural year 2013-2014, followed by Italy with 461,000 tones for the same period. Morocco remains in the seventh with 120,000 tons.

Olive Cake Caracteristics

The residues are composed of solid stones, pulp, water and residual oil in the mixture. The distribution of the percentages of the components varies according to the extraction system of olive oil but the moisture content.

Tests and past results:

1. Air drying heated from 80 ° C to 110 ° C. :

The initial moisture content in the residues is 44.78% ± 0.5 with respect to the weight (wet basis); The olive residue contains an important energy. The behavior of the "OC" residues with respect to drying in a drying booth was examined using ambient air at temperatures of 80 ° to 110 ° C and a constant air velocity of 1.2 m / s . In addition to the effect of the thickness of the sample on the drying characteristics, the drying time and the energy quality of the dried product are also determined. The experimental data are compared with the values predetermined by the model page, and the model of Henderson and Pabis, a good approval is obtained with the model page. The diffusion model is used to describe the transfer of moisture and the effective diffusivity varies between 489.2 and 998.4 μm² / s. Dependence of the temperature diffusivity coefficient is described by the Arrhenius type relation. The activation energy is 26.71 KJ / mol. Furthermore, the influence of the drying temperature on the calorific value is not observed. [By IBRAHIM Doymaz et al 2004].

2. Drying of a thin layer by infrared:

The infrared drying behavior of a thin layer of olive oil residues was experimentally invested in a temperature range of 80 ° C to 140 ° C. The time required to reduce the moisture of the sample from 91.97% to less than 8.69% (dry basis) changed from 105 to 35 min. [Ruiz Celma, A. et al 2008].

3. Innovative drying based on a fluidized bed:

Innovative drying Moist bed attached to the fluidized bed through a conical device, the objective is to improve the drying of the residues with low cost and high quality by the use of optimal conditions of operation, temperature and Air flow, feeding solid moisture, and a control system. The operating temperature of the bed is set at 125 ° C. to obtain a quality of residue olive oil and to reduce the power consumption and the drying time. The power consumption of the improved fluidized bed is 1 kWh / kg of water; This means a reduction in the cost of energy compared to the rotary dryer which, with respect, consumes 1.4kWh / kg of water [by JOSE S. TOWECILLA et al 2006].

4. Solar drying:

The solar drying technology offers an alternative that can proceed to the cleaning of plants and fruits, in hygienic and sanitary conditions for national and international standards with zero energy costs. It saves energy, time, takes up less space and improves quality; Also it can be used as a complete drying process or in addition to artificial drying systems.

5. Dehumidification by centrifugation.

Dehumidification by centrifugation involves carrying samples at high rotational speed to create a pressure to separate the liquid, mainly water with traces of residual oil, solid particles. The previous experimentation by researchers consisted in putting a sample of the Olive Cake of a moisture of about 59.2% (Ec1) and a second of about 54.7% (Ec2). Tests at a rotation speed of 6000 rpm for 20 minutes gave the following results:

- Ec1, about 41.2% humidity.
- Ec2, about 38.2% humidity.

The energy required to reduce moisture by 1 kg of residue is 0.3kWh / kg of olive residue, and the energy consumed to dehumidify 1 kg of water is 1kwh / kg of water. The cost to reduce the moisture contained in 1kg of residues from 54.7% to 38% is 0.12 Euro / kg based on the cost of electricity in the industry of 120 Euro / MWh [by Ahmed El Sayed Azab, Achille Pellerano].

Discussion Of Past Results

The Drying Systems Studied

Previous studies deal with the drying of residues by heat input or by centrifugation, the contribution of heat remains expensive even if it is the most answered process in several areas of drying products; Centrifugation is an alternative for drying. However, for olive residues, drying by vacuum is not treated. Our approach focuses on vacuum drying while studying the technico-economic feasibility with a view to designing an industrial process that can be used in the drying and separation of olive cake.

Method And Tool (Design Of The Experimental System)

To do this, our experimental vacuum drying system consists of a vacuum pump and a filter (filter cloth) for separating the filtrates from the solid particles of the mixture.

Filter and filter cloth, vacuum pump, filtrate collector and dried solid (without washing system) with measuring points:

- Vacuum.
- Power consumption (optional).
- Filtrate volume.

Possibility of variation of the vacuum.

We will determine the energy consumed to dry 1.2 kg of olive residue in comparison with drying by heat and centrifugal drying.

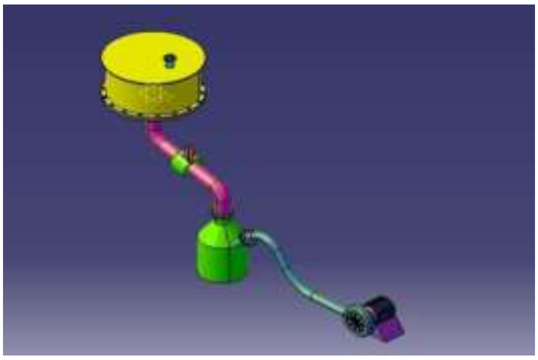

Figure 1 : experimentation vacuum drying.

Material

We used a sample for the experimentation of a mass of 1200 kg of the residues of olive oil brought to a humidity of 53% close to the maximum value which is of the order of 54%, this sample is under An ambient temperature of 20 ° C.

Results and Discussions

Table 1: result of the experimentation of the drying of olive oil residues by a vacuum system.

Tests	Volume removed water/liquid (ml)	Ratio % (/ total weight) Removed
Experience 1	195	16.3
Experience 2	185	15.4
Experience 3	200	17.2
Experience 4	180	15
Experience 5	190	15.8

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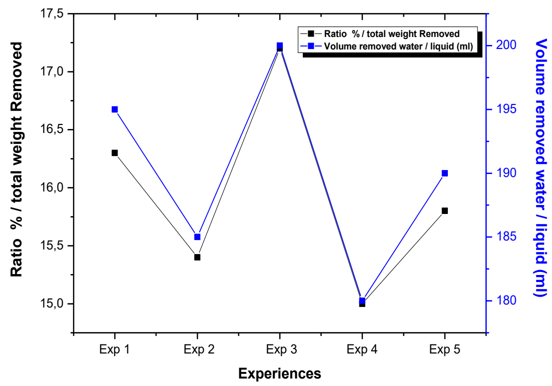

Figure 2: graph representing a ratio of total weight removed.

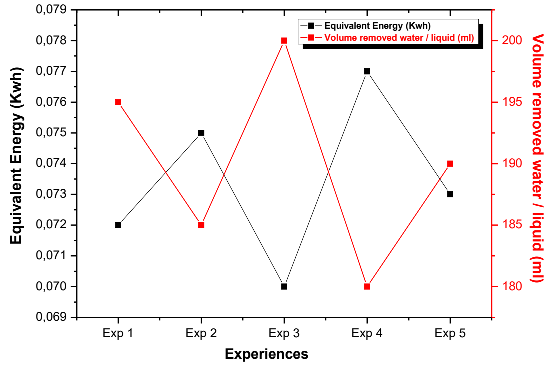

Figure 3: graph representing an energy consumption relating to total weight removed.

Discussions

Technical: With this experimentation we rich a medium dry performance about an average of 15.94 % of liquid removed from 1.2kg of olive cake residues with a vacuum pump working at power of 120 W.

On first column illustrates the medium of water removed is 190 ml from our prototype containing 53% of wet. The equivalent percentage of liquid removed is a medium of 15.94%. We observe variations between experimentations with an ecartype of 7.9 and medium of 190 ml removed liquid. The percentage of liquid removed (on column 2) we find an ecartype of 0.85 and medium value of 15.94 %.

After our investigation we conclude that this variation depends on cloth washing and mastering of vacuum level which can be stabilized by insuring absence of leak on the vacuum system.

Economic: For removing 1Liter of liquid we consume about an average of 0.32 Kwh. This consumption is economic to compare it with drying by gas witch consume around 1.4 kwh.

Environment: With drying by vacuum we avoid effluent that pollutes air; all chemical elements presents in olive cake are recovered on liquid and can be treated separately.

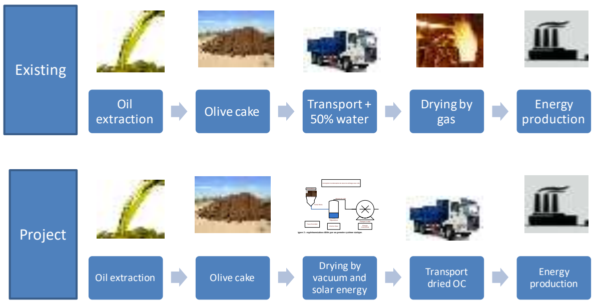

Figure 4: comparison of life cycle between gas dryers and vacuum drying.

Comparison: on the figure 4 we show a gain on tree aspects:

- Transport: we transport minimum of water by proceeding with direct drying by vacuum.
- Consumption: with drying by vacuum we consume less on energy.
- Effluents and filtrates: by gas we generate effluents and more of CO2 but with vacuum we recover chemicals on filtrates.

Perspectives

The subject of our innovation (research) concerns an innovative combination in order to make profitable and optimize the process of drying the residues which will be a source of energy and animal feed. It consists on a combination of drying by vacuum with option of drying by solar energy.

The process consisting in reducing the humidity of a high threshold of the order of 54% plus at least and on average at a threshold of less than 12% by an energy-saving and technically feasible system compared to the existing processes.

Innovation

The objective of this improvement is the design of an economic system to recover the residues of olive oil "olive cake" in view of their re-use in the energy supply for the case of the pomace and in the industry of Cattle for pulp. The design takes into account drying and vacuum separation and optionally additional drying by solar energy.
A patent was published on under WO/2016/163866 (Espacenet patent search), The aim of the invention is to design a cost-effective system for recovering olive-oil residue or "olive cake" that is intended for use in energy supply in the case of olive pomace and in the livestock industry in the case of olive pulp. The design comprises the drying, vacuum separation and, optionally, additional drying using solar energy of solid olive paste residue, which is subsequently stored in order to be shipped for the proposed uses. The separation is performed continuously in parallel with the existing oil production process.

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