Study of the best condition for the use of combined drying technologies in artisanal noodle pasta, to improve the technological characteristic and consequent retention of nutrientes

Estudo das melhores condições para o uso de tecnologias combinadas de secagem em massas de macarrão artesanal, para melhorar a característica tecnológica e consequente retenção de nutrientes

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ABSTRACT
Pasta is a popular food item that is produced in several shapes and dimensions. Therefore, the industry and research need updates regarding novel technologies applicable to the processing of new products. The aim of this work was to evaluate the effects of drying pasta arranged in nests using a convective dryer combined with a microwave oven and that influence the offer of a more nutritious product for the consumer. An experimental design was carried out in five assays with varying conditions of drying temperature and microwave oven power. After drying, moisture analyses were performed to assess whether or not the samples were in accordance with the legislation (moisture content not higher than 13%). Technological quality analyses were also carried out. Assay 5 (60°C / 107 W) led to the best drying condition, as indicated by the lowest loss of soluble solids and the shortest cooking time. Thus, this condition is considered ideal for conducting further research on the development and shelf life evaluations of pasta.

Keywords: pasta, tagliolini, drying technology.

RESUMO
A massa é um item alimentar popular que é produzido em várias formas e dimensões. Por conseguinte, a indústria e a investigação necessitam de atualizações no que diz respeito às novas tecnologias aplicáveis à transformação de novos produtos. O objetivo deste trabalho foi avaliar os efeitos da secagem de massas dispostas em ninhos usando um secador convectivo combinado com um forno de micro-ondas e que influenciam a oferta de um produto mais nutritivo para o consumidor. Foi realizado um projeto experimental em cinco ensaios com condições variáveis de temperatura de secagem e potência de micro-ondas. Após a secagem, foram realizadas análises de umidade para avaliar se as amostras estavam ou não em conformidade com a legislação (teor de umidade não superior a 13%). Também foram realizadas análises de qualidade tecnológica. O ensaio 5 (60 °C/107 W) conduziu à melhor condição de secagem,

conforme indicado pela menor perda de sólidos solúveis e pelo menor tempo de cozedura. Assim, esta condição é considerada ideal para a realização de mais pesquisas sobre o desenvolvimento e as avaliações do prazo de validade da massa.

Palavras-chave: massa, tagliolini, tecnologia de secagem.

1 INTRODUCTION

Pasta is consumed worldwide and by all social classes. It is considered a widely consumed food in Europe and was popularly introduced in Brazil in the early 19th century, mainly due to the Italian immigration (Akillioglu & Yalcin, 2010; Silva *et al*., 2013). In Brazil, consumption is quite expressive, mainly associated with the low cost of the product and its nutritional value (Associação Brasileira das Indústrias de Biscoitos, Massas Alimentícias e Pães & Bolos Industrializados, 2019).

Drying is an important unit operation in the industry as it increases food shelf life. Upon heat input under controlled conditions, drying is set out to slower or even prevent microbiological, enzymatic, and biochemical reactions because of the removal of the high content of free water (Fellows, 2006). Microwave drying can enhance drying kinetics and have a good impact in product quality, being reported as a fast and efficient technique (Altan & Maskan 2005, Berteli & Masaioli, 2005; De Sousa, Coelho & Rodrigues, 2020). Altan & Maskan 2005 reported a reduction of drying time by more than 2.5 times when microwave finish drying was combined to hot air drying. Berteli & Marsaioli 2005 reported a reduction of more than 10 times for short cut pasta dried in a pilot scale microwave assisted hot air rotary dryer in comparison to industrial conventional hot air drier.

In the microwave heating process, the most used frequencies for industrial and scientific applications are 915 MHz and 2,450 MHz (wavelengths of 32.8 and 12.5 cm, respectively, in free space) and 5,800 MHz for small-scale processes (Marsaioli Jr., 1991; Barboza *et al*., 2001). These waves heat food matrices by promoting interactions between the chemical constituents of the food and the electromagnetic field (Campos, 1986).

According to Verma *et al.* (2020), during microwave heating, heat is generated due to energy conversion instead of transfer. That is, electromagnetic energy acts on the food molecules so that the food product is heated. This way, electromagnetic energy turns into thermal energy.

Sommer, Ribeiro e Kaminski (2022) observed in their studies that, with the use of microwaves for drying ora-pro-nobis leaves, there was a reduction in the subsequent drying time, in an oven.

The microwave-assisted drying of pasta is not new for food research and industry. Many reports dating back to the last century already described this technology with the use of tunnel dryers (Smith, 1979; Svenson, 1987; Chandrasekaran *et al.*, 2013). Microwave in combination with hot convective air is used to optimize moisture removal (Gonçalves *et al.*, 2017). According to Rosa (2010), the drying speed can be influenced by the sample geometry. Thus, despite the plethora of research on this topic, considering the countless forms of pasta produced by food industries, further research is needed to prove the process efficiency for all types of pasta.

The aim of this study was to establish and evaluate the drying effects of artisanal pasta with a convective dryer combined with microwave in order to achieve the optimum drying condition.

2 MATERIAL AND METHODS

2.1 SAMPLE PREPARATION

The original formulation was prepared at the Unit Operations Laboratory at the *Universidade Estadual Norte Fluminense* (UENF), according to the formulation used by a partner agribusiness located in the city of Venda Nova do Imigrante, Espírito Santo, Brazil. In addition, part of the ingredients was donated by the company. The traditional pasta was formulated and nest-shaped into tagliolini.

2.2 DETERMINATION OF THE INITIAL MOISTURE CONTENT

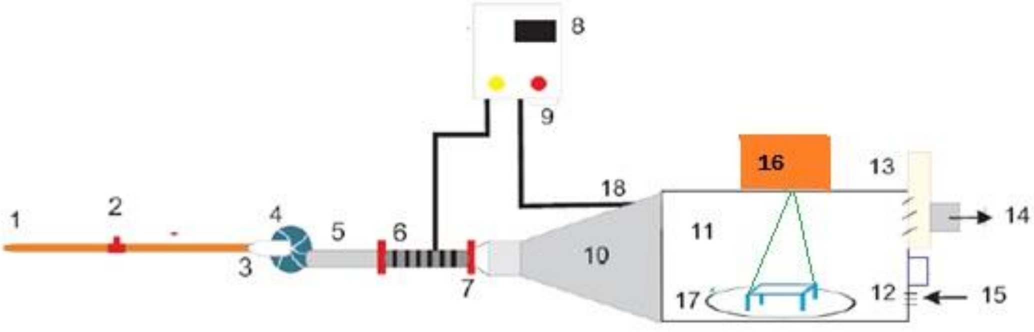
The moisture content was determined according with the Adolf Lutz Institute (Instituto Adolfo Lutz, 2008) in an oven at 105°C for 24 h. The initial moisture content (before drying) was quantified on an infrared scale GEHAKA model IV2000 - Version 4.21, operating at previously optimized conditions, including the auto-dry function at 120°C.

2.3 MICROWAVE-ASSISTED DRYING

2.3.1 Adapted microwave oven

The assays were performed on a domestic microwave oven, model BMC38-A (Brastemp). A 38-L cavity with 900 W of maximum rated power, properly adapted to a hot air system. Figure 1 depicts the apparatus set up.

Figure 1 - Adaptation of the domestic microwave oven.



Legend: (1) air inlet, (2) valve, (3) connector tube, (4) fan, (5) electric heater, (6) flexible tube, (7) quick connector, (8) controller and temperature indicator, (9) controller on/off switch, (10) air diffuser, (11) microwave oven cavity, (12) product holder, (13) exhaust, (14) air outlet, (15) microwave generator cooling air, (16) scale, (17) turntable, and (18) temperature sensor (type-K thermocouple).
Source: Adapted from Lopes (2013).

A product holder was placed inside the microwave oven cavity to suspend the tray until it reached the central plane of the oven, above which a semi-analytical scale was placed to determine the product mass throughout drying. In addition, inlet and outlet temperatures (T), outlet and ambient relative humidity (RH), and room temperature (T) were monitored. Before drying, microwave oven power was determined by the "IMPI 2 - Liters" method adapted from Buffler (1991, cited by Marsaioli Jr., 2001).

2.3.2 Sample drying

The product was evenly distributed onto a two-tier tray (Fig. 2) and placed on the glass turntable inside the microwave oven. The tray was suspended during the weighing time and coupled to a semi-analytical scale to measure the mass [g]. The initial mass was measured and, *via* a mass balance, the final mass that should be removed was calculated. The drying process was carried out until the samples reached a 12% moisture content (w.b.), in accordance with the legislation (Brasil, 2000).

Figure 2 - Two-tier tray for microwave oven drying.

2.4 MOISTURE CONTENT

The pasta moisture content after drying was determined according with the Adolf Lutz Institute (IAL, 2008): briefly, 5.0 g of grounded pasta was oven dried at 105ºC for 24 h.

2.5 TECHNOLOGICAL ANALYSES

The quality of the pasta was inferred by following the method nº 16-50 of the American Association of Cereal Chemists (1995), with adaptations, as follows.

2.5.1 Cooking time

The cooking time was determined by cooking 10.0 g of pasta within 500 mL of boiling distilled water. The samples were placed between two glass sheets and compressed (at determined intervals) until the central white core of the pasta disappeared, when the pasta was considered cooked.

2.5.2 Water absorption

Water absorption (WA) was determined in 10.0 g of pasta, which was cooked (for the previously determined cooking time) and weighed. WA considered the masses of cooked and raw pasta and was expressed as percentage (%), according to Equation 1.

$$\% \, WA = \frac{Mass \; of \; the \; cooked \; pasta}{Mass \; of \; the \; raw \; pasta} \; X \; 100 \qquad (1)$$

2.5.3 Volume expansion

The volume expansion (VE) was determined using a beaker containing 60 mL of toluene. VE was determined by the ratio between the volume of toluene displaced by 10.0 g of cooked product and the volume of toluene displaced by 10.0 g of raw product and expressed as percentage (%), according to Equation 2.

$$\% \, VE = \frac{Toluene\ volume\ displaced\ by\ cooked\ pasta\ (mL)}{Toluene\ volume\ displaced\ by\ raw\ pasta\ (mL)} \, X \, 100 \qquad (2)$$

2.5.4 Loss of soluble solids

The loss of soluble solids was determined by measuring, in a beaker, the volume of water drained after cooking the pasta. Then, 10 mL of the cooking water was collected, in duplicate, and placed in Petri dishes, which were oven dried at 105ºC until constant weight. The loss of soluble solids [%] was calculated by Equation 3.

$$\% \, Loss\ of\ soluble\ solids = \frac{(Drained\ water\ volume\ \ x\ Dry\ residue\ mass)\ x\ 10}{Raw\ pasta\ mass} \qquad (3)$$

2.6 EXPERIMENTAL PROCEDURE AND STATISTICAL ANALYSIS

A 2x2 factorial experimental design with the central point (Table 1) was adopted, wherein the independent variables were air temperature (T) and microwave power (MP), and the dependent variables were drying time and technological properties.

Table 1 - Experimental design for convective drying combined with microwaves of artisanal pasta

Assay	Independent Variables			
	Coded Values		Real Values	
	T	MP	T (ºC)	MP (W)
E1	-1	-1	45	1 (39)
E2	+1	-1	75	1 (39)
E3	-1	+1	45	3 (187)
E4	+1	+1	75	3 (187)
E5	0	0	60	2 (107)

Legend: MP – Microwave power; W – Watts.

After the drying, the samples underwent moisture determinations and technological analyses (cooking time, water absorption, volume expansion, and loss of soluble solids). The five treatments were tested using ANOVA followed by Tukey’s test with statistical significance considered at 5%.

3 RESULTS AND DISCUSSION

The E1 assay showed a process time of 105 min, but it was not efficient as far as moisture (13.7%), disagreeing with the legislation.

On the other hand, the assays E2 (90 min), E3 (45 min), E4 (25 min), and E5 (55 min) presented, respectively, average moisture contents of 12.8%, 12.1%, 12.2%, and 12.1%. These values are within the established maximum value of 13% (w.b.) for dry pasta by the RDC nº 93, of October 31, 2000 (ANVISA) (Brasil, 2000).

Table 2 presents the outcomes of the five tested treatments using ANOVA followed by Tukey's means comparison test. Among the five assays, E5 (central point) led to the best average values.

Table 2 - Results of the technological analyses of the pasta

	E1	E2	E3	E4	E5
Cooking time (min)	14.473a	10.767b	10.887b	11.78c	9.9344d
Water absorption (%)	193.23a	235.93a	199.66a	194.33a	241.58a
Volume expansion (%)	200.46a	203.7a	193.81a	198.02a	296.31a
Loss of soluble solids (%)	12.808ab	18.283a	13.055ab	15.395a	4.1312b

Legend: Means followed by the same letter within the same line do not differ ($p > 0.05$) by the Tukey's test.

The E5 assay was selected for its shorter cooking time and lower loss of soluble solids when compared to the E2 and E4 assays. These results guarantee a more nutritious product for the consumer.

According to Casagrandi *et al*. (1999) and Minguita *et al*. (2015), cooking time is an extremely important parameter for the consumer as, in addition to varying pasta shape, it can interfere with other quality parameters. According to Reis (2013), cooking time may be associated with purchase intention, as it directly influences parameters such as texture and appearance.

Chang and Flores (2004) also discuss the importance of cooking time. In their work on fresh pasta, they report that the moisture content can influence the cooking time. This way, low-moisture pasta requires more time for proper cooking. Therefore, following the legislation (Brasil, 2000), it is important not only for microbiological stability, but also for improved technological characteristics, as it considers an optimal moisture range.

Another important factor for choosing the ideal treatment was the loss of soluble solids. According to Romero and Zhang (2019), the recommendation for high quality wheat pasta is a loss lower than 12%, which is also reported by Hummel (1966) and Ormenese and Chang (2003), who claim that pasta with a loss of soluble solids higher than 10% is labeled as low quality. According to these data, therefore, the E5 assay presented itself as the most suitable condition.

According to Braibanti and C.S.p.A. (1980), the pasta can be subjected to high temperatures with a strict control of the time variable so that there is partial gluten coagulation. With this, during the cooking process, the gelatinized starch remains surrounded by the protein reticule not dispersed in the aqueous phase, avoiding dough gumminess and loss of solids to the aqueous phase. However, according to Altan & Maskan (2005), the fact of having water in the pasta may not be enough to promote gelatinization, as the samples will suffer a rapid loss of moisture at the beginning of drying. The authors, however, agree that with the use of microwaves, the structure of the starch changes in an interesting way.

4 CONCLUSION

The assay 5 (107 W power and drying air temperature of 60°C) presented the ideal conditions for drying pasta (nest-shaped tagliolini) without imparting technological problems for the final product. And, in addition, it showed that the dough under these conditions has greater nutritional power by retaining more nutrients in its interior. These conditions, therefore, serve as the basis for more specific studies, such as those on the shelf life of pasta.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Note: This reference provides updates on the consumption and production of pasta in Brazil and also has reports as a basis for studies.

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Note: This reference is related to the study because it is mainly about the use of microwave-hot drying.

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Note: This book was considered as a basic theoretical reference for working with pasta, that is, before the analysis started, it was consulted to understand the basic principles.

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Note: This reference used a microwave oven equipment combined with hot air similar to that used in this work.