

Feasibility Analysis of Drying Process Habanero Chili Using a Hybrid-Solar-Fluidized Bed Dryer in Yucatán, México

Elizabeth Cortés Rodríguez¹, Isaac Pilatowsky Figueroa² and Claudia A. Ruiz Mercado³

1. Create, Innovate, Develop, SAdCV, 21 Street No. 83E, by 18 and 16th, Chuburná Hidalgo, Mérida 97205, Yucatán, México

2. Energy Research Center, National Autonomous University of México, PO Box 34, Temixco, México

3. School of Chemical Engineering, University of Yucatán, Yucatán 97203, México

Received: January 11, 2013 / Accepted: April 22, 2013 / Published: October 31, 2013.

Abstract: Drying processing of Habanero chili was improved, through solar energy usage. Habanero chili is a notable seasonal product being drying such important for Mexican producers; this process is expensive and wasteful of energy. A feasibility analysis was developed, to determine the market tendency and the optimal drying conditions for redesign Habanero chili drying process, through a hybrid solar-electric energy usage. The new drying process would be held in two stages: (a) an open solar dryer was used; (b) an existing pilot fluidized bed dryer was adapted with a low temperature solar collector for air heating. Habanero chili was dehydrated from 90% to 5% moisture in 10.3 h, with good quality product, available for commercialization. A reduction in the average drying time of 50% was obtained, also, in the energy usage of 77% in the fluidized bed dryer, with an energy saving of 0.52 kg of natural gas per kg of fresh Habanero chili. An innovative sustainable efficient drying process was developed, and will be strategic to expand the market for Habanero chili with low energy cost.

Key words: Hybrid system, solar usage, Habanero chili, feasibility analysis, drying process, redesign.

1. Introduction

In last decades, the dried products demand has increased in domestic and international markets, however, in many practical applications, drying is an expensive process due to the high consumption of energy associated to the high latent heat of water evaporation and the low energy efficiency of industrial equipment utilized. Indeed, industrial dryers consume 12% in average of the total energy required in manufacturing process [1], therefore, this process is one of the most demanding and wasteful of energy in the industrial sector, so, it is expensive, affecting the final product cost.

Nowadays, a global initiative for energy saving has

been emerged, whose importance is growing as primary energy costs continue rising, therefore, there is a priority interest to develop a sustainable drying with features capable of competing with industrial processes, in this way, the increasing demand with the final product requirements will be supplied, being an opportunity area for search of new energy resources seeking to minimize drying process costs and solar energy usage, due to the low temperature process requirements, improving the efficient use of energy and resources. It is worth to note that a sustainable process could be obtained [2].

Solar energy stands out from other renewable energy, being more available, accessible and free, and it is considered such as potential area of the greatest technological development. Highlighting solar heating technologies, due to the market availability and

Corresponding author: Elizabeth Cortés Rodríguez, Ph.D., engineering doctor, research fields: technology development and energy efficient use. E-mail: elcoro@prodigy.net.mx.

relatively low inversion costs, where solar energy provides thermal energy to diverse applications through solar collectors, such as flat plate collectors and evacuated tube, which dominate the market of low temperature solar concentrating. There are good prospects for a wider application of this technology, especially in sunny climates, where it can be economically competitive and deployed. Achieving this position requires a package of measures to promote market confidence, the capacity of the supply chain, and the technology itself through the stages of initiation and development [3] in feasible processes to implement it, according the energy requirements, so, it has become a future field of study, within the most common applications: the heating of water for domestic use, thermal conditioning of swimming pools, power generation and drying of leave tea, hot spices like paprika and chilies [4-6].

In general, an efficient drying process has been obtained through the use of low-temperature solar collectors, being the better yield in energy use and a good quality dry product obtained at temperatures close to 60 °C [7]. Several energy analyses have been conducted, establishing that the characteristics of the solar collector, such as the length of collector, its surface as well as the operating conditions are the main variables in the heat transfer process [8]. Also the coupling of a solar collector to drying system has been analyzed and the energetic efficiency values into the process were increased [9].

Indeed, the incursion of solar technology in drying process has modified the traditional solar drying process, which has been one of the most used in the food processing area, because of the lower operating costs, since solar energy has zero costs, this process is used in fruits and vegetables obtaining good results, also, it is efficient, providing a longer product life and preserving properties and vitamins [10].

Solar dryers can be classified into three groups, which are defined in base of the energy source, such as:

(1) Solar dryers: using only environmental natural

energy, like cabin and natural convection dryers, like the static bed;

(2) Semi-artificial solar dryers: with a fan and a motor that maintains continuous airflow into drying area, so, forced convection is used;

(3) Artificial solar-assisted drying, using electricity or other energy source as power backup, which provides the option to operate when environmental conditions are not conducive to solar drying.

The solar-assisted artificial dryers, have several advantages such as operating in a continuously form, using solar energy as a primary source as much as possible. This system is called hybrid due to the combination in an integrated manner of solar energy with another energy source, usually from a fossil fuel, providing greater efficiency in the drying process and decreasing energy loss [11].

Nowadays, there are several reasons to use hybrid systems, the main is the reduction in fossil fuels usage; also there is an increase in the energy efficient. However, these systems are most expensive in installation and operation aspects, compared to common devices that use petroleum products like gasoline, coal or natural gas as fuels. However, there are many economic advantages with the use of these devices, the most important is the use of sustainable energy because it is easily accessible and low or zero costs, such as wind, solar or geothermal, besides, a continued system operation is obtained, avoiding intermittency associated to renewable energy. The solar technology will excel in the use of hybrid systems due to that it has several applications, both to the heating currents in an air conditioning and drying processes [11].

Recently, hybrid systems are an emerging alternative in drying industry to reduce energy consumption due to improving the energetic efficiency, which is obtained through combining solar energy with other energy source, so, the current industrial drying system has been modified with this technology. Therefore, industrial drying of Habanero chili is an

ideal process for hybrid systems usage, this process is wasteful of energy to get a moisture content of 5% wet basis, it takes place in trays, the disadvantages of this equipment are the high costs in maintenance and operation and the long drying time, the average time is 12 h [1].

As any agricultural production, Habanero chili crop is a seasonal product, this occurs in October and November of each year because of the ending of rainy season, being important to consider the products preservation. Therefore, dehydration is an important process, reducing the moisture content (1%-5%), also another benefit of great relevance is the weight and volume reduction with the costs reduction in storage and transport [12], in addition to the desirability of preserving the color and nutrients of the dried product.

The Habanero chili (*Capsicum chinense* Jacq) is a crop of great economic importance for Mexican producers in the Yucatán State (Fig. 1). México has the highest genetic diversity of capsicum and ranks second after China in terms of world production. Among the biological properties of the chilies, highlighting the antioxidant activity, anticancer properties, antimicrobial properties, anti-inflammatory and analgesic property of the hot varieties, are because of the capsaicin presence [12].

The major crop is located in the north of the state and contributes over 90% of the volume of state production, which is for local marketing and some is used in industry as raw material for hot sauce preparation [13]. The condiments production is the main application of dehydrated Habanero chili, as well as the extraction of capsaicin, which is the substance that gives the itch to chili, and may also have other uses, including the making of tear gas, insects or rodents repellents. Traditionally, dehydration of Habanero chili is done in ovens' woods, which are built by the same producers. These furnaces are characterized by the rudimentary construction form and consequently have many energy losses. The drying process can take several hours, requiring a constant supply of wood, causing the



Fig. 1 Fresh Habanero chili (*Capsicum chinense* Jacq), native of the Yucatán Península, México .

unwanted emissions of pollutants to the environment [14]. It is worth to note that it is not done under controlled conditions so that the product is contaminated and the final characteristics are not standardized and neither complies with food safety standards, therefore, it is lacking of real value added for export.

Several analyses have been realized to the Habanero chili, to determine its content features like pungency, capsaicin, water content, antioxidant and nourishing properties. In Refs. [13, 14], also 50-70 °C has been established as the range of temperature operation for drying process, to avoid thermal degradation of product assuring final product quality. The drying kinetics of the Habanero chili normally is realized in times greater than 20 h in rotary dryers [5]. The process reflects a high operating cost because it is a continuous process where the amount to be treated is in function of the capacity of the dryer.

10 years ago in Yucatan Peninsula, the drying need was generated, due to the demand of dried Habanero chili in international markets with specific organoleptic characteristics, so, several dryers were designed, however, low energetic efficiencies are reached to date, being an important requirement and an innovative design process with control critical process variables that affect the product quality.

According the above mentioned, it is clear that the requirement of developing a new drying process for energy saving using new technologies such as a hybrid energy system and a fluidized bed dryer, which is one of the most used in the industry. It is worth to note that

there is not a similar research developed to date, also, fluidized bed dryer was selected to dry Habanero chili.

In this research, an opportunity area to redesign an existing process through solar energy usage by a hybrid system was determined due to the low temperature requirements and solar radiation availability in Yucatan Peninsula. Therefore, the dehydration of Habanero chili was improved through the redesign of a drying process in two stages, including a pretreatment in an open solar dryer and a pilot fluidized bed dryer with a hybrid solar-electric air heating, the humidity content was decreased from 90% to 5% in 10.3 h, obtaining the optimum energy use in the global process. An innovative sustainable and efficient process was developed in drying, one of the most demanding and wasteful of energy in the industrial sector.

2. Methodology

The proposed methodology in this research to obtain the feasibility analysis with an energetic optimization is as follows (Fig. 2):

(1) Market analysis: In this first phase, two factors were analyzed into the market study development, solar radiation availability and Habanero chili dehydrated demand to determine the market trends of Habanero chili outside of Yucatán Península;

(2) Determining the optimal conditions for the drying process: The existing drying processes were studied and analyzed with the aim to choose the technology to be used and establish a new sustainable alternative. Once the drying process was selected, the initial process of drying Habanero chili was analyzed and according to the results obtained, the optimal operating conditions were established such as temperature, drying time and energy usage;

(3) Redesigning the drying process: In this phase, the redesign of the drying process using solar energy was performed, the global drying process was divided into two stages: solar pretreatment and fluidized bed drying by coupling a hybrid solar-electric system for air heating;

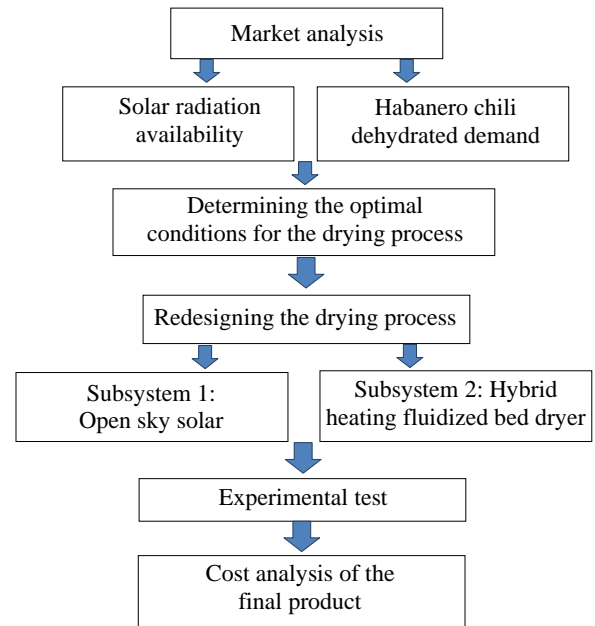


Fig. 2 Methodology proposed.

(4) Experimental test: Tests were conducted with the prototype developed with the aim to analyze and the results obtained were compared with the initial process and the final product quality was corroborated;

(5) Final product cost analysis: Finally, the final product cost was compared against the commercial product cost existing in the market, which is obtained by the common treatment.

3. Results

Market analysis: The first stage into feasibility analysis development, solar radiation availability and Habanero chili dehydrated demand are the main factors to be considered due to the choosing of the technology and drying process performance depends on the target market and environmental conditions.

Solar radiation availability: The current climatologically conditions in Merida Yucatán in México are suitable to have a good opportunity of success in the application of solar technology (Fig. 3). There are three important conditions that are worth to remark:

(1) The monthly average number of hours per day ranges between 6 h and 8.5 h.

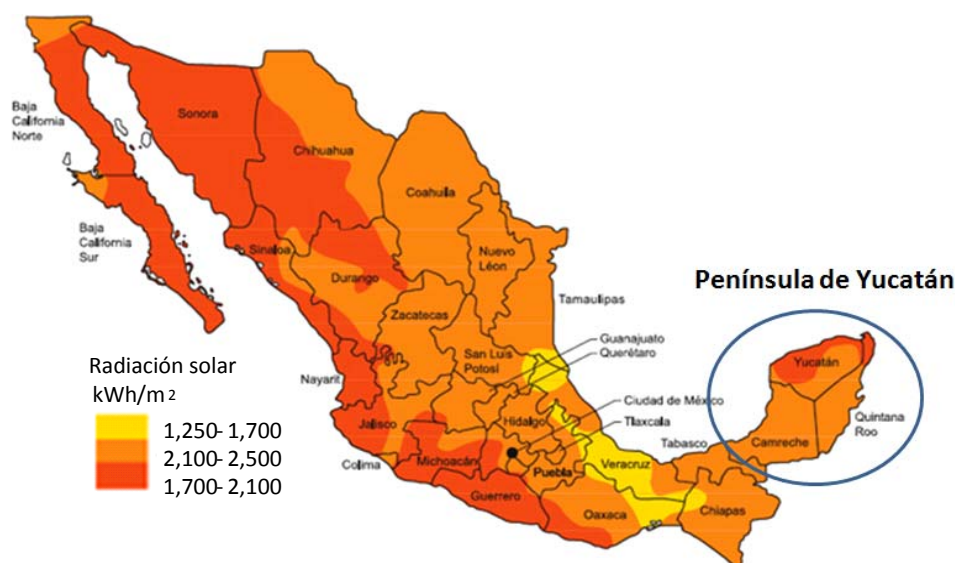


Fig. 3 Solar map of México .

(2) The average daily temperature is above 30 °C from March to October, however, the critical period occurs in April, May and June with an average maximum temperature of 37 °C and an extreme maximum of 40 °C.

(3) The availability of solar radiation per hour in the summer period is highest in May and June with a maximum daily solar radiation of 560 W/m² (Fig. 4).

Market demand: The dried chilies are consumed in large quantities, however, the most part of the producing countries are captive markets. Tasting for new flavors and successive migrations, occurring since the beginning of this century, are leading to rising demand for these products and preparations based on them.

In recent years, the demand for Habanero chili dried has increased in domestic and international markets; also, there is interest in developing processes to achieve this goal in a cheap way with the least possible energy consumption. Several factors are considered to determine the market demand, which are such as follows:

Cultivation and consumption: Nowadays, Habanero chili is cultivated throughout the year in Yucatán State and according to statistics from the Ministry of Agriculture and Rural Development, about 500 ha are

seeded annually; 4,000 t of this product are consumed in the state and the rest is sent to different parts into the Mexican Republic and abroad, with a turnover of 3 million dollars per year. Consumption of this product is 65% fresh and 35% in industrialized chutneys.

Diagnosis of the offer: According to statistics, the average annual production over the past 10 years is estimated in 500 t or 600 t per year, being the major yield obtained in the months of September, October, November and December [16]. Production and harvest area of fresh Habanero chili in Yucatán have increased with an annual growth rate of 9.7% and 11.4%, respectively.

Marketing: The major part of the total production is sold in Merida City, which would be sent to different destinations [17].

Until three years ago, the production was sold to the following markets:

- local 60%, regional 30%, national 10%.

In the last three years, the distribution of marketed production has had the following trend:

- local 40%, regional 10%, national 20%, export 30%.

Therefore, the time when the production of Habanero chili was focused in local consumption, is giving way to a new vision in these times of globalized trade.

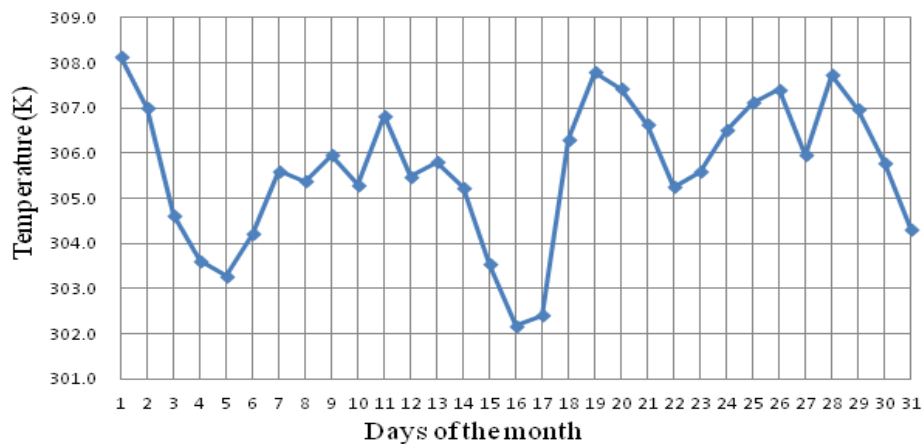


Fig. 4 Average temperature in Merida, Yucatán in May 2011 [15].

Demand diagnosis: This demand is covered by two sectors: commercial and industrial with 90% and 10% of the total demand, respectively, with a no reliable history, or a specified number of sector activity.

Market size: The target market is the United States, which demands this kind of products for domestic consumption of ethnic groups, for usage in industry as condiments and spices and as basis for paintings with high resistance in the industry of alkaloids and extracts, which are exported to other countries. Like the United States market, the local market represents a large percentage of the Habanero chili consumption, so that Yucatán State market is also considered.

The economy in the destination country and the consumption area were established, consumption of hot peppers is concentrated in the western region and in the Atlantic region, with location specified in the following cities in these three regions:

- West Coast Region with location in the California area in the cities of Los Angeles and San Francisco;
- East Coast Region with locations in the cities of Chicago, Illinois and New York;
- Region Southeast Region with city location in the city of Miami, Florida.

In these cities, the highest populations of Mexican immigrants, Oriental origin and Latino population in general are located with the highest consumption of hot and spicy foods. Also these regions have one of the highest incomes per capita into the United States,

ranging between \$18,000.00 and \$36,000.00 per year. According to statistics published by the ASTA (American Spice Traders Association) [18], consumption of spicy foods and spices in general has grown by 25% in the last 10 years in the United States.

Consumer buying patterns end: For Chili Habanero, there is no consumer buying patterns end, because it is a product that has been recently introduced to the United States of America, however, the buying pattern of similar products could be considered, such as fresh and processed Jalapeño chili, which in the 80's and 90's decades had an important purchase volume, and distributors, commissions and brokers realize the purchase procedure in different international entry points of fresh product from México, located in the cities of Nogales, Arizona, Mc Allen and Laredo, Texas and Miami, Florida and Pompano Beach, Florida.

Trending market: The consumption of Habanero chili as fresh, dried, crushed or processed has an annual growth tendency of 59% for the next 5 years.

Products tendency: The main products that the market demands of Habanero chili are classified as: fresh chili, whole dried chili, dehydrated chili powder, chili paste for processing. The market trend is upwards (Fig. 5), especially in the first two forms (fresh and dried whole), 90% of Habanero chili production is marketed as fresh product and the remaining 10% goes to the preparation of sauces, pastas and dehydrated.

Feasibility Analysis of Drying Process Habanero Chili Using a Hybrid-Solar-Fluidized Bed Dryer in Yucatán, México

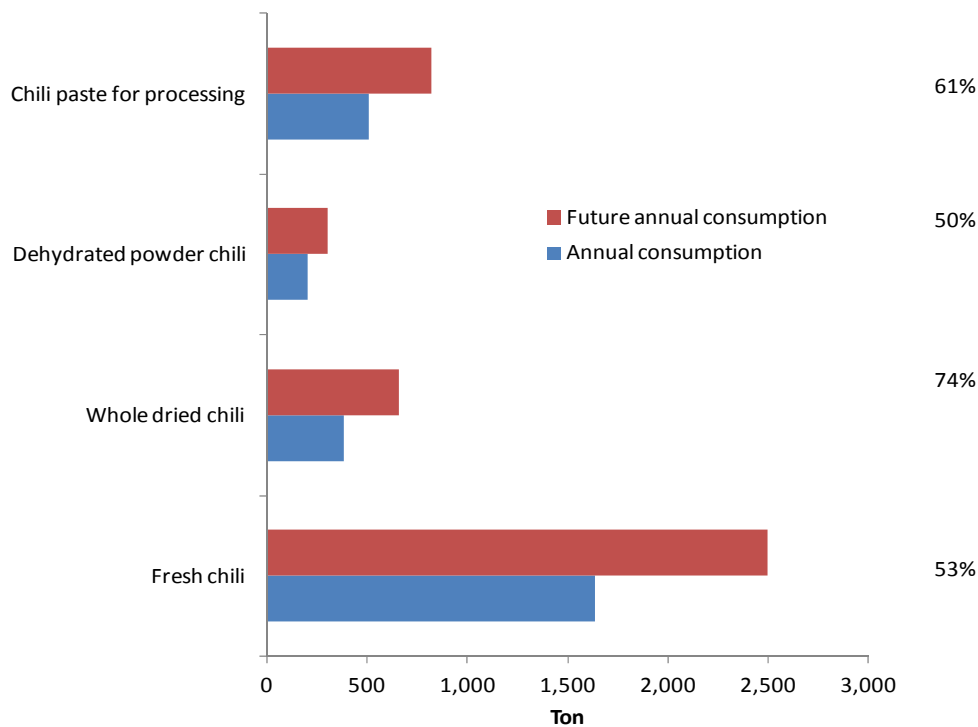


Fig. 5 Trending market for Habanero chili.

The final product is intended to a market, which included the main consumers of Habanero chili production in the Yucatan State, located to the local market, represented by the Merida City in Yucatan and foreign market is represented by the United States.

Five hundred acres of Habanero chili are being planted in Yucatan, which is the most notable product in the region. Today, its production is so important due to the increasing popularity either at México or in various parts in the world. Demand in the U.S., with its growing Latin population, should be maximized. The Habanero chili exportation presents an interesting investment alternative, therefore, in these times there is interest to develop an efficient, sustainable process to obtain the highest percentage of earnings and profits because of the Habanero chili production has a high potential for significant development in a growing market and low investment costs.

Determining the optimal conditions for the drying process: Current drying processes using trays, rotary dryers and ovens' woods are not competitive due to the

high energy consumption and low efficiency, which are reflected in the product costs, currently the dehydrated chili powder reaches cost up to \$47,000 USD per ton, and it is worth to note that a ton of fresh chili is around \$1,570 USD, with a drying time average of 12 h, which is due the high cost of the fuels and technology used for the dehydration of chili, therefore, a new process to dehydrate Habanero chili through renewable energy with a continuous process needs to be developed, such as the usage of a fluidized bed dryer with solar energy. Fluidized bed dryer, one of the most utilized equipment in drying processing industry, was selected among the available drying technologies, because it allows to dehydrate a wide materials variety, such as granular materials, cereals, polymers, chemical compounds, pharmaceutical compounds, fertilizers, crystalline products and mineral crystal, by employing particles in the range of 50-5,000 μm . This dryer offers great advantages, compared to other drying equipment, such as Ref. [1]:

- High transfer of energy and matter between the

drying gas and solid particles are obtained, which increases the drying rate;

- Suitable mixing process of solids is obtained in short time, allowing a homogeneous drying;
- Easy to control temperature within the bed, due to exposing the solid particles to the same treatment conditions;
- Simplicity in design, allowing handled in an easy way the dry sample into the drying process because of the simple construction;
- This equipment can be operated in batch and continuous form, compared with other drying techniques.

The conclusive variables in the fluidization process are purge gas velocity and temperature within the bed; however, the last one effect is the most important because that it determines the drying time in a significant value [10] and indirectly the energy consumption into the drying equipment operation.

Despite the operational advantages of fluidized bed dryer, in this research, preliminary analysis showed the initial system had low energetic efficiency related to the operation temperature, air velocity and moisture content of the sample.

According to temperature and energy efficiency profiles, energy efficiency decreased as operational temperature was increased, indeed, the final moisture

content required (5%) (Fig. 6) was affected by operational temperature range (50-70 °C), so, temperature was the first operational factor to be analyzed and the study range selected was 50-60 °C due to the most important quality attributes such as color and pungency, which has been preserved [4-6, 13, 14] into the dried product.

The bed formation and fluidization velocity were affected by the solid wet loss due to the tendency to stick it on the column walls, in fact, this is a characteristic of wet solids with high moisture content (90%) and pretreatment as first stage into the drying process is generally utilized [5, 10], in this case, from the economic point of view a solar pretreatment offers many economical savings, also reduces the residence time in the final dryer, therefore, an efficient and sustainable process could be obtained. In this pretreatment type, energy utilization increased the energetic efficiency of the whole drying process.

Through a technical-economic analysis, the use of solar technology of low cost such as a flat plane collector and an open sky dryer to redesign the initial system were chosen. The first one was coupled to the electric air heating existent into the fluidized bed dryer (Fig. 7) and the open solar dryer was the pretreatment for Habanero chili before the fluidized bed dryer, avoiding the stick effect.

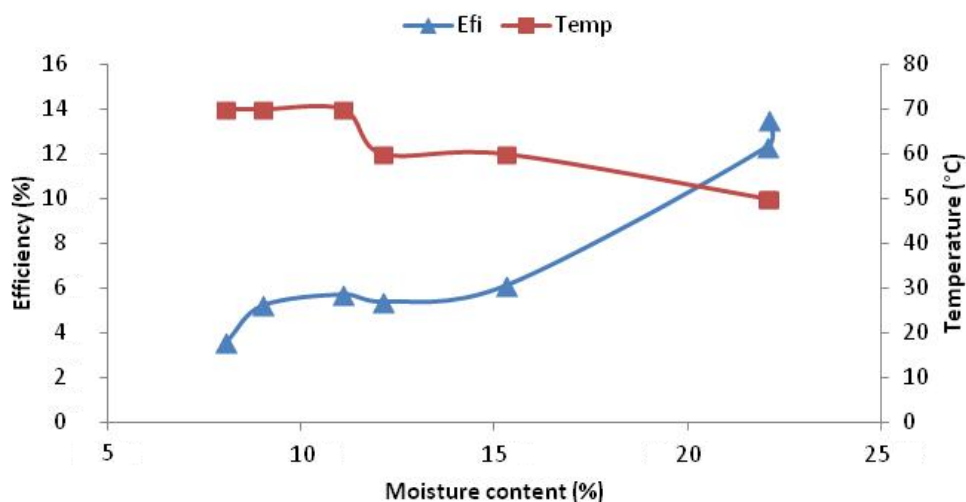


Fig. 6 Energy efficiency of the initial operation conditions into the fluidized bed dryer.

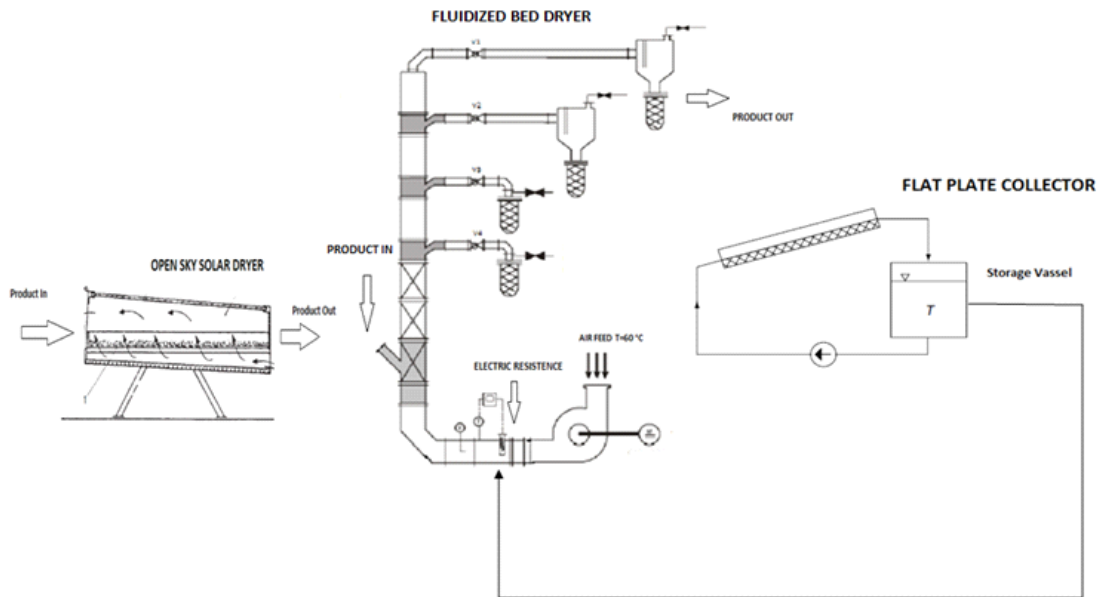


Fig. 7 Hybrid drying process design.

The energy analysis indicated the energy efficiency was almost the same value at 50 °C and 60 °C (4.80% and 4.87%, respectively) and considering the efficiency of the solar flat plane collector (80%) according to maximum daily solar radiation of 560 W/m² integrated existing in Yucatan, the optimum air temperature was established at 60 °C and the fluidization velocity utilized in the analysis was 3-3.5 m/s. The optimum operation conditions were determined according to the real cost of the final product in base of the air heating system.

(1) Redesigning the drying process

The system was conforming by two subsystems: an open sky solar dryer and a flat plane collector coupled a pilot fluidized bed dryer (Fig. 7).

Subsystem 1: Open solar dryer. The moisture content of the fresh chili was reduced from 90% to 30% in 6.8 h (Fig. 8), this process required the major quantity of energy 70% (Table 1) in the drying process due to the biggest water lost takes place. This subsystem avoided the stick effect and reduced the time and electric energy used in the fluidized bed dryer.

Subsystem 2: A flat plane solar collector coupled to a fluidized bed dryer. In this system the solid got into the fluidized bed dryer which has an electric blower,

the leaving air from the blower exchanged heat with the hot water from the storage vessel from the flat plane collector, to obtain the required temperature ($T = 60\text{ °C}$) then, the drying process was completed and the final product had the moisture required of 5% in 3.5 h with 30% (Table 1) of the drying energy.

Therefore, improvements in the energy efficiency (11%) and in the drying time (3.5 h) into the fluidized bed dryer were reached (Fig. 8), after the implementation, an energy saving of 2.6 kW was obtained, which represents 0.52 kg of natural gas per kg of fresh Habanero chili with this technology usage.

(2) Cost analysis of the redesign process

The results obtained through the development of the redesign of Habanero chili drying process allowed reducing the overall drying time, increasing the energy efficiency while electric energy use is reducing with the consequent cost saving (Table 2), even the cost per kg of dried chili was less than half of the commercial cost, increasing the percentage of earnings and profits obtained in the medium and long term in a growing market, where the investment in dried chili production is an attractive alternative. Therefore, the hybrid system developed is a feasible and economic option for redesign the Habanero chili drying at industrial scale,

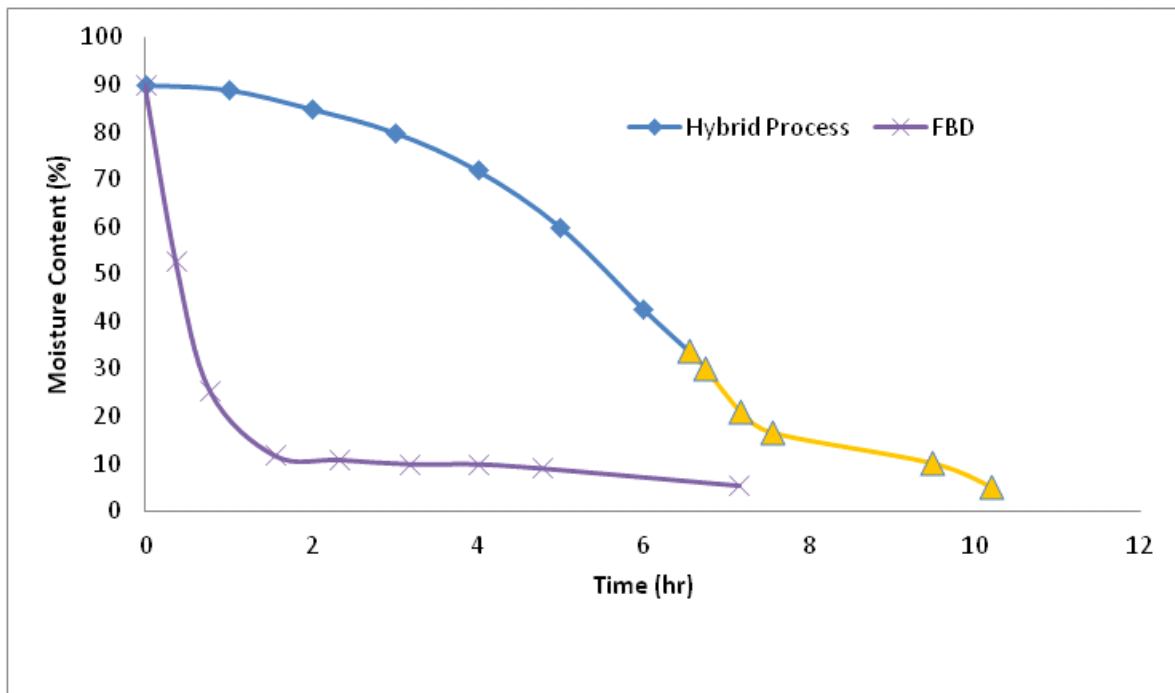


Fig. 8 Experimental results: hybrid drying process vs. FBD (fluidized bed dryer).

Table 1 Heat streams involved in drying process.

Process	Time (h)	η Efficiency (%)	Energy input (%)
Open sky solar dryer	6.80	10.13%	70.00
Solar-electric fluidized bed dryer	3.50	11.00%	30.00
Redesign process	10.30	7.00%	100.00

Table 2 Comparison of different drying processes.

Cost per kg of dried chili (\$)	Drying time (h)	Energysource	Type of process	Final moisture of dried chili (%)
15.40	12.00	Natural gas	Comercial	8.00
40.40	7.50	Electric power	Fluidized bed dryer	5.00
7.70	10.30	Solar electric	Hybrid process	5.00

due to the most important qualities such as color and pungency, which are preserved, even are superior comparable with other industrial dryers such as forced convection heat dryer and tray industrial dryer, which are reflected in color loss (Fig. 9).

4. Conclusions

Habanero chili drying by a solar electric hybrid system is a real alternative to dehydrate this product, being comparable with other industrial dryers such as forced convection heat dryer and tray industrial dryer, being the overall drying time improved with an efficient energy use and important savings in costs production.



Fig. 9 Final product characteristics: (a) hybrid drying process vs. (b) conventional process.

The redesign process distributes the total of the energy usage, being 70% of the energy used in the pretreatment of open sky solar dryer while 30% was used in the fluidized bed dryer. An energy saving of 2.6

kW was obtained, that represents 0.52 kg of natural gas per kg of fresh Habanero chili.

The hybrid system developed is a feasible and sustainable option for redesign the Habanero chilli drying process at industrial scale, according to the Habanero chili production in Yucatan, México, the increasing demand in the local region and other countries and cost and quality of the final product, indeed this redesign could be considered as strategic at this time, where the availability of conventional energy is in crisis, being the final product cost affected.

References

- [1] A.S. Mujumdar, Handbook of Industrial Drying, Taylor & Francis, CRC Press, USA, 2007.
- [2] C. Tam, Energy Technology Transitions for Industry: Strategies for the next Industrial Revolution, International Energy Agency, Paris, France, 2009.
- [3] A. Brown, S. Moller, Z. Dobrotkova, Renewable Energy: Markets and Prospects by Technology, International Energy Agency, Paris, France, 2011.
- [4] A. Artnaseaw, S. Theerakulpisut, C. Benjapiyaporn, Development of a vacuum heat pump dryer for drying chili, Biosystems Engineering 105 (2010) 130-138.
- [5] Y. Soysal, Z. Ayhan, O. Estürk, M.F. Arıkan, Intermittent microwave-convective drying of red pepper: Drying kinetics, physical (colour and texture) and sensory quality, Engineering 103 (2009) 455-463.
- [6] S. Kaleemullah, R. Kailappan, Drying Kinetics of red chilies in a rotary dryer, Biosystems Engineering 92 (1) (2005) 15-23.
- [7] B.K. Bala, M.A. Morshed, M.F. Rahman, Solar drying of mushroom using solar tunnel dryer, in: International Solar Food Processing Conference, Bangladesh, 2009, pp. 1-11.
- [8] J. Facao, A.C. Olivera, Analysis of a plate heat pipe solar collector, in: International Conference on Sustainable Energy Technologies, Bonn, 2004, pp. 1-5.
- [9] S. Sami, N. Etesami, A. Rahimi, Energy and exergy analysis of an indirect solar cabinet dryer based on mathematical modeling results, Energy 36 (5) (2011) 2847-2855.
- [10] S. Syahrul, F. Hamdullahpur, I. Dincer, Energy analysis of fluidized bed drying of most particles, Energy 2 (2) (2002) 87-98.
- [11] J.F. Manwell, Hybrid energy systems, Encyclopedia of Energy 3 (2004) 215-226.
- [12] J.L. Rubio-Pino, S.B. Iloki-Assanga, Chemical characterization, nutritional and biological activity evaluation in vitro of habanero peppers (*Capsicum chinense*), chiltepín (*Capsicum annuum* var. *glabriusculum*), green and red pepper (*Capsicum annum* L), in VII Congress III Northeast and National Food Science and Biotechnology 2010.
- [13] J.J.G. Trujillo-Aguirre, O. Gutiérrez-Alonzo, C.R. Pérez-Llanes, Morphological characteristics of flower and fruit again habanero chili genotypes (*Capsicum Chinense* Jacq.) collected in Yucatán México, in Breeding and Genetic Resources 2003.
- [14] R. Hernández, Martínez, D. Quinto, D. Cuevas, O. Acosta, J. Aguilar, Drying of habanero chili with solar energy, Revista Iberoamericana de Tecnología Postcosecha (10) (2010) 120-127.
- [15] Weather Station of Faculty of Engineering, University of Yucatán consulted on 20.10.11.
- [16] Mexican Association of Secretaries of Rural Development (AMSDA) Home Page, <http://www.amsda.com.mx/>.
- [17] Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA) Home Page, <http://www.sagarpa.gob.mx/Paginas/default.aspx>.
- [18] ASTA (American Spice Traders Association) Home Page, <http://www.astaspice.org/i4a/pages/index.cfm?pagei>.