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Flavored Drink Production Using Broken Rice: Evaluation of Physical-Chemical Properties and Power Consumption of Industrial Stirring System

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Abstract

The industrial rice processing generates, in average, 14% of broken grains called grits, which are not well accepted by consumers, representing large economic loss. Researches have been conducted to increase the use of rice by-products as well as their benefit. Among them, beverages are attracting the attention, being develop. To contribute to this field, this study aimed to prepare a non-alcoholic flavored drink from rice grits; evaluate the physical-chemical properties and evaluate de power consumption of stirring system for the drink industrial production. The drink production involved the cooking of the rice grits, followed by crushing, homogenization, filtration and flavorization in a stirring tank, obtaining the final product for consumption. The power consumption calculation for mixing tanks was evaluated in three different situations at 25ºC, considering the pre-defined tank design and the drink characteristics. Results based on the physicochemical characteristics indicate that the rice flavored drink is a food alternative to substitute milk or soy extract drinks. On the industrial production aspects, the increasing in the consumed energy to the small stirring variations was observed, and it needs to be considered to the stirring equipment design in the industrial process.

Keywords: food waste recovery, drink industrial processing, stirring system, rice industry

1. Introduction

Rice (*Oryza sativa* L.) is one of the main foods consumed by humans (Costa et al., 2016). It is a great staple carbohydrate sources which is classified as whole grain and contains a range of essential nutrients such as vitamin A and B, phosphorous, sodium, manganese, potassium and magnesium (Folorunso, Omoniyi, & Habeeb, 2016). Starch is the major constituent of milled rice, about 90% of the dry matter, it is also composed of proteins (6.3-7.1%), lipids (0.3-0.5%) and fibers (0.2-0.5%) which can be found in the rice endosperm (De Souza et al., 2016).

During the processing of this cereal about 14% of the rice grains break and become the major byproduct known as rice grits (Setyawati et al., 2016; Silva et al., 2015). Its production was about 67.34 million tons, considering world rice production in 2016 of 481 million tons (United States Department of Agriculture Service - (USDA) Research Economic Service - (RES), n.d.). This quantity justifies the need to add value to this by-product through the development of new products. A lack of researches to evaluate the rice grits potential as a food source is observed. One alternative that is growing up is the development of extracts and fermented beverages using rice bran and grits (De Souza et al., 2016). It can provide low-cost products with nutritional and functional quality. Besides that, the flavored drink produced by rice byproduct is pointed out as new option for people who are lactose intolerant, allergic to milk proteins, soy proteins or opt for vegetarianism (Costa et al., 2016).

To develop new industrialized food products it is necessary to evaluate some important properties, such as the rheological behavior (Helena & Desireé, 2013). This is important to verify the structural behavior of foods and their processing capabilities, allowing the correct dimensioning of pumps, pipes, heat exchangers, stirrers, preventing any damage to the quality of the final product (Costa et al., 2016).

The stirring is influenced by the velocity of a liquid, the intensity of turbulence, the rate of energy dissipation and its distribution in the vessel, and finally by the viscosity of the reaction; all of which determine the fluid dynamics of the reactor (Battista, Fino, Mancini, & Ruggeri, 2016). Viscosity is an essential feature for this kind of study, as it determines the acceptance or rejection of such products on sale, besides the evaluation and operation of food processing equipments (Bezerra, Rigo, Junior, & Córdova, 2009).

Stirring systems are very important in the food industry for performing functions such as the mass and heat transfers, liquids mixture, emulsions formation and reagents mixture in a reactor (Rao, 2013). The stirring and mixing process doesn't have any conservation effect and has the only intention to help the processing or alter the sensorial qualities of the food (Fellows, 2009). Many factors are important in determining the best stirring system; one of them is the energy consumption that has its cost directly bounded to the costs of the goods sold (COGS). The energy consumption in a stirrer depends on the quantity and viscosity of the food in the stirrer, and the position, type, speed and size of the rotor (Fellows, 2009; Levenspiel, 2012).

The consumed energy calculation becomes important to the industries for help to define the better stirring equipment with the minimum energy consumption (Cremasco, 2014). Thus, it is necessary to analyze the viscosity properties to verify the energy consumption of a stirring system and to operate with low costs. To contribute to the food waste recovery field, this study aimed to develop drinks using rice grits as raw material, to determine its physicochemical characteristics, and calculate the required power for a stirring system, considering its industrial production.

2. Methodology

Rice grits (EPAGRI 109 variety) was provided by a rice processing industry located in São Paulo State, Brazil. The fruit pulp and sucrose were obtained from a local supplier.

2.1 Flavored Drink Preparation

The process to obtain the rice grits extract was made following the Soares Junior methodology (Soares Junior et al., 2010) with some modifications. Rice grits were washed with drinking water and it was cooked (1 part grits: 2 parts water) at 70ºC for 10 minutes. After that, the cooked material was mixed with water and crushed (1 part cooked grits: 2 parts water) in a food multiprocessor for 5 minutes. The mixture was filtered in a fine mesh cotton fabric filter. The filtered material was called rice grits extract.

Sucrose (20% wt) and fruit pulp (30% wt) were added to the rice extract to obtain the rice flavored drink. The mixture was homogenized in a blender. The obtained product was stored in high density polyethylene bottles with screw lids. The sealed bottles were pasteurized at 65ºC for 30 minutes and stored under refrigeration at 5ºC.

2.2 Physical-Chemical Characterization

The physical-chemical analyses of rice grits extract were realized in triplicates, utilizing analytical grade reagents and deionized water.

2.2.1 Humidity and Ashes Levels

For the humidity level determination, the samples were put in hot bath at 100ºC and evaporated until dryness. Thus, they were dried in oven at 105ºC for 8 hours, determining the level of humidity gravimetrically (equation 1). The ashes level was determined gravimetrically (equation 2) after dry matter calcination in muffle furnace at 550 ºC for 2 hours, following the Association of Official Agricultural Chemistry (AOAC) (Association of Official Agricultural Chemistry (AOAC), 2005).

$$H(\%) = \frac{(WS - DS)}{WS} \, x\, 100 \tag{1}$$

Where: H (humidity); WS (wet sample weight); DS (dry sample weight)

$$Ash(\%) = \frac{(DS - CS)}{DS} \, x\, 100 \tag{2}$$

Where: DS (dry sample weight); CS (calcined sample weight).

2.2.2 Proteins

Proteins in samples were determined following the Kjeldahl method (AOAC) (Association of Official Agricultural Chemistry (AOAC), 2005) multiplying the total obtained nitrogen by the factor corresponding to the rice. (5,95). Equations (3) and (4) express the nitrogen (%) and the protein level (%) calculation.

$$(\%)\, nitrogen = \frac{0.014\, x\, N\, x\, f\, x\, V(mL)\, spent}{sample\, weight\, (g)} \, x\, 100 \tag{3}$$

Where: N (mol number); f (sodium hydroxide solution factor).

$$Protein(\%) = Nitrogen(\%)\, x\, Analysed\ sample\ factor \tag{4}$$

2.2.3 Lipids

The lipids were evaluated through Bligh and Dyer method (Bligh & Dyer, 1959), using a three solvents mixture: 1 part chloroform, 2 parts methanol and 0.8 parts water. As the samples contain a larger than 10% water quantity, a correction on the water quantity added must be made according to the beverage humidity. Initially, the sample is mixture with methanol (20 mL), chloroform (10 mL) and water (5.9 mL). Thereafter, more chloroform and water are added to form two distinct phases: non-aqueous (chloroform), containing the lipids, and aqueous (methanol and water) phase, containing the non-lipid substances. The chloroform phase was isolated, and, after the chloroform evaporation, the lipids quantity was obtained by weighing. The lipids level (%) is expressed by equation (5) and the quantity of lipids in grams is expressed by equation (6).

$$Lipids\ level\,(\%) = \left(\frac{20\ x\ lipids\ mass}{\frac{5}{P3}} \right) x\ 100 \tag{5}$$

$$(P1 - P2) = lipids\,(g)\ in\ 5\,mL \tag{6}$$

Where: P1 (Beaker weight with the lipids); P2 (Empty Beaker weight); P3 (Initial sample weight).

2.3.4 Carbohydrates

The carbohydrates content was determined by mass difference (equation 7), i.e., the level corresponding to the value of 100 (% sample mass) subtracting the humidity, ashes, lipids, and proteins levels, following AOAC (Association of Official Agricultural Chemistry (AOAC), 2005).

$$Carbohydrates(\%) = [100 - (Humidity - Ashes - Lipids - Proteins)] \tag{7}$$

2.3.5 Energetic Value

The energetic value (equation 8) was determined following the methodology proposed by Adolfo Lutz Institute (Instituto Adolfo Lutz, 2008).

$$Energetic\ value = (Protein\ x\ 4) + (Carbohydrate\ x\ 4) + (Lipid\ x\ 9) \tag{8}$$

2.3.6 Density, pH and Acidity Level

Density was determined with pycnometer in accordance to the methodology proposed by Adolfo Lutz Institute (Instituto Adolfo Lutz, 2008). The pH was determined in pHmeter at 24 ºC using the methodology described by AOAC (Association of Official Agricultural Chemistry (AOAC), 2005). The acidity was determined by equation (9).

$$Acidity(\%) = \left(\frac{V\ x\ f\ x\ 100}{P\ x\ c} \right) \tag{9}$$

Where: V (volume mL); f (sodium hydroxide solution factor); P (sample mL nº used in titration); c (correction for sodium hydroxide solution).

2.3.7 Soluble Solids Level (ºbrix) and Viscosity

The soluble solids level was determined with refractometer, following the methodology proposed by Adolfo Lutz Institute (Instituto Adolfo Lutz, 2008). The rheological measurements and viscosity were obtained in a rotational viscometer, Brookfield Model DV -I+, with Spindle S01 accessory. The analyses were performed at 25ºC.

2.3.8 Consumed Energy Evaluation

The stirring system dimensioning for the industrial production of flavored drink was based on Levenspiel (Levenspiel, 2012), considering parameters such as: tank geometry, stirred tank energy, and drink density (Table 1).

Table 1. Parameters adopted for consumed energy determination in the stirring system at the industrial process of flavored drink

Parameter	Value
Tank inner diameter	2 m
Tank height	3 m
Number of flat blade impeller	3
Stirred tank power	150 W
Flavored drink density (ρ)	1.154 $g.mL^{-1}$

The impeller diameter (d), and tank diameters (D) relation was established as 0.2. Three distinct rotations were selected for this study (20, 30 and 50 rpm). Based on these assumptions, the stirring level and consumed energy was evaluated.

3. Results and Discussion

The physical-chemical characterization results of energetic value, average humidity level (humid base), ashes, lipids, proteins, total carbohydrates (dry base), acidity level, pH, soluble solids, density, and viscosity of the beverages obtained from the rice grits extract are presented in Table 2.

Table 2. Physicochemical characterization of flavored rice grits drink

Parameter	Result
Energetic Value ($Kcal.100g^{-1}$)	79.043 ± 0.443
Humidity ($g.100\ g^{-1}$)	80.126 ± 0.113
Ashes ($g.100\ g^{-1}$)	0.115 ± 0.011
Lipids ($g.100\ g^{-1}$)	0.002 ± 0.001
Proteins ($g.100\ g^{-1}$)	0.866 ± 0.161
Carbohydrates ($g.100\ g^{-1}$)	18.890 ± 0.056
acidity (% in phytic acid)	0.623 ± 0.054
pH	4.00 ± 0.006
Soluble Solids (°Brix)	10.0
Density ($g.mL^{-1}$)	1.154 ± 0.009
Relative Viscosity (mPa.s)	65.5 ± 0.707

The average soluble solids levels, the acidity and the pH of rice grits extract values are on the required standard by Brazilian Normative Instruction nº 01, January 7th 2000 (Brasil, 2000). However, the average soluble solids level and acidity are inferior to the values reports by (Carvalho et al., 2011; Jaenkel, Rodrigues, & Silva, 2010), while the pH is above the range obtained in these same studies. This fact is because these authors utilized mixed beverages, i. e., mixtures of rice and soy extracts, in addition to possible differences in feedstock characteristics and its processing, once stages such as maceration and autoclaving weren't applied in this work.

The rice grits beverage is characterized by being more viscous product in comparison to the soy extract (Carvalho et al., 2011), which is associated to its higher starch level. The relative viscosity obtained from different rotation speed is shown in the Table 3. The viscosity of the rice grits drink was found as 65.5 mPa.s. Studies with rice extract and mixtures of rice and soy extracts showed similar values of viscosity with an average of 63.2 mPa.s (Russell & Delahunty, 2004) and 51 mPa.s (Jaenkel et al., 2010).

It was possible to observe that under the increase in the stirring system torque, there is a decline in the viscosity values, independent of time; thus, presenting pseudoplastic fluid characteristics. This fact favors the mixing process; however, it has implications for the energy cost, due to the increase of the energy consume for stirring.

In this way, the evaluation of the mixing system in different situations assists in determining the best technical and economic conditions for the flavored rice drink production.

Table 3. Viscosity determined as a function of the rotation adopted for the situations 1, 2, and 3, at 25°C

Situation	Viscosity* (mPa.s)	Adopted rotation speed (rpm)
1	65,5 ± 0,707	20
2	53,5 ± 0,707	30
3	46,6 ± 0,848	50

(*) Relative viscosity

The rice drink can undergo starch retrogradation during the thermal process of preparation, possibly altering the rheological properties of the product. In this case, it is important to have knowledge about the stirring energy consumed in different situation of viscosity and stirring rotation at 25ºC. The results of the parameters obtained for each studied situation are presented in Table 4.

In all studied situations, the stirring level has shown itself too low, becoming then inadequate for the realization of ideal homogenization of the mixture. It is believed that these low values are due to the temperature, once the 3 situations were measured at 25ºC. Depending on the product viscosity and the impeller rotation, differences in the draining type, in the yield (NQ) and stirring levels (NA) are observed, influencing, consequently, in the consumed energy.

Table 4. Energy consumed and industrial parameters for the analyzed situations

Parameter	Situation 1	Situation 2	Situation 3
N Rey	936.5	1719.8	3291
Fu	1	1	1
Npo	4	4.5	5
NQ	0.58	0.6	0.683
Q (m^3/min)	0.7424	1.152	2.2
v (m/min)	0.236	0.37	0.7
NA	0.13	0.2	0.4
Pot. (W)	5.25	19.8	102.6

N Rey = Reynolds' number; fu = N Rey correction factor in function of viscosity; Npo = Potency Number; NQ = Stirring yield; Q = Volumetric dislocation; v = average speed; NA = Stirring Level; Pot. = Consumed energy for 3 impellers.

Results showed that the situation 1 presented a lower energy level of 5.25 W. The situation 2, in turn, demonstrated that the consumed energy was 19.8 W, despite presenting high N Rey. It was identified that situation 3 presented high N Rey value and consequently the fluid is in turbulent regime, resulting energy for the engaging of the 1026 W impeller. In this evaluation, the usage of a 150 W engine was assigned for the stirring system. This way, it will have proper energy to stir all the studied conditions.

As for the industrial production, viscosity analysis showed that rice grits extract is a more viscous product than soy extract, possessing pseudoplastic characteristics. Situation 3 achieved the highest level (0.4) requiring the highest power required to drive the impeller (102.6 W). The required power of the situation 2 was reduced by approximately 81% (19.8W), with 50% less of stirring level of situation 3. The calculation of consumed energy in the stirring tanks demonstrated that the small stirring variation alters the required energy, this way generating higher production spending, due to the energy consuming costs.

4. Conclusion

It is concluded that the flavored beverage produced from the rice grits extract possesses physicochemical characteristics to be used as alternative food viable for the substitution of milk or soy extract by people who are intolerant to animal milk lactose or allergic to the soy proteins. Besides that, the production of flavored beverage utilizing rice grits represents an increase in the possibilities of valuation of this residue, contributing to the diminishing of food waste, with positive environmental impact.

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