Alternative methodology of special coffee roasting in the electric popcorn maker

Metodología alternativa de tostado especial de café en la máquina eléctrica de palomitas de maíz

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ABSTRACT
The aim was to develop and evaluate an alternative method for roasting coffee, using a domestic electric popcorn machine, estimating an ideal roasting time to obtain a drink of high quality. The experiment was conducted under laboratory conditions, with 10 treatments, with roasting times ranging from 3 to 8 minutes. Grain mass reduction and roasting color classification, according to the ABG Agtron scale, were evaluated.
Roasting was carried out in a domestic electric popcorn maker, from Mondial brand, model PP-04, with a power of 1200W. Time intervals of five to six minutes showed better coffee characteristics, medium roasting point, ideal for specialty coffees. The use of the popcorn machine as a coffee roaster showed a satisfactory result, since in a short period of time, it provided a uniform roast, which attributes superior quality, compared to conventional coffee found on the market.

**Keywords:** Coffea, Drink Quality, Coffee Waves, Roast Color.

**RESUMO**
Objetivou-se desenvolver e avaliar um método alternativo na torrefação de café, utilizando a pipoqueira elétrica doméstica, estimando um tempo de torra ideal para obtenção de uma bebida de alta qualidade. O experimento foi conduzido em condições de laboratório, com 10 tratamentos, com tempos de torra variando de 3 a 8 minutos. Avaliou-se a redução de massa de grãos e a classificação de cor de torra, segundo a escala de ABG Agtron. As torras foram realizadas em pipoqueira elétrica da marca Mondial, modelo PP-04 com uma potência de 1200W. Os intervalos de tempos de cinco a seis minutos apresentaram melhores características do café, ponto de torra média, ideal para os cafés especiais. A utilização da pipoqueira como torrador de café apresentou resultado satisfatório, pois em um curto período de tempo, proporcionou uma torra uniforme, que atribui qualidade superior, comparadas ao café convencional encontrado no mercado.

**Palavras-chave:** Coffea, Qualidade de Bebida, Ondas do Café, Cor de Torra.

**RESUMEN**
El objetivo fue desarrollar y evaluar un método alternativo para tostar café, utilizando una palomita eléctrica doméstica, estimando un tiempo de tostado ideal para obtener una bebida de alta calidad. El experimento se realizó en condiciones de laboratorio, con 10 tratamientos, con tiempos de tostado que variaron de 3 a 8 minutos. Se evaluó la reducción de masa de grano y la clasificación del color tostado, según la escala ABG Agtron. Los asados se realizaron en una palomitera eléctrica de la marca Mondial, modelo PP-04 con una potencia de 1200W. Intervalos de tiempo de cinco a seis minutos mostraron las mejores características del café, punto de tueste medio, ideal para cafés especiales. El uso de la palomita como tostador de café mostró resultados satisfactorios, ya que en un corto período de tiempo proporcionó un tueste uniforme, lo que brinda una calidad superior, en comparación con el café convencional que se encuentra en el mercado.

**Palabras clave:** Café, Calidad de la Bebida, Ondas de Café, Color de Tueste.
1 INTRODUCTION

The coffee tree (*Coffea* spp.) is a shrub of the Rubiaceae family, which produces fruits with a fine and sweet pulp, which is responsible for the production of coffee drinks appreciated for their aroma, acidity and flavor. Coffee is the most consumed drink worldwide, after water (Souza & Santos, 2013), justifying investments and evolution of research to improve the quality of this product.

The coffee production chain is closely related to a network of agroindustry interactions, with production, export, retail and wholesale activities (Gonçalves, 2006). In this way, coffee farming generates income and jobs, which highlights the great importance of the sector, moving people and financial resources to the members of this production chain (Melo, Elias & Silva, 2019).

According to the Brazilian Coffee Industry Association (ABIC), Brazil is the second largest coffee consumer in the world, second only to the United States. In Brazilian territory, it produces about a third of the international coffee production, occupying the position of the world's largest producer for over 150 years (ABIC, 2021).

Fresh coffee, after harvesting, still does not have the desired properties of the drink, which only occurs after processing, a fact that highlights the great importance of post-harvest processes, mainly coffee roasting. This process can be defined as the thermal treatment of foods, for the development of aromatic compounds and the color of the products, in addition to transforming the texture of the food, facilitating the grinding process.

Roasting reduces the coffee acidity, enhancing the drink flavor, but if this process does not occur correctly, it leads to loss of the beneficial properties of the bean, in addition to a decrease in the organoleptic characteristics of the drink and, finally, in the quality of the coffee beverage (Granja, 2021).

The coffee bean roasting process can be divided into three stages: drying, roasting and cooling. In the first stage, the grain loses water and mass, and the release of volatile compounds from the grain. In the next phase, exothermic reactions of pyrolysis and caramelization occur, when the coffee bean undergoes physical and chemical changes. The third and final phase must be carried out to prevent the coffee carbonization (Silva, 2021).
The color change is an indication of the increasing degree of roast level. During this process, the grains change color from blue-green-gray, to yellow, orange, brown, dark brown, and finally, almost black, moderately dark (Poisson, 2017).

The change in grain color is related to the generation of melanoidins, which are products of Maillard reactions (chemical reactions between amino acids and reducing sugars) that provide the brown color of coffee (Belitz, Grosch & Schieberle, 2009; Bemiller & Huber, 2010; Poisson, 2017). Melanoidins are large molecules that give rise to the brown color of coffee and also aid in the texture and body of the beverage. However, the characteristic coloration of coffee does not originate only from these molecules, but also from the caramelization of sugars (Belitz et al., 2009).

The kinetics of the chemical reactions that occur during coffee roasting, such as the Maillard reaction, caramelization and pyrolysis, are established by specific conditions of time and temperature. There are still few studies related to pressure variation during roasting. Roasting begins with heating the coffee beans, which are exposed to temperatures above 190°C (Schenker & Rothgeb, 2017; Pimentel et al., 2020). The characteristic reactions of roasting, such as Maillard, occur between 170°C and caramelization at 220°C. Pyrolytic reactions (decomposition by heat) are the degradation of the chemical and physical properties of grains using thermal energy, which predominate at temperatures above 230°C (Poisson, 2017).

Currently, according to coffee specialists, we are experiencing the fourth coffee wave, which is characterized by the appearance and availability of gourmet and specialty coffees on supermarket shelves. In this context, people have more knowledge about the production process and origin of the beans and even do their own roasting at home. In this fourth wave, coffee is appreciated as an art that can be compared to the sophistication of drinks such as wine. With sensory aspects, coffee can have notes of chocolate, flavors of lemon peel and chocolate and aroma of orchids, with variations between planting regions and roasting classes. Still in the fourth wave, there is a need for the final roasting process to be carried out in the beverage consumer’s own residence (Broadway et al., 2017).
In this sense, with the fourth wave, coffee consumers, more demanding and knowledgeable about the product, are always looking for a product of high quality, which is not usually found on the shelves of conventional markets. This occurs mainly for cultural reasons, as there is still a great demand for a strong drink, that is, a coffee with excessive roasting. Thus, as light to medium roasting is indicated for specialty coffee, it is important to create practical and viable alternatives for current consumers of specialty coffee, who value the beverage of high quality.

A viable option is the homemade roasting of the grain, carried out in common environments, such as in the kitchen of a residence, by homemade equipment, such as a popcorn maker or a microwave, in order to obtain a fresh drink, with adequate and personalized roasting, maintaining all the beneficial characteristics of the drink (Melo, Elias & Silva, 2019).

The characteristics of the domestic popcorn maker are similar to those of an industrial roaster, which operates from a heat source, with agitation of the grains, with two processes of heat exchange, by conduction and convection. Convection occurs by airflow at high temperatures and conduction occurs through physical contact in a specific cylinder that favors heat exchange. The domestic popcorn maker has a relatively low cost and it is easy to buy for people looking for alternative roasting, thus increasing the quality of the drink without leaving home, at a low cost (Silva et al., 2015).

Given the above, the aim of the present work was to develop and evaluate an alternative method of coffee roasting, using a domestic electric popcorn machine, estimating an ideal roasting time to obtain a drink of high quality.

2 MATERIAL AND METHODS

2.1 EXPERIMENT DESCRIPTION

The test was carried out between April and May 2023 at the Laboratório de cafecicultura of the Instituto Federal Goiano, Campus Morrinhos, GO, Brazil. To compose the roasting samples, coffee classified as special was used, in a raw state, with a score of 84
in the sensory classification, according to the Specialty Coffee Association (SCA, 2003). The domestic electric popcorn maker, from Mondial brand, model PP-04, with a power of 1200W (Figure 1) was used for coffee roasting.

Figure 1: Electric popcorn maker used (A) and technical information on the popcorn maker (B).

The mass of each coffee sample, to be used in the popcorn machine, was estimated in a pre-test, where the best results were obtained with 70 grams of raw beans, which also coincides with the amount of popcorn kernels suitable for the popcorn machine used, according to the equipment manufacturer. The amounts of beans were measured using a coffee scale, with timer from the Lyca brand, Timer scale model, capacity of 5000 g, and precision of 0.1g.

The coffee samples, of 70 grams each (Figure 2, A and B), were submitted to 10 treatments and 5 repetitions, being the treatments separated according to the roasting time in the popcorn machine, with intervals of 30 seconds: T1: 3 min , T2: 3 min and 30 s, T3:
4 min, T4: 4 min and 30 s, T5: 5 min, T6: 5 min and 30 s, T7: 6 min, T8: 6 min and 30 s, T9: 7 min, T10: 8 min.

Figure 2: Obtaining raw coffee samples from treatments (A); Coffee beans inserted in the popcorn maker (B and C); assessment of internal temperature (D); and removing and cooling the roasted coffee beans (E and F).

In the first treatment, it was necessary to pre-heat the popcorn machine in 30 seconds and for the other treatments, only 10 seconds. However, before starting the roasting processes, all coffee samples were at the same ambient temperature of 25°C, in order to standardize the initial temperature and eliminate interference from this variable in the treatments.
Following the popcorn maker manufacturer’s recommendation, it is necessary to pause for 3 to 5 minutes between roasts, for the equipment to cool down, avoiding overheating of the popcorn maker’s thermostat and heater.

The maximum internal temperature of the equipment is monitored, during roasting, by a culinary digital thermometer, model TP101, skewer type, which allows measures from -50°C to 300°C, scale of 0.1°C, weight of 75g, with a measurement frequency of 1 sec and 10 sec (Figure 2D). The maximum temperature was 225°C, in 5 min 10s.

At the end of roasting for each treatment, the temperature of the grain mass was reduced by quickly pouring the roasted grains into perforated metal containers, proceeding with manual agitation, in order to interrupt the roasting process. The passage of ambient air through the hot grains cooled them down to room temperature (Figure 2, E and F). Then, the Agtron scale (EMBRAPA, 2004) was used to compare the colors of the roasted beans (Figure 3A and D).
After the grains had cooled (Figure 3A), the coffee was ground using a manual grinder, brand MHW-3BOMBER, racing model M1, with a capacity of 20g, weight of 500g and setting of 15, obtaining a particle size of 340 micron (1 micron = 0.001mm), for further classification of the coffee powder color.

The color of the ground coffee was classified into light, medium and dark roast, using the ABG Color System or Color Scale, from the Presca brand, which allows the
visualization of brown tones, instantly, through the comparative method, allowing the classification of the roasts from very light to burnt (ELMACI & GOK, 2021).

The ground samples were placed in the containers of the ABG color system (Figure 3B), filling them completely, and promoting the compaction of the coffee powder in the containers using the tamper (flat tool for compaction) (Figure 3C). This process was performed for all treatments and the surface became even for more accurate color grading.

Throughout the experiment, other utensils were also used, such as: silicone glove, grain spoon, plastic and metal containers, glass jars and beaker for storing roasted grains.

2.2 EVALUATED VARIABLES

The following dependent variables were evaluated: weight loss of coffee beans, by measuring the beans before and after roasting; and roasting quality, estimated by classifying roasted coffee colors, using the ABG Color System scale.

2.3 QUANTITATIVE DESCRIPTIVE ANALYSIS

Quantitative descriptive analysis was used to analyze the data of this research, as it is the most used sensory description technique in food research, which performs the description, data collection and quantification of the sensory attributes detectable in the sample (Stone et al., 2004).

3 RESULTS

Treatments 1, 2, 3 and 4 (respectively, 3 minutes, 3 minutes and 30 seconds, 4 minutes and 4 minutes and 30 seconds of roasting) showed a loss of grain mass of 10g (14.38% loss) (Table 1). The following treatments showed greater loss of grain mass, directly proportional to the roasting time (Table 1 and Figure 4).
Table 1: Treatments referring to each time interval and means of initial and final mass of the coffee sample, Agrtron scale, ABG color system color standard and coffee color classification.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Time (min)</th>
<th>Initial mass (g)</th>
<th>Final mass (g)</th>
<th>Agrtron scale</th>
<th>ABG system</th>
<th>Color classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>70</td>
<td>60</td>
<td>#</td>
<td>#</td>
<td>Not classified</td>
</tr>
<tr>
<td>2</td>
<td>3.5</td>
<td>70</td>
<td>60</td>
<td>85</td>
<td>2</td>
<td>Light</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>70</td>
<td>60</td>
<td>75</td>
<td>3</td>
<td>Moderately light</td>
</tr>
<tr>
<td>4</td>
<td>4.5</td>
<td>70</td>
<td>60</td>
<td>65</td>
<td>4</td>
<td>Medium light</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>70</td>
<td>59</td>
<td>65</td>
<td>4</td>
<td>Medium light</td>
</tr>
<tr>
<td>6</td>
<td>5.5</td>
<td>70</td>
<td>59</td>
<td>55</td>
<td>5</td>
<td>Medium</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>70</td>
<td>58</td>
<td>55</td>
<td>5</td>
<td>Medium light dark</td>
</tr>
<tr>
<td>8</td>
<td>6.5</td>
<td>70</td>
<td>57</td>
<td>45</td>
<td>6</td>
<td>Medium</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>70</td>
<td>57</td>
<td>45</td>
<td>6</td>
<td>Medium dark</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>70</td>
<td>57</td>
<td>35</td>
<td>7</td>
<td>Dark</td>
</tr>
</tbody>
</table>

Source: Adapted from the methodology proposed by Elmaci et al. (2021).

Figure 4: Weight loss of coffee beans as a function of roasting time in the electric popcorn maker, for treatments from 2 to 10.

In treatment 1, it was not possible to perform the color classification, because the Agrtron and ABG indices were below the minimum of the referred scales. However, the coffee color varied from light to dark (Table 1), between treatments from 2 to 10, with darkening of the grain as a direct function of the roasting time.

In treatment 4, the presence of small grain cracks was observed. In treatment 5, temperature stabilization was observed in relation to roasting, similar to the previous treatment. In treatment 6, flakes of the grain suspended in the popcorn maker were observed, the surface of the grain was dry, which indicates the high temperature and the release of compounds by the grain. In treatment 8, an oiliness was observed on the surface.
of the grains, which promotes the aroma of the drink. This oiliness was increased in treatment 9.

In the last treatment, the beans were subjected to a longer roasting period of eight minutes, where the appearance of “overdone” coffee was observed. In this treatment, a high presence of oil was observed on the surface of the grains, and a burning smell in the environment, due to the excess in the roasting point and in the loss of mass (Table 1).

4 DISCUSSION

The roasting of the coffee beans from treatment 1 was not suitable for a drink of high quality, as the time of 3 minutes was insufficient for the coffee to go through all the roasting processes, which resulted in a very light color, with a cream tone, below the analysis standard used, making the drink taste of high acidity and even an astringency in the drink.

The light and moderately light colors, presented in treatments 2 and 3, respectively (Table 1), are still considered unsatisfactory for a drink of high quality. In these periods of roasting (3.5 and 4 minutes), the beans do not have any oily viscosity on the surface of the beans (MELO, 2004). This fact is expected, since a longer time in the roasting process to obtain a darker roasting level causes the beans to have greater moisture loss (SCHMIDT et al., 2008). In the four minutes time (Treatment 3), the grains showed expansion, the acidity tends to be higher than the sweetness and the surface of the grain is still dry, without the presence of oil.

It is noteworthy that the higher the degree of roasting, within the optimal limit, the greater the release of internal oils to the coffee grain surface (GUIA DO CAFÉ, 2016). According to EMBRAPA (2004), light roasting has a predominant characteristic of an acidic drink, but as the roasting time increases and the coffee has a darker color, the tendency is to reduce the acidity, highlighting other characteristics, such as aroma and “body”.

The cracking of the grains, presented from treatment 4 (4.5 minutes of roasting), allows the release of gases and compounds present inside the grain, facilitating the heating
and the roasting process. The hot grain undergoes high pressure inside and, with the crack, releases the gases and oils necessary for roasting (MELO, 2004).

In the roasting process in the electric popcorn machine, a medium color (light brown) was obtained, in the roasting times from 5 min and 30 s to 6 minutes (Table 1). There is an alternative denomination for this color which is the “Full City Roast” and this phase is obtained with temperatures ranging from 213 to 220°C (EMBRAPA, 2004). In this phase, the expansion of the grain occurs, where carbon dioxide and water leave the grain, with the increase in temperature, initiating the physical rupture in the grain and generating a noise, a pop, popularly known as “crack”. The ground grains are light brown in color, have a light body, minimal aroma, flavor similar to tea, the drink has high acidity, with an acidic and citric taste, fruit and flower notes.

The second popping (crack) of the coffee grains, within approximately 5 minutes, occurs because the internal pressure of the grain increases enough to break the cell wall of the grains. In the roasting process, there are two clicks: the first occurred with a time of one minute and fifty seconds and the second close to 5, in the electric popcorn maker. The second pop happened at a temperature of 225°C, close to the temperature above 230°C mentioned in the literature, where the noise indicates that the roasting is close to the desired point (EMBRAPA, 2004).

According to Fermiano et al. (2022), the aroma is proof of the drink quality, perceived in two periods. In the grinding process, the first fragrance is released, that is, the smell of coffee, which qualifies the aroma, this fragrance will vary in terms of freshness, qualities or even expose undesirable characteristics such as mold. The aromas appreciated in high quality coffees are floral notes, of nuts (walnuts and others) and fruity. The coffee body is an important evaluation in a tasting that deals with the sensation of the coffee in the mouth, the aftertaste. It is a tactile impression on the palate, being the drink “texture” promoted by the greater or lesser presence of essential oils in the grains, which changes according to each roast. In beverage tastings, terms such as light, medium or full-bodied relate to the perception of coffee texture (ABIC, 2018).

Roasting in the popcorn machine suitable for special coffee took between five and six minutes, obtaining a medium light to medium color (Table 1). This roasting point
gives the drink body (sensation of the touch or texture of the coffee in the mouth, the “heaviness that coffee has on the tongue”, called aftertaste, due to the presence of some colloids and sugars in the drink) with a more rustic flavor and velvety. To achieve this flavor, roasting from light to medium is indicated (Pedrosa, 2018). According to Modesta et al. (1999), the light roasting of the grain, when preparing an infusion, makes it possible to obtain a greater amount of aromatic substances, due to a lower volatilization of these substances.

The dark coloration observed after 7 minutes (Table 1) and more pronounced in the last treatment (8 minutes of roasting) is not recommended for a quality drink of a special coffee. At this point of roasting, considerable loss of drink characteristics occurs, with a bitter and burnet coffee taste. According to Smith (1985), dark-roasted coffee has mass losses greater than 18%, compared to light-roasted coffee (12% loss), showing a reduction in the desirable physical and chemical properties of coffee. Dark roasting is very close to burning the beans, as all processes are excessive. Therefore, it is important to be careful in the roasting process to avoid excess, because even if only a few grains are affected, that is, burnt, the drink will have the undesirable characteristics without acidity, without aroma and flavor, prevailing only the bitter, reducing coffee quality (CLUBE CAFÉ, 2014).

In the present work, the treatments with the best results were those classifying light medium tones to medium tones, represented by times of five to six minutes (table 1). Therefore, aspiring coffee roasters are advised to use the average time in this interval as a reference, using the electric popcorn maker as equipment. In this way, the roasting process will result in a coffee with a color between light brown to chocolate brown or caramel. In order to obtain the maximum use of the beans, with a drink of high quality, the roasting activity should be more frequent and distributed in smaller quantities, to guarantee freshness and quality (Reis, 2021). This procedure was carried out in our roasting process, since samples were prepared in the treatments in small quantities, 70 grams each roasting, providing uniform roasting in the popcorn machine and the possibility of always having fresh coffee available to the person at home. Unlike wine, in the case of coffee, the younger the roast, the better the quality of the coffee. Due to the release of CO₂ by the
beans after roasting, it is recommended to wait 24 hours for crushing and the respective preparation of the drink.

The present research showed that roasting times in the popcorn machine below four minutes are not indicated, since they do not allow the main processes of conversion of coffee compounds so that the drink has the characteristics of a full-bodied coffee, or even, a high quality of drink. Roasting times of less than 4 minutes leave the grains pale, without roasting uniformity. Also, roasting longer than six minutes and thirty seconds is not indicated, because it generates a dark roast, impairing the drink quality for a special coffee.

The roasts showed high contrast between the roasting times analyzed in relation to color (Table 1). Roasting with a time of less than 5 minutes was not enough for a good quality coffee, with the grains having a very light color. On the other hand, roasting times greater than 7 minutes were too dark for the quality standard of a special coffee. Times ranging from 5 to 7 minutes provided the best results for a quality coffee, indicating medium roasting with six minutes in the electric popcorn maker (Table 1). It is worth mentioning that to obtain high quality of the coffee drink, it is necessary to monitor the exact roasting varying in this last interval.

It is worth noting that the degree of roasting varies according to the consumer market, that is, the consumer who will define the roasting standard. For example, coffees with lighter colors are appreciated in the United States, but more intense colors are appreciated in Europe. In Brazil, medium-dark roasts are more usual, but for conventional grains (Halal, 2008).

According to Traore, Wilson & Fields (2018), specialty coffees require medium shade roasting (brown) to obtain maximum sensory quality and higher coffee notes. However, with the cultural or habitual influence of drinking traditional coffees, coffee consumers tend to prefer darker coffee, whose roasting provides a fuller-bodied coffee drink (Reis et al., 2021).

The use of the electric popcorn machine as a coffee roaster was considered very satisfactory, as the use of this equipment provided uniform roasting. However, some precautions are necessary, such as roasting time and waiting time for the popcorn machine
to cool, as these are the main details that will influence the color of the roast and the quality of the drink. After roasting, for better conservation and maintenance of the drink’s qualities, it is recommended to store the coffee in a well-closed, dark container, protecting it from moisture, light and oxygen. To always have fresh coffee, you should not roast an amount that lasts for more than a week.

The popcorn machine proved to be a practical, low-cost and efficient alternative for roasting coffee at home, as it is a simple, portable, affordable piece of equipment, with good results for roasting specialty coffees at home. It is worth mentioning that the second author of this work, who is a coffee specialist, has been using this equipment for over 6 years with success in obtaining a drink of high quality. On average, about 1 kg of coffee is roasted per month, and the electric popcorn maker has proven to be durable, even when used for this purpose.

Another great advantage of the popcorn machine, as an alternative roasting equipment, is the dual use of the equipment, as in addition to being used for roasting coffee, it can also serve its original function of making popcorn, diluting the cost of investment in the equipment.

A trend that we are currently experiencing is the fourth generation or wave of coffee, where knowledge and techniques about coffee processing at home are expanding, giving rise to roasting at home, with methodologies that add quality to the drink. Thus, this research highlights the importance of roasting using domestic equipment that is easy to handle and relatively low cost, which provides controlled roasting, according to the appropriate color or consumer preferences.

5 CONCLUSIONS

The popcorn maker is efficient as an alternative coffee roaster, with light to dark colored roasts.

The time of five to six minutes is indicated for a quality coffee roast, in the popcorn machine used, presenting medium coloration and higher quality drink than the conventional ones.
It is recommended to use an electric popcorn maker for homemade coffee roasting.

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