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Research Article

# Mapping the Incidence of Radiation from the Microwave Oven by the Texture of Cheese Breads (*Pães de Queijo*)

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**Abstract:** Food heating in microwave ovens is fast but not uniform. To understand the temperature distribution in these ovens, it is necessary to know the operation of the oven and the interaction of microwaves with the food, in this case, cheese bread. Cheese bread (*Pão de queijo*) is a traditional Brazilian bread widely sold and consumed throughout Brazil. This study aimed to map the incidence of radiation in the domestic microwave oven by evaluating the texture of cheese breads, depending on their formulation and location on the plate during baking. The three formulations used were a control, one with a higher amount of milk, and another with a higher amount of cheese. The response variable evaluated was texture, using a texturometer. The texture of cheese bread was measured by compressive strength analysis using the Stable Micro Systems texture analyzer equipment. All tests were carried out after cooling the cheese breads for 20 minutes after baking, and in triplicate. An analysis of variance of the texture was applied to test the treatments, position on the microwave plate (nine levels), and composition of the cheese bread (three levels), and the means were compared by Tukey's test (95% confidence). The microwave distribution was not uniform in the control and in the formulation with a higher quantity of milk. The lack of uniformity in the distribution of radiation caused by the position of the cheese bread on the microwave oven plate occurs because of cold spots and hot spots in specific places in the oven during operation. In conclusion, the incidence of radiation in the domestic microwave oven during the baking of cheese bread is a function of its formulation and location during baking.

***Keywords*:** baking, food heating, cheese bread, texturometer

## 1. Introduction

Eating habits have been a very important component of society. Changing trends and lifestyles require more specific attributes, such as convenience in food preparation and consumption. Taste, nutrition, and convenience are the driving forces in today's market. There is also a great emphasis on preparing simple meals at home, especially baking using a microwave oven [1].

Microwaves are electromagnetic waves that are reflected by metallic objects, absorbed by dielectric materials, or transmitted through glass. In a microwave oven, these waves penetrate the food and are converted into heat within it, causing the entire food to heat up quickly. This heating is used in many processes like reheating, pre-cooking, tempering, baking, drying, pasteurization, and sterilization in the food industry and at home [2-3]. Ovens using this


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technology are easier to operate and require less maintenance compared to conventional cooking methods [4].

Microwave ovens quickly heat food; however, in some cases, unevenly. Improvement in this regard has been a real challenge for product development food scientists, and microwave oven designers. The different designs of this appliance can lead to better processes, where it is possible to heat food more homogeneously using this radiation. Efficient engineering projects require knowing and understanding the properties with a significant effect on microwave energy absorption, as well as the temperature distribution in food during heating [5-6]. As noted by Ahmed and Ramaswamy [5], the positioning of the food inside the oven is one of these properties since specific places can receive different intensities of irradiation, resulting in variations in temperature distribution. According to Ryynänen [7], the composition of the food is also one of these factors. To improve the oven design, it is necessary to know the product to be handled and its interaction with microwave waves.

One possible application of microwave heating is in products within the bakery industry. Cheese bread, for example, is a traditional Brazilian bread product from the state of Minas Gerais, which is widely sold and consumed throughout Brazil. According to Cavalcante et al. [8], it is a product with high acceptability. It is a recognized source of carbohydrates with a considerable lipid content [8], and is also a gluten-free bakery product that can be consumed as an alternative food by allergic patients and intolerant to wheat proteins [9-10].

An important factor that influences the quality of baked goods is the baking process [11]. In addition to conventional ovens, a microwave oven can be used to bake bread. This type of oven is gaining relevance in cooking processes due to its faster heating speeds, shorter processing time, and lower environmental impact than traditional heating [12], being a sustainable technology that reduces the negative environmental impact and energy consumption [13]. Gutiérrez-Cárdenas et al. [12] compared biscuits baked in a microwave to cookies made from the same dough and baked in an electric oven at 160 °C for 12 minutes. The baking time in the microwave was shorter, indicating its potential for this type of dough.

To understand the temperature distribution in the microwave oven in cheese bread, it is necessary to have a better understanding of the operation of this oven and the interaction of microwaves with this food. Thus, this study aimed to map the incidence of radiation in the domestic microwave oven by the texture of cheese breads, depending on their formulation and location on the plate during baking.

## 2. Material and methods

### 2.1 *Raw material and preparation of cheese bread*

For the experiment, raw materials (sweet cassava starch, sour cassava starch, UHT (Ultra High Temperature) whole cow milk, margarine, refined iodized salt, fresh chicken egg, and half-cured Canastra cheese) were purchased in stores in the city of Lavras, state of Minas Gerais, Brazil.

The experiment consisted of comparing the texture of cheese bread depending on its composition and position on the microwave oven plate (MOP) during baking. Nine positions on the MOP were tested, as shown in Figure 1, and three types of formulations, i.e., control, with a higher amount of milk or a higher amount of cheese.

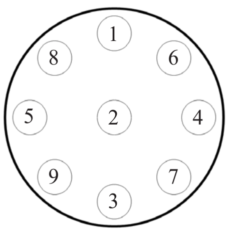


**Figure 1.** Arrangement of cheese breads on the microwave oven plate

The control formulation used to prepare the cheese bread, based on the total amount of starch (sweet + sour), was 50% sweet cassava starch, 50% sour cassava starch, 55% UHT (Ultra High Temperature) whole cow milk, 20% margarine with 80% lipids, 3% refined iodized salt, 25% fresh chicken eggs, 40% half-cured Canastra cheese. The treatment containing more cheese used 60% cheese, and the treatment with more milk used 65% milk, with the amounts of the other ingredients being kept the same as the control. The measurements of all ingredients were measured on a semi-analytical scale.

In a bowl, the sweet and sour cassava starches were scalded by the boiling mixture of milk, margarine, and salt and mixed to homogenize and cool the dough. Eggs and cheese were added and mixed until the ingredients were completely dispersed. After mixing, a cylindrical mold (diameter of 2.8 cm and height of 2.4 cm) was used to mold cheese bread, which was packaged in a Styrofoam tray (23.5 cm × 18 cm × 3.3 cm), and PVC plastic film and refrigerated for 24 hours in a horizontal freezer before baking. After 24 hours, the molded and frozen doughs were baked in a microwave oven, LG model MS3047G, 1,000 W power, for 3 minutes at 80% power (real power 488 W according to the methodology described by Gallawa [14]).

### 2.2 *Texture*

Cheese bread texture was measured by compressive strength analysis using the Stable Micro Systems texture analyzer equipment, model TA.XT2. All tests were carried out after cooling the cheese bread for 20 minutes after baking (approximately 25 °C), in triplicate. The P/75 probe was used in the tests, configured with the parameters: test and pre-test speeds of 2.0 mm · $s^{-1}$, post-test speed of 10.0 mm · $s^{-1}$, and compression distance of 50.0% of the deformation. The software used to obtain the results was Exponent Lite Express (STABLE MICRO SYSTEMS, 2017-Version 4 [15]).

### 2.3 *Statistical analysis*

Analysis of variance of the texture was applied to test the treatments, position on the microwave plate (nine levels), and composition of the cheese bread (three levels). Tukey's test was used to compare means. The analyses were carried out at a 95% confidence level using the STATISTICA 8.0 software (StatSoft, 2007-Version 8.0 [16]).

## 3. Results and discussion

In the food industry, texture can be assessed to control the manufacturing process of a product, especially when there are changes in equipment for its production [17]. Texture can be related to baking conditions, since, according to Gava [18], the duration of heating and the temperature reached by the food is a factor that, if used in excess, damages the texture characteristics (hardness, softness, and juiciness) of a product. As stated by Dariva et al. [19], the compressive strength of the product is related to its softness. In this way, texture was used to evaluate the method of baking cheese bread in a domestic microwave oven.

To analyze the homogeneity of microwave incidence in the microwave oven, the location of the cheese bread on the microwave oven plate (MOP) was varied in nine different positions, and the composition of the product increased the quantities of cheese and milk in the control formulation.

**Table 1.** Analysis of variance of cheese bread texture as a function of position on the MOP and composition and interaction between treatments

| Source of variation | DF | SQ | MQ | F | p-value |
|---|---|---|---|---|---|
| Formulation | 2 | 679,703,218.84 | 339,851,609.42 | 33.7470 | 0.000000* |
| Position on the MOP | 8 | 2,108,802,616.31 | 263,600,327.04 | 26.1753 | 0.000000* |
| Formulation*Position | 16 | 626,559,517.36 | 39,159,969.83 | 3.8885 | 0.000088* |
| Residual (Error) | 54 | 543,811,702.63 | 10,070,587.09 | | |
| Total | 80 | 3,958,877,055.13 | | | |

MOP: microwave oven plate; DF: degrees of freedom; SQ: sum of squares; MQ: mean squares; *statistically significant value at 5% ($p < 0.05$)

Table 1 lists the results of the analysis of variance (ANOVA). The p-values evidenced differences in the texture of cheese bread baked in different positions on the MOP and having different compositions (control, with a higher amount of milk or with a higher amount of cheese), and that there was an interaction between the treatments. These differences indicated that there is no uniformity in the distribution of radiation in the oven and in the way it interacts with the cheese breads so its composition and location influenced the absorption of these microwaves.

Food components such as proteins and triglycerides have low dielectric activities. Free water, monosaccharides, and ions significantly interfere with the dielectric properties, as the polarity means that the component can easily absorb microwave energy [3]. Therefore, changing the amount of ingredients, such as cheese and milk in the cheese bread formulation, can interfere with their interaction with radiation since, according to Bezerra [20], cheese is a concentrated product of protein and fat, and milk is made up of water, proteins, sugars, minerals, fats, and vitamins.

The Tukey's test compared the mean values of the treatments, the results of which are listed in Table 2. At a 5% probability level, sample 2 was the position among the 9 tested here that received the highest incidence of microwaves in the control and the formulation with a higher quantity of milk. Adding more milk results in less interaction of radiation with the cheese bread in position 2. However, when adding more cheese to the formulation, it can be said with 95% certainty that there is uniformity in the distribution of radiation in the oven. These changes resulting from different formulations can be explained by the dielectric properties of cheese breads that change according to the composition of the food, and are also functions of the position on the microwave oven plate.

**Table 2.** Mean values of texture, in N, of cheese bread depending on treatments

| Position on the MOP | Formulation | | |
|---|---|---|---|
| | Control | Higher amount of milk | Higher amount of cheese |
| | Texture (N) | | |
| 1 | 8,069.31$^{A}$ | 5,372.58$^{A}$ | 4,171.47$^{A}$ |
| 2 | 36,236.28$^{C}$ | 21,343.18$^{B}$ | 10,587.66$^{A}$ |
| 3 | 9,940.53$^{A}$ | 6,528.26$^{A}$ | 4,099.99$^{A}$ |
| 4 | 7,993.60$^{A}$ | 7,124.13$^{A}$ | 4,686.57$^{A}$ |
| 5 | 8,791.74$^{A}$ | 6,014.05$^{A}$ | 4,872.42$^{A}$ |
| 6 | 8,099.50$^{A}$ | 5,600.34$^{A}$ | 4,427.18$^{A}$ |
| 7 | 8,421.75$^{A}$ | 5,467.17$^{A}$ | 4,735.69$^{A}$ |
| 8 | 8,972.14$^{A}$ | 6,815.96$^{A}$ | 3,875.99$^{A}$ |
| 9 | 13,274.35$^{AB}$ | 7,543.64$^{A}$ | 4,892.37$^{A}$ |

Different letters, in the same column, indicate significant differences ($p \leq 0.05$) between samples by Tukey's test. MOP = microwave oven plate

The lack of uniformity in the distribution of radiation observed by the position of cheese bread on the MOP occurs because of cold spots (destructive interference between waves) and hot spots (constructive interference) in specific places in the oven during operation, as the microwave incidence has a stationary pattern and these spots are generated by the reflection and absorption of radiation by the oven walls [21-22]. The plate spins to minimize the overexposure to these points, resulting in an average between the effects of high- and low-intensity radiation incidence on the food. However, this food may still be exposed to strongly localized field patterns, such as at the center of the plate, as observed in sample 2 for the control and the formulation with a higher quantity of milk.

According to Teixeira et al. [23], the firmness of commercial cheese bread baked in an electric oven was approximately 991.99 N, a value lower than in the present study. This difference may be due to the baking method and/

or ingredients used in making the cheese bread. Furthermore, a major issue in microwave-baked food products is hard or firm texture [24]. Bou-Orm et al. [25] state that the firmness of microwave-baked bread seems to be related to three main factors: moisture loss, total leaching of amylose from starch granules, and the interaction of gluten and microwave. In the present study, gluten-microwave interaction does not occur, as cheese bread is not made with wheat flour but with cassava starch.

An alternative for baking bread is the use of ovens in combination, that is, microwave and infrared radiation (halogen lamp), for example. As stated by Keskin et al. [26], the oven combined with the two radiations provided specific volume and color values of the bread similar to conventionally baked pieces of bread but the weight loss and firmness values were still higher. These results show that the issue of texture is not specific only to microwave baking. The hybrid oven (infrared and electric), for example, results in lower bread crumb firmness [27]. The incidence of radiation in the aforementioned ovens should also be evaluated in future studies.

## 4. Conclusion

In conclusion, the incidence of radiation in the domestic microwave oven during the baking of cheese bread depends on their formulation and location on the microwave oven plate during the baking process. The microwave distribution was not uniform in the control and in formulations with a higher quantity of milk. However, it showed uniformity when the amount of cheese increased.

## Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## References


[1] Rahman MS. Food preservation: Overview. *Handbook of Food Preservation*. Boca Raton: CRC Press; 2007.

[2] Ramesh MN. Cooking and frying of foods. *Handbook of Food Preservation*. Boca Raton: CRC Press; 2007.

[3] Sahin S, Sumnu SG. *Physical Properties of Foods*. Ankara, Turkey: Springer; 2006.

[4] Vadivambal R, Jayas DS. Non-uniform temperature distribution during microwave heating of food materials-A review. *Food and Bioprocess Technology*. 2010; 3(2): 161-171.

[5] Ahmed J, Ramaswamy HS. Microwave pasteurization and sterilization of foods. *Handbook of Food Preservation*. Boca Raton: CRC Press; 2007.

[6] Pitchai K, Birla S, Subbiah J, Jones DD. *Heating Performance Assessment of Domestic Microwave Ovens*. International Microwave Power Institute's Annual Symposium; 2010. Avaible from: https://digitalcommons.unl.edu/biosysengpres/55/ [Accessed 27th May 2018].

[7] Ryynänen S. *Microwave heating uniformity of multicomponent prepared foods*. Dissertation (Master in Food Technology)-University of Helsinki, Helsinki; 2002.

[8] Cavalcante RBM, Ferro MLCR, Souza Machado R, Dias T, Castro Ferreira TAP. Composição centesimal determinada e a declarada de pães de queijo de diferentes marcas [Determined and declared centesimal composition of cheese breads of different brands.]. *DESAFIOS-Interdisciplinary Journal of the Federal University of Tocantins*. 2019; 6: 79-85.

[9] Pereira J, Ciacco CF, Vilela ER, Pereira RGFA. Função dos ingredientes na consistência da massa e nas características do pão de queijo [Role of ingredients in the consistency of the dough and the characteristics of cheese bread]. *Food Science and Technology*. 2004; 24(4): 494-500.

[10] Kazerski RTS, Biduski B, Weber FH, Plata-Oviedo MSV, Gutkoski LC, Bertolin TE. Substitution of chemically modified corn starch with heat-moisture treated cassava starch in Brazilian Pão de queijo. *International Journal of Gastronomy and Food Science*. 2022; 28: 100541.

[11] Cappelli A, Lupori L, Cini E. Baking technology: A systematic review of machines and plants and their effect on

final products, including improvement strategies. *Trends in Food Science & Technology*. 2021; 115: 275-284.
[12] Gutiérrez-Cárdenas MG, Kaur T, Corona-Chávez A, Olvera-Cervantes JL, Gómez-Salazar JA, Rojas-Laguna R, et al. Dielectric properties analysis of dough and further microwave baking for cookies. *Journal of Food Processing and Preservation*. 2022; 46(9): e16940.
[13] Komarov VV. A review of radio frequency and microwave sustainability-oriented technologies. *Sustainable Materials and Technologies*. 2021; 28: e00234.
[14] Gallawa JC. *How to Check the Output Power (wattage) of a Microwave Oven*. Gonzalez, Florida: Microtech Factory Service; 2013. Available from: http://www.microtechfactoryservice.com/output.html [Accessed 7th March 2017].
[15] Stable Micro Systems. *Exponent Lite Express. Texture Analysis.* Version 4. Godalming: Stable Micro Systems; 2017. Available from: https://www.stablemicrosystems.com/SoftwareUpdateExponentLiteExpress.html [Accessed 7th March 2017].
[16] Statsoft. *Statistica*. Version 8.0. Data analysis Software System. Tulsa: StatSoft; 2007. Avaible from: www.statsoft.com/Products/STATISTICA-Features [Accessed 7th March 2017].
[17] Fani M. Agentes de textura: importância no desenvolvimento dos alimentos [Texturing agents: importance in food development]. *Additives & Ingredients*. 2012; 92: 24-30.
[18] Gava AJ. *Princípios da Tecnologia de Alimentos [Principles of Food Technology]*. São Paulo: Nobel; 1984.
[19] Dariva RC, Bucior D, Colet R, Fernandes IA, Hassemer GS, Miotto SP, et al. Techno-functional properties of cheese breads with native and modified cassava starch produced in an industrial system. *Starch*. 2021; 73(3-4): 2000116.
[20] Bezerra JRMV. *Tecnologia da Fabricação de Derivados do Leite [Technology of Manufacturing Milk Derivatives]*. Guarapuava: Unicentro; 2008.
[21] Annis PJ. Design and use of domestic microwave ovens. *Journal of Food Protection*. 1980; 43(8): 629-632.
[22] Curnutte B. Principles of microwave radiation. *Journal of Food Protection*. 1980; 43(8): 618-624.
[23] Teixeira CS, Neves GADR, Oliveira TFD, Caliari M, Soares Júnior MS. Brazilian cheese bread rolls from fermented and native waxy maize starch. *Science and Agrotechnology*. 2020; 44: e012920.
[24] Sumnu G. Uma revisão sobre cozimento de alimentos em micro-ondas [A review on microwave cooking of food]. *International Journal of Food Science and Technology*. 2001; 36(2): 117-127.
[25] Bou-Orm R, Jury V, Boillereaux L, Le-Bail A. Microwave baking of bread; a review on the impact of formulation and process on bread quality. *Food Reviews International*. 2023; 39(2): 1203-1225.
[26] Keskin SO, Sumnu G, Sahin S. Bread baking in halogen lamp-microwave combination oven. *Food Research International*. 2004; 37(5): 489-495.
[27] Chhanwal N, Ezhilarasi PN, Indrani D, Anandharamakrishnan C. Influence of electrical and hybrid heating on bread quality during baking. *Journal of Food Science and Technology*. 2015; 52: 4467-4474.