Immersion Frying Characterization of

Colombian Donut

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Abstract

Frying by immersion is a cooking process where edible oil or fat is used at a temperature above the boiling point of water. In this investigation the effect of the fry variables was evaluated by immersion in the donut, a very characteristic food product in Colombia, a base of coastal cheese, corn starch among other ingredients; a 2x3 factorial design was used, the temperature levels were 150°C, 160°C and 170°C and the 3 time levels were 120s, 240s and 300s; it was detected that the process of reduction of the affect (p <0.05) the absorption of oil and the loss of humidity in all the treatments studied, finally the sensory evaluation for the color parameters and the general acceptance was influenced by the frying treatment, while the gravity was the least valued parameter under the conditions of the process.

Keywords: oil absorption, donut, frying, moisture loss

1. Introduction

The donut is a representative food of Latin American cuisine, especially in Colombia where it is consumed throughout the year as a fried appetizer with a prevalence at Christmas time, although there is a market for street vendors and small
shops where it is consumed daily. It is the product of the mixture of basic ingredients such as corn starch, cassava starch, cheese, water or milk, in addition it can include force flour, yeast, eggs, salt and sugar with which a consistent and homogeneous mass is formed, forming spheres that are subsequently fried by immersion in oil; after frying the fritters obtain characteristic attributes such as golden color, a crunchy crust, a soft spongy crumb; in general they are consumed fresh since the aging phenomenon starts quickly once the frying process ends, generating undesirable properties such as hardening and stiffness when kept at room temperature; in Colombia these products are widely commercialized, they are distributed in the form of pre-mix or frozen dough, however there is no standardization nor is enough information known to improve the quality parameters [1]. It has diverse variations around the world, as well as many ingredients and names; in Mexico for example, the raw material for the production of the donut includes refined or whole wheat flour, sodium bicarbonate, acidulants, preservatives and other additional substances that improve the flavor, texture and extend the useful life of the food; The process of mixing the dough including the factors of water absorption, time and temperature is paramount to produce an optimum mass [2].

Frying by immersion or simply frying in oil is one of the oldest and most widespread unit operations in food preparation [3]. This technique can be summarized in four basic stages [4] such as: heating where there is no significant evaporation of water but the food is heated to the boiling point and lasts a few seconds, the next stage is the surface boiling that involves a rapid increase in the coefficient of heat transfer by convection, then the third stage that corresponds to the period of decreasing speed takes more time and is characterized by the physical phenomena of evaporation to reach the boil in the center of the food, important changes are generated at a biochemical level, denaturation of proteins, gelatinization of starches and the formation of a crust that acts as a barrier to the heat transfer mechanism continues, the fourth stage is the bubble end point where the bubbling stops and conforms the definitive crust; In general, the frying process involves temperatures of 150°C to 190°C under atmospheric conditions; the sensory attributes such as flavor, color and texture of fried products favors its high popularity among consumers, however there are several disadvantages the quality of the oil exposed to high temperatures and the oil content of the final product [5].

Frying process study is vital to understand the phenomenon of oil absorption and the behavior of fried products, one of the main challenges for the food industry at a global level is precisely to reduce the oil content and maintain the quality characteristics of the food. Three components have been investigated Dana and Saguy, [6] to explain the absorption of oil: the mechanism of water replacement represented by the heat transfer and the consequent evaporation of water, the second mechanism is the effect of the cooling phase argued by the absorption of oil when the food is removed from the fryer taking into account the surface and viscosity of the oil, the last mechanism is that of surfactants that provide a very
limited explanation about the phenomenon of oil absorption to such an extent that some Authors contradict this mechanism concluding that they do not significantly influence when frying times are prolonged [7]. The reports of studies on the frying process in starchy matrices are very limited, so this research focuses on establishing the incidence of temperature and time parameters in the frying process of the Colombian traditionally made donut.

2. Methodology

2.1 Materials

The coastal cheese was purchased in a dairy establishment in the city of Cartagena Bolívar, it was transferred to the Research Laboratory of the University of Cartagena, the corresponding conditioning was carried out and it was kept at 4 ± 1 °C until its use. Corn starch, flour, baking powder and other ingredients were supplied by a commercial distributor in the city.

2.2 Manufacturing Procedure donut

The formulation provided by vendors of traditional donuts from the city was used, the elements described in Table 1 were mixed, initially the coastal cheese, the corn starch (Zea mays), the flour of strength, the baking powder and the sugar was mixed by hand, then the previously beaten egg was added slowly and the mixing process was continued, adding the water until a consistent and homogeneous mass was obtained spheres of 30 ± 0.01 g were formed and kept at room temperature until the frying process.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal chese</td>
<td>38</td>
</tr>
<tr>
<td>Cornstarch</td>
<td>21</td>
</tr>
<tr>
<td>Sugar</td>
<td>7,2</td>
</tr>
<tr>
<td>Flour of strenght</td>
<td>8</td>
</tr>
<tr>
<td>Egg</td>
<td>7</td>
</tr>
<tr>
<td>Water</td>
<td>18</td>
</tr>
<tr>
<td>Bakingpoder</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

2.3 Frying and experimental design

Each experimental unit constituted by 30 ± 0.01 g of donuts were fried by immersion at atmospheric pressure (100.813 kPa) in a mixture of oil (palm olein and soybean) in a commercial fryer with temperature control and 6L capacity (Waring Pro Df280, China). We worked with a 2x3 factorial experimental design
(Table 2) where the factors were the temperature of the process in three levels 150, 160 and 170 °C and times of 120s, 240s, 300s, the product / oil ratio was 1:20 p/v with three repetitions per treatment.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
<th>T7</th>
<th>T8</th>
<th>T9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>160</td>
<td>160</td>
<td>160</td>
<td>170</td>
<td>170</td>
<td>170</td>
</tr>
<tr>
<td>Time (s)</td>
<td>120</td>
<td>240</td>
<td>300</td>
<td>120</td>
<td>240</td>
<td>300</td>
<td>120</td>
<td>240</td>
<td>300</td>
</tr>
</tbody>
</table>

2.4 Determination of moisture and oil content

5 ± 0.01 g of sample were taken in a previously tared and dry laboratory crucible, placed in an electric oven (HE 2652, Challenger, Colombia) at a temperature of 105°C for 24 hours until reaching a constant weight; the samples were cooled in a desiccator (4906019, Normax, Portugal) and weighed, the results were expressed on a dry basis. The oil content was determined with 1 ± 0.01 g of sample using a Soxhlet Extractor and ethyl ether as solvent at 99.8% purity and boiling point 40-60 °C, with reflux for 8h, each test was performed five times. The extract was dried at 60°C ± 0.1 for 30 min in an electric oven until the solvent was removed, cooled and weighed, the results were expressed on a dry basis [8], [9].

2.5 Sensory evaluation

A five-point modified hedonic scale was used where 1 = I dislike a lot, 2 = dislike me moderately, 3 = I do not like or dislike, 4 = I like moderately and 5 = I like it a lot. The untrained sensory panel was made up of 30 people, habitual consumers of donuts who evaluated three basic parameters: color, fatty and general acceptance.

2.6 Statistic analysis

The results were analyzed using STATGRAPHICS Centurión XVI.I® in Windows 10, an analysis of variance (ANOVA) was applied with a level of significance of 95% for the results of the donut in the different treatments of temperature and time each in triplicate; the differences were considered significant (p < 0.05); The method used to discriminate between means is Fisher's minimum significant difference procedure (LSD).

3. Results

The results of this investigation show that the percentages of oil absorption of the donut (Figure 1) increased significantly (p <0.05) as the process times increased in the three frying temperatures. The phenomenon of oil absorption can be explained mainly by the considerable loss of moisture in the food, which is replaced by oil Bermúdez et al., [10] but the oil gain also depends on the operating
conditions between the interaction of the factors that intervene in the frying process [11]. In the process heat and mass are transferred simultaneously, causing fundamental changes at the microstructural level in the outside of the product and in the mass that forms it, generating multiple chemical reactions such as starch gelatinization, protein denaturation, water vaporization and changes in color [12]. However, in the treatments with higher temperature, that is, 160°C and 170°C, the absorption percentage was lower compared to the treatment at 150°C, obtaining an oil absorption peak of 13.8%, in T3 at 150°C and 300s, while the lowest corresponded to T7 when the temperature was increased to 170°C and the shorter processing time. Some authors Montes et al., [13] report that the temperature does not have a significant effect between 150°C and 180°C, the higher the temperature, the lower the absorption of oil on the surface, so that low process temperature implies an absorption elevated the frying time is a very important factor, a relation between these two parameters on the absorption of oil in food has been evidenced since generally the frying times are shorter when the temperature is higher [14]. Analysis in other foods have found that the oil content can increase rapidly in banana slices up to 13.38% at 160°C and 60s [10], in the frying of arepa de huevo at 170°C and 420s the fat content reached up to 45.7 ± 1.8 (g fat g⁻¹ dry solids), for the same time of frying the fat content was lower at a higher temperature [15]; the kinetics of oil absorption in starchy matrices increased exponentially during the first 120s of frying [16]. In addition, the incidence of frying has been demonstrated by immersion in the absorption of oil in sweet potatoes [17], corn chips at frying temperatures between 170°C and 190°C [18] and the study simultaneo of the phenomenon of heat and mass transfer that affects the quality of the final product to optimize and control the frying process [19].

![Figure 1. Absorption of oil (%) of the donut in the different frying treatments by immersion.](image)
There is an inversely proportional relationship between the fat content and the moisture loss of the donut (Figure 2); this implies that while the absorption of oil is high, the percentage of humidity is lower in all frying treatments; at the highest temperature (170°C) the water content is significantly lower (p <0.05) with respect to the treatments at 150°C and 160°C. This can be explained by the high temperatures in the frying stage by immersion above the boiling point of the water contained in the food; since in essence it is a dehydration process that necessarily implies the evaporation of important amounts of water [20], very complex to control due to factors such as time, temperature, type of oil, size and nature of the product [21]; the loss of humidity is a phenomenon of mass transport of the frying process, in this investigation the minimum peak was 27.5% of water at approximately 170°C and 300s, this decrease during the first minutes is due to the increase in the thickness of the superficial crust, which leads to the reduction of the heat transfer rate of steam on the surface [22]. Likewise, in the superficial boiling stage where there is a water loss simultaneous to the previously reported oil absorption, an increase in the surface transfer and the beginning of the formation of the crust originates [23], which can act as a barrier to slow down the exchange of dough and oil as a means of frying, in addition the composition of the food matrix, structure and porosity involved in the dehydration of the food [24]. Other investigations have found similar values of moisture loss in the frying of foods such as potatoes [25], [26], chicken meat [27] and plantain slices, which although are values comparable have certain differences due to experimental conditions and food [28].

![Figure 2. Humidity loss (%) of the donut in the different frying treatments by immersion](image)

The sensory evaluation of the Colombian donut (Table 3) allowed to know the influence of frying by immersion in the product obtained; Statistically significant differences were established (p <0.05) in all the evaluated parameters, in a general
way it can be inferred that the increase of the time and temperature of frying had a positive effect on the results of the sensory panel, the color was affected by the conditions of fried generating changes that can be as harmful as beneficial, because a bad use of these factors deteriorates the final color of the product, consequently T6 gave the highest values (4.1 ± 0.38), while T1 was the least valued (2.0 ± 0.51), this can be explained by the combination of process factors (120s-150°C), so a higher temperature will favor the development of the characteristic color changes in this type of fried food [29], in addition the sensory characteristics of fried foods such as color can be related to the compounds generated in the oil, it is believed that when it is fresh, the food does not brown enough [30].

The fattening of the donut was the least valued parameter, this suggests a practical challenge to find a treatment that meets the best conditions starting from the alimentary matrix of the donut with a minimum of 2.3 ± 0.43; finally, the acceptability of the donut indicates that T6 was the product that had the most preference on the part of the sensory panel with an assessment of 4.5 ± 0.34 / 5 equivalent to 90% acceptability; these results are similar to those reported frying cassava chips variety Armenia with 120s and 160C reached an acceptability of 92% (4.6 / 5) and potato chips that were sensorially very well evaluated [31].

**Table 3.** Summary of results obtained in the sensory evaluation test.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Color</th>
<th>Greasy</th>
<th>Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>2.0 ± 0.51&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.5 ± 0.31&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.9 ± 0.40&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T2</td>
<td>2.6 ± 0.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.6 ± 0.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.0 ± 0.36&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T3</td>
<td>2.8 ± 0.47&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.3 ± 0.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.1 ± 0.43&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T4</td>
<td>3.3 ± 0.53&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.1 ± 0.37&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.2 ± 0.40&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>T5</td>
<td>3.7 ± 0.51&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3.1 ± 0.40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.9 ± 0.42&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T6</td>
<td>4.1 ± 0.38&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.3 ± 0.30&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.5 ± 0.34&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>T7</td>
<td>3.7 ± 0.54&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2.9 ± 0.55&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.9 ± 0.38&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T8</td>
<td>3.6 ± 0.50&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3.0 ± 0.38&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>4.0 ± 0.41&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T9</td>
<td>3.4 ± 0.46&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.0 ± 0.44&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.6 ± 0.40&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**4. Conclusions**

The results of this investigation show that there is an inversely proportional relationship between the absorption of oil and the loss of moisture in the frying by immersion of the Colombian donut; this implies that the oil content decreases under the conditions of time vs. temperature of the frying process, and the request for humidity is greater with the high treatments in said conditions. From the sensory point of view, treatment six presented the best values for color, fatty and acceptability; This study can provide input to understand the donut frying, a very consumed food in Colombia, also should consider the structure of the food matrix and more advanced techniques, because they can help to understand the heat treatment of frying in the product.
References


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