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An Economically Viable Way to Produce Beer from the Maize Malt

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This work was done to dry of maize malt (*Zea mays*) by a infrared dryer in order to generate a derivative of high commercial value beer industry, and try to add value to maize culture. Models of drying curves were used to simulate the drying isotherms at 45, 55 and 65°C. From this maize malt a beer has been obtained and its sensorial qualities were compared with two commercial beers. The cost of production of the malt was also being measured to verify the economic feasibility of the process. Results showed that the best condition to dry the maize malt in a infrared dryer was 55°C for 1.5 h and this process time was about 4-times minor than drying in a convective dryer. Comparing the sensory quality of maize beer showed that the beer is as good as the commercial beers. It was found that the production cost of beer reduces by 10% when changing the barley malt by maize malt.The proposed of applying of infrared drying process to obtain the maize malt obtain was viable, obtaining therefore a competitive advantage for both the producer, industrial and consumer, providing an alternative source of income as well as to the beer industrial for which the innovation of raw materials will determine the adaptability, processing flexibility and competitiveness in the market.

1. Introduction

The economy of various countries have been busy the maize trade, despite the international crisis, Brazil is expected to reap a record maize harvest total of 67.8 million tons in 2011/12, compared to a production of 57.4 million tons in the previous cycle, according to projections released by the National Supply Company (CONAB), surpassing the volume of soybeans. The competition has influenced the industry to develop new sources of competitive advantages, requiring a continual process of innovation. This has led companies to generate and use technologies or tools that will create opportunities for new products, services and business processes (Simon and Satolo, 2009). Thus, this study aimed to analyze the insertion of a malt production from maize as a competitive alternative to the beer industry. A new drying process (infrared drying) has been used to obtain the maize malt and it was used in beer production.

Beer is not a drink distilled, obtained by alcoholic fermentation of must from malted cereal, usually barley malt. The addition of other raw starch or hop is optional, and in general the alcohol content is low, 3% to 8%, being considered an almost complete food because its membership encompasses compounds such as proteins, amino acids, carbohydrates (glucose, maltose, dextrin, etc.), various mineral elements (calcium, phosphorus, sulfur, etc.) alcohol, carbon dioxide and most of the B vitamins. The basic raw materials for the manufacture of beer are water, hops, malt and yeast. The malt is still the saccharification agent allowed in brewing, although techniques may be proposals for its replacement by the use of pure enzymes. In its preparation can be kept active enzyme system, mainly composed of α and β-amylase (Aquarone at al., 2001).

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However, as barley is little produced in Brazil, the effect of barley malt in beer production cost is high, since, most of this raw material is imported. Thus, the producing malt from a source which is produced in Brazil will reduces its costs for breweries. As malt is obtained from either germinated seed, which must be subsequently dried, so that are reduced the moisture content and maintained its enzymatic activity. Therefore, a study of the ideal conditions of the drying process should be performed (Benvenga et al., 2011; Curvelo Santana et al., 2010).

Besides its importance in the removal of moisture, which serves to avoid microbial contamination and increase the shelf life of products, the drying processes are used to improve the taste, enzymes, vitamins and other functional contents into foods. Due to importance of drying process to industries, several techniques have been applied to fruits and vegetables, from the simplest ones as solar and sun drying to the most expensive, like microwave and freeze drying. In order to get dried products with high nutritional and sensorial attributes, non-conventional drying methods have also been used, like those with modified atmosphere, microwave, osmotic dehydration, sun/solar, freezer drying, foam mat drying, spray drying and others (Cui et al., 2008; De Jesus and Maciel Filho, 2011; Fernande and Rodrigues, 2008; Oi et al., 2013; Santos and Silva, 2008).

De Jesus and Maciel Filho (2011) have been optimized the drying process of amylase by response surface methodology. In this study a microwave vacuum drying was used to estimate the main effects of vacuum pressure and power on the enzymatic and water activities. The experimental in star design revealed that microwave vacuum drying is influenced mainly by power. The dehydrated product showed high enzymatic activity and low water activity. Benvenga et al. (2011) and Curvelo Santana et al. (2010) have been used an aired convective dryer to dry the amylases from maize malt, After the execution of the experiments an optimal condition to obtain the high enzymatic activity has been found at 54°C for 5-6 h of drying process.

2. Material and Methods

2.1. Maize malt and beer production

Maize seeds were selected, weighted, washed, carried to the moisture absorption from 40 to 45 % and carried to germination in laboratorial scale. The germination time was between 4 and 5 days. Maize malt was dried according to drying methodology and after that, it was triturated and stored at 5°C (Biazus et al, 2009). In each drying samples of maize malt the enzymatic activity was determined by Wohlgenuth method, modified for Sandstedt, Kneen & Blish (SKB), according to Biazus et al. (2009) and protein content in drying samples of the maize malt was measured by Bradford (1976) modified method. The maize malt was mixed with maize starch and hydrolyzed for 8 h at 55-60°C, as described by Aquaroni et al. (2001). When hydrolyzed inorganic nutrients were added, the pH adjusted pasteurized and added to the Saccharomyces cerevisiae (Fermix ® or Flashman ®) yeast. The fermentation was maintained at a temperature of about 6 ° C in order to hold greater amount of CO_2, and after fermentation, the alcohol content of the beers was close to 6 ° GL. The sensory analyzes were made comparing appearance, flavor and aroma of two maize beers with two commercial barley beers according to 1-9 time of a Hedonic scale. The samples passed through a statistical analysis by Student's t test (Aquaroni et al., 2001).

2.2. Drying process methodology

Infrared dryer with air circulation was utilized in maize malt drying process. Dryer operated in constants conditions of temperature, air relative moisture (60 ± 2%) and air flux (1 m^3/h). Tree drying temperature were utilized in the assays, 45°C, 55°C e 65°C, according to Curvelo Santana et al. (2010). The germinated seeds (malt) were placed in watch glass (previously dried and weight measured in drying temperatures), weight moistures were measured and they were placed to dryer in the assays temperatures. After each drying hour (12 h in total), drying samples were collected for measuring the drying weight ($\boldsymbol{X_i}$) and; the moisture content ($\boldsymbol{M_i}$) withdrawal from maize malt was obtained by weight difference (on percent form). The initial moisture content was measured at 103-105°C of drying temperature, during 40 at 50 hours in convective dryer according to Curvelo Santana et al. (2010). The malted seeds weights were dimensionless ($\boldsymbol{X}$) after division for moisture weight of germinated seeds. The drying isotherms were made in the temperatures studied (Benvenga et al., 2011; Curvelo Santana et al., 2010).

$$X = \frac{X_i}{X_0} \tag{1}$$

$$M_i = \left(\frac{X_0 - X_i}{X_0} \right) \quad \text{(2.a) or in percents} \quad \boldsymbol{M_i} = \left(\frac{\boldsymbol{X_0} - \boldsymbol{X_i}}{\boldsymbol{X_0}} \right) * 100 \tag{2.b}$$

While: $\boldsymbol{X}$ as the malt weight varying with the drying time ($\boldsymbol{t}$, min), from an initial, $\boldsymbol{X_0}$, is the initial malt weight and Xi is the malt weight at time i (i varying from 0 until 12, equivalent to the hours of drying process). For simulation of the drying process of maize seeds some model have been used, such as it showed in Table

1, found in Curvelo Santana et al. (2010). While, consider X as the malt weight varying with the drying time (t, h) from an initial, X_0, until an equilibrium weight, X_e, on a constant rate of moisture withdrawn, K (h^{-1}).

Table 1. Drying models used in this work

Equation	Model	Author
3	$X = A \exp(-K.t)$	Brooeker *et al*. (1974)
4	$X = \exp(-K.t)$	Lewis (1921)
5	$t = A.\ln X + B.[\ln X]^2$	Thompson *et al*. (1968)
6	$X = 1 + A.t + B.t^2$	Wang e Singh (1978)

2.4. bibliographic

Taking into account that the development of new products from by-products and / or wastes, it is not only environmental awareness as well as competitive strategy and also in view of that maize possesses interesting chemical-producing maize malt, carried out a study of the main destinations of this raw material to include the optimization of drying of malt as part of the maize chain. Therefore, a literature search was performed, based on the consultation papers selected through a search engine for database SciELO (Scientific Electronic Library Online) and Scopus-Elsevier, and conference proceedings and libraries renowned universities. The focus of the research was the interaction between the concepts of competitiveness, sustainability, supply chain and the use of maize byproducts. Within this context, this work was divided into five stages. In the first step, it was determined the maize supply chain, identifying the critical points of this chain. The second determines the concentration of total protein. In the third stage presents analysis of enzyme activity. In the fourth step is presented obtaining the malt and the fifth stage the drying of the malt. In this study we propose a methodology for the extraction of malt (Simon and Satolo, 2009).

3. Results and Discussions

3.1. Maize malt production

Table 2 shows the results of measurements of change in mass of maize malt with the drying time in dimensionless form. Note that the time to stabilize the mass of malt is approximately 360 min at temperature of 45 ° C and near 100 min for all other temperatures. The mass of moisture removal (M) at temperatures of 45 and 65 ° C was close to 40% and at temperatures of 55 °C was around 46% of the initial mass. Figure 1 shows the drying data of maize seeds drying process. According Biazus et al. (2009) the β-amylases have the optimum temperature close to 55 °C and the α-amylases, close to 75 °C, and they are deactivated by thermal denaturation when exposed at temperatures above their optimum temperature for a long period of drying. Thus, the temperature of 55 ° C was regarded as the optimal for this drying process because there is lower energy expenditure at this temperature. By the variance analysis was found that from 90 min drying no significant differences for the experimental points and the average dry weight was 54.1% of the initial mass, indicating that there was a moisture removal of 46%.

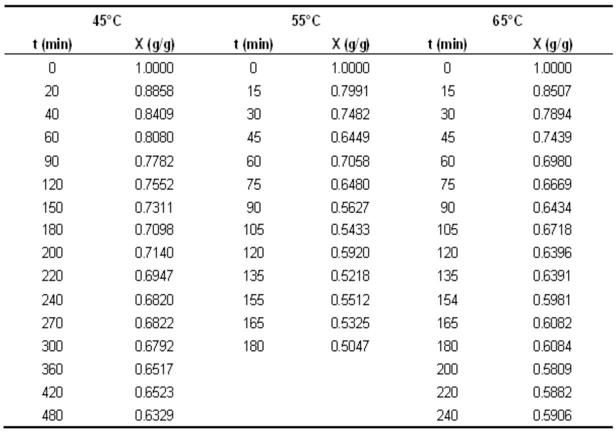
Bevenga et al. (2011) and Santana et al. (2010) also showed that the best temperature for the drying of malt using convective dryer with air circulation is close to 55 °C. However, the ideal time for drying was between 5.18 and 6 h (311 and 360 min), since only after these conditions malt was dry, losing up to 43% moisture. Under these conditions, the enzyme activity of dry malt was 5.26 times higher than the initial activity of malt, 20 000 times higher than the activity of maize "in nature" and 6-times higher than the activity of malt barley. So, infrared is the best drying process than other drying processes.

A comparison between the results obtained in this work with those obtained by Bevenga et al. (2011) and by Santana et al. (2010) showed that it is possible to obtain malt, maize dried by the drying method with infrared waves, while maintaining the quality obtained in a convective dryer, but with a drying time of 3 to 4 times lower and removing more than 7% moisture drying of the joint. And as drying time, means energy expenditure and, consequently, spending money, just an economic advantage between drying with respect to conventional infrared can be observed. According Biazus et al. (2009), the dry malt can be stored for up to 19 weeks at room temperature so as cooled to 10 °C. Thus, the product can be stored for a long period without being contaminated by microorganisms and without losing its quality.

Table 3 shows the results of the fit of the models, their parameters of drying kinetics and correlation (R). According to Barros Neto et al. (2001), the closer to 1.0 is its correlation coefficient (R) will be adjusted over the model. Thus, according to the data presented in Table 3, it can be considered that the model of

Thompson et al. (1968) is among the models studied in this work, the most adjusted to the experimental data for drying of malt by infrared waves, since all the values of R were higher than 0.90.

Table 2. Drying data of corn malt drying process in a infrared dryer



45°C		55°C		65°C	
t (min)	X (g/g)	t (min)	X (g/g)	t (min)	X (g/g)
0	1.0000	0	1.0000	0	1.0000
20	0.8858	15	0.7991	15	0.8507
40	0.8409	30	0.7482	30	0.7894
60	0.8080	45	0.6449	45	0.7439
90	0.7782	60	0.7058	60	0.6980
120	0.7552	75	0.6480	75	0.6669
150	0.7311	90	0.5627	90	0.6434
180	0.7098	105	0.5433	105	0.6718
200	0.7140	120	0.5920	120	0.6396
220	0.6947	135	0.5218	135	0.6391
240	0.6820	155	0.5512	154	0.5981
270	0.6822	165	0.5325	165	0.6082
300	0.6792	180	0.5047	180	0.6084
360	0.6517			200	0.5809
420	0.6523			220	0.5882
480	0.6329			240	0.5906

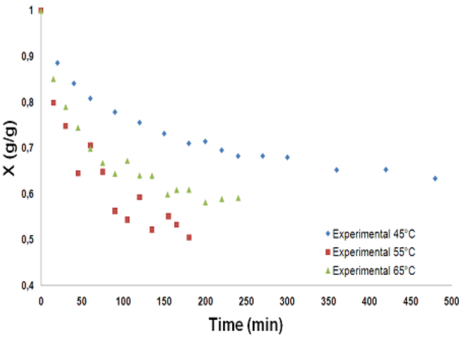


Figure 1. Variation of seed mass to the drying time during the corn drying process

Table 3. Results on the fit of models

Models	Brooeker *et al.* (1974)		Lewis (1921)	
T(°C)	***X*** = ***A*** exp(-***Kt***)	R	***X*** = exp (-***Kt***)	R
45	X=0.8613exp(-0.0008)t	0.9003	X=exp(-0.0010)t	0.5520
55	X=0.8330exp(-0.0030)t	0.9061	X=exp(-0.0050)t	0.7540
65	X=0.8299exp(-0.0020)t	0.8856	X=exp(-0.0030)t	0.5740
Models	**Thompson et al (1968)**		Wang & Singh (1978)	
T(°C)	***t*** **=** ***A*** **ln** ***X*** **+** ***B*** **[ln** ***X*** **]^2**	**R**	***X*** = 1 + ***At*** + ***Bt***^{2}	R
45	t = 453.1 lnx+3358 (lnx)^2	**0.9847**	X=1-0.0021t+2.10^{-6}t^2	0.8973
55	t = -1.244 lnx +360.9 (lnx)^2	**0.9416**	X=1-0.0070t+210^{-5}t^2	0.9275
65	t = 186.4 lnx +1134 (lnx)^2	**0.9622**	X=1-0.0050t+1.10^{-5}t^2	0.9184

3.2. Maize beer as a factor of competitiveness

Thus, competition is seen as an active process of creating spaces and opportunities through innovation in a broad sense, not restricted by technological change, but considering innovation as any effort aimed at the development of new production processes, sources of raw materials, managerial dimensions or field of activity of the company. In studies on sustainable supply chain was considered not only the product from initial processing of raw materials to delivery to the customer, but also integrating sustainability issues and flows that extend beyond the core management of the supply chain and product design, production of by-products, by-products produced during the use of the product, extending product life, product end of life and recovery processes at end of life (Simon and Satolo, 2009). The analysis life cycle, according to Dias (2009), is a tool to study the environmental aspects and impacts associated with a product, process or service. Such an assessment, in addition to environmental concerns, aims to improve the competitiveness of products in markets with conceptual concerns of sustainability and reduce production costs, to include decisions regarding end of life for products. Increasingly valued by consumers, environmental awareness has become a differentiator, not only the image of the company that adopts, but the real impact that occurs in the environment.

Figure represents the possible inclusion of maize malt in beer chain, which is obtained from a product (fresh maize) come from the retailer and going directly to the industrialization and being marketed mainly for brewing industry thus the main consumer in this chain. From the farm, from where you get the seed maize, past the warehouses, where the quality control of the maize is done, until the industrial brewers. The good quality control of seeds in warehouses will lead to a good quality malt that will be obtained in the malting and thus, if you get a good quality beer.

Beer is the result of the combination of basically four raw materials: water, barley malt, yeast and hops. Another component is the packaging, in particular, the high share in the total cost of the product. Another raw material added in substitution for malt are non-malted cereals (adjuncts) such as broken rice, maize grits and syrup, invert sugar maize, better known by the name of high-maltose. The use of the latter is growing considerably the production of factories. The proportion of adjuncts beer, however, most breweries, does not exceed 35%.

Table 4 is shown a survey of the production cost of beer, Brazil. It is noted that overhead costs represent more than 70% of beer production costs. On individual costs, the barley malt represents approximately 15% of beer production costs (Setti, 2013). The barley price exported to Brazil is approximately US$ 240 per ton of seeds, which the maize price commercialized in Brazil is US$ 180 per ton of seeds, which will have a reduction of 25% in cost with raw material for the beer production (AGROLINK, 2013; WORLD BANK, 2013). According to Curvelo Santana et al. (2010), the amylases from maize malt were 6-times more active than the barley malt and therefore can be reduced in 6-times the amount of malt to be used in beer production and thus, the raw material cost is reduced by 87% and more than 10% of total costs. These arguments make maize a raw material of high competitive degree for Brazilian brewing industry. Figure 3 shows the variation of sensory results attributed by consumers for appearance, flavor and aroma of two maize beers (this work) and two barley beers marketed in Brazil.

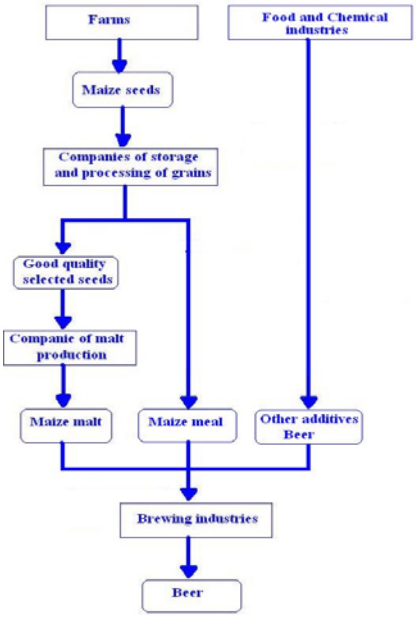


Figure 2. Supply chain malt barley for obtaining beer

Table 4. Composition of beer costs using barley and maize malt

Item	Barley malt	Maize malt
Variable Costs	**27.5**	**17.8**
Barley Malt	**14.8**	**3.40**
High-Maltose	3.30	3.74
Hand Labor	3.70	4.20
Utilities	3.20	3.63
Breaking	0.70	0.79
Other	1.80	2.04
Overhead Costs	**72.5**	**82.2**
Sales	18.4	20.9
Administrative	13.9	15.8
Depreciation	11.0	12.5
Other	29.2	33.1

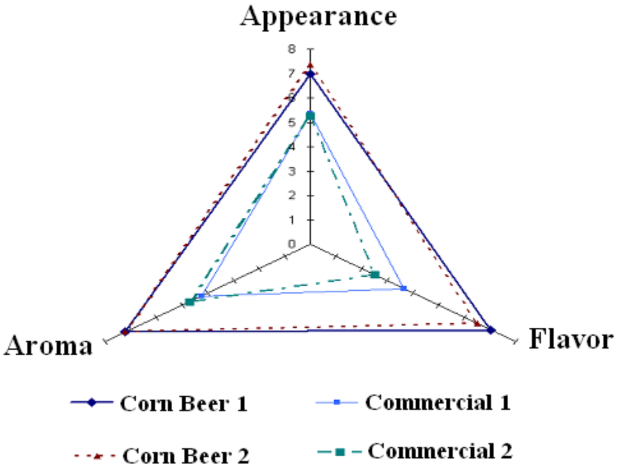


Figure 3. Sensorial evaluation of beers by the hedonic scale.

Sensory analysis showed that beer obtained by *S. cerevisiae* yeast from Flashman ® was the best in all sensory qualities. However, even maize beer (*S. cerevisiae* yeast Fermix®) that had bad results presented with sensory values equal to one of the marketed. The physico-chemical analyzes show that the beers are within the standards set for beers with the already produced industrially. Thus, it proved that is possible to produce beer from malted maize, looking to add economic value to a cereal as consolidated in the regional economy and high availability.

4. Conclusions

It is possible concluded that the best condition to dry the maize malt in a infrared dryer was 55°C for 1.5 h and this process time was about 4-times minor than drying in a convective dryer. Comparing the sensory quality of maize beer showed that the beer is as good as the commercial beers. It was found that the production cost of beer reduces by 10% when changing the barley malt by maize malt.The proposed of applying of infrared drying process to obtain the maize malt obtain was viable, obtaining therefore a competitive advantage for both the producer, industrial and consumer, providing an alternative source of income as well as to the beer industrial for which the innovation of raw materials will determine the adaptability, processing flexibility and competitiveness in the market.

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