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Proceeding Paper

Effect of Extrusion Compression Ratio and Particle Size of Rice on the Sectional Expansion Index of Third-Generation Snacks †

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Abstract: Third-generation (3G) rice pellets were obtained using rice flour (RF) and rice grits (RG), raw materials of similar compositions but different particle sizes. The samples were mixed with water to 25% moisture and extruded using a laboratory single-screw extruder (Kompakt KE 19/25 extruder) and three compression ratios (1:1, 2:1, and 3:1). The pellets were expanded using a microwave oven subjected to 1000 W/g power. After evaluating the expansion kinetics and the sectional expansion index (SEI), it was observed that the 3:1 compression ratio allowed for greater expansion, while the particle difference showed no significant difference ($p > 0.05$) in the SEI.

Keywords: extrusion; microwaves; rice flour; rice grits; 3G snacks

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1. Introduction

The indirect extrusion process allow the obtention of third-generation (3G) extrudates, called pellets, by applying moderate temperatures. Compared to second-generation (2G) extrudates (obtained via direct extrusion), these extrudates have the advantage of requiring less storage space and a longer shelf life [1]. After extrusion, the pellets are dried before being stored or expanded to obtain 3G snacks, which require heat treatment. The heating technique can be microwaving, frying, or baking, among others. However, it has been studied that using microwaves, in addition to avoiding the increase in fat content by not requiring oil, helps to better preserve the color, texture, and functional properties of the snacks compared to those under frying [2]. This reason may explain why recent studies have chosen microwaves as a method for the expansion of snacks from lentil and egg powder [3], beetroot by-products [4], blue corn, black bean, sweet chard [5], and Andean tuber and tuberous root flours [6].

The heating method is not the only parameter that determines the expansion of extrudates, since the parameters chosen to perform the extrusion and the sample's composition also influence this result [7]. For this reason, the present work has studied how different compression ratios (CR; 1:1, 2:1, and 3:1) affect pellet expansion. Likewise, we also sought to evaluate whether or not the particle size of the samples used would affect the expansion process. For this purpose, two types of flours of similar composition were selected. Specifically, the study used rice flour (RF) and rice grits (RG) as raw materials. The effect of both parameters was evaluated by considering the sectional expansion index (SEI), to check which compression ratio provided greater pellet expansion and whether or not particle size affected pellet expansion.

2. Materials and Methods

2.1. Raw Materials

Rice flour was provided by Herba Ricemills S.L.U (Valencia, Spain), while rice grits was supplied by Arrocerías San Cristóbal, S.L. (Valencia, Spain). Commercial companies provided the raw materials' compositions (Table 1).

Table 1. Chemical compositions of rice flour and rice grits with average values per 100 g.

Chemical Composition	Average Values per 100 g of RF	Average Values per 100 g of RG
Carbohydrates	79.5 g	78.0 g
Proteins	6.5 g	6.5 g
Fat	0.6 g	0.3 g
Fiber	2.1 g	1.9 g

RF: rice flour; RG: rice grits.

2.2. Preparation of Rice Flour and Rice Grits in 3G Extruded Pellets

A mixer (Bosch MFQ40303, Gerlingen, Germany) was used at medium speed to mix both samples with water to give them a moisture content of 25%.

The third-generation pellets were obtained using Kompakt extruder KE 19/25 (Brabender, Duisburg, Germany), a single-screw laboratory extruder with a length-to-diameter ratio of 25:1 and a barrel diameter of 19 mm. Compression ratios 1:1, 2:1, and 3:1 were applied to analyze the effect of CR on the expansion of the rice samples. The samples were dosed at a constant speed of 12 rpm, and the screw was constantly rotating at 70 rpm. The extruder barrel is divided into 4 parts in which the temperature is controlled. The temperature of parts 1–4 operate at 95, 90, 67, and 28 °C, respectively. A 3 mm diameter nozzle was used.

After the extrusion process, the pellets were dried for 18 h at 25 °C. For further analysis, polyethylene bags were used to store the dried samples at room temperature (25 °C).

2.3. Particle Size

The particle size of RF and RG was measured with a particle sizer analyzer (Malvern Instruments Ltd., Mastersizer 2000, Malvern, UK), which included a dry sample dispersion unit (Malvern Instruments Ltd., Scirocco 2000). The laser diffraction method and Mie theory, described in the ISO 13320:2020 [8] were applied. The volume of material of a given size is determined via laser diffraction since the light energy collected by the detector is proportional to the volume of material present. Volume (%) versus particle size (mm) was recorded and the volume mean diameter (D[4.3]) was used to characterize the size distribution. Considering the particle diameter, the Mastersizer 2000 software (version 5.6) allowed the estimation of the standard percentiles d(0.1), d(0.5), and d(0.9). These parameters refer to the particle size below which 10%, 50%, and 90% of the sample are found, respectively.

2.4. Microwave Expansion

The rice pellets were cut to a length of 1 cm and introduced into a microwave oven (MH7265DPS, LG Electronics Inc., Beijing, China), which was used to perform the expansion process by applying a power of 1000 W/g. The expansion kinetics of the 3G rice snacks were obtained by heating the samples at times of 10, 30, 60, 80, 90, 110, 120, 130, 140, and 150 s.

Microwave Expansion Kinetics

Patil et al. [9] described the methodology followed to determine the sectional expansion index (SEI). A digital caliper (Comecta S.A., Barcelona, Spain) was used to measure the die diameter (D_d), which corresponds to the diameter of dry extruded pellets, and the diameter of the expanded samples (D_e).

$$SEI = \frac{{D_e}^2}{{D_d}^2} \quad (1)$$

2.5. Statistical Analysis

Statgraphics Centurion 18 software, version 18.1.13 (Statgraphics Technologies, Inc., The Plains, VA, USA), was used to apply the analysis of variance (ANOVA), at a 95% confidence level ($p < 0.05$), to evaluate how different compression ratios affect SEI. Fisher's least significant difference procedure allowed the selection of the most interesting compression ratio for which, by means of a new ANOVA and following the same method, the effect on SEI of the difference in particle size between samples was evaluated.

3. Results and Discussion

3.1. Particle Size

The products marketed as flour and grits are differentiated by their particle size, which is greater in the case of grits, and, as described by other authors in their studies, particle size affects the expansion of extrudates [10,11]. Figure 1 shows the volume distribution of the particle size of the rice samples. Specifically, the particle sizes of samples were mainly between 60 and 630 µm for RF and between 105 and 1096 µm for RG. The particle size characterization of the rice samples is shown in Table 2 by the volume mean diameter values along with the standard percentile values.

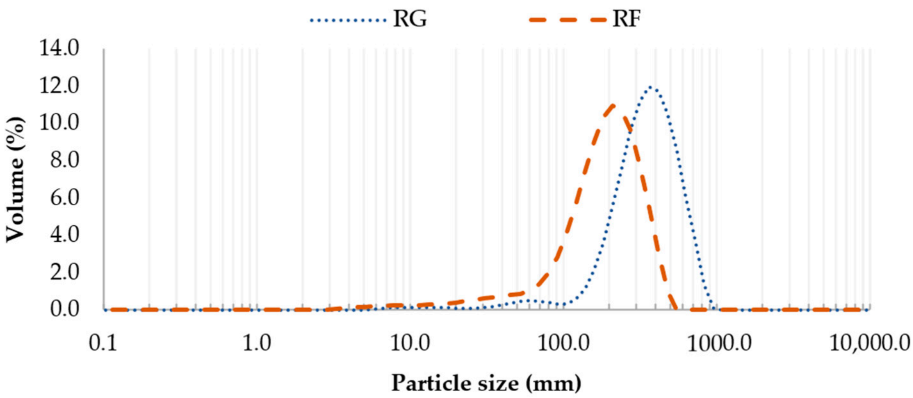


Figure 1. Representative curves of the volume particle size of rice flour (RF) and rice grits (RG).

Table 2. Mean values (and standard deviations) of volume mean diameter (µm) D[4,3], and standard percentiles (µm) d(0.1), d(0.5), and d(0.9) of samples.

Sample	D[4,3]	d(0.1)	d(0.5)	d(0.9)
RF	186.2 (0.4) ^{b}	67.9 (0.6) ^{b}	178.9 (0.4) ^{b}	313.9 (0.7) ^{b}
RG	348 (2) ^{a}	170 (2) ^{a}	331 (2) ^{a}	563 (2) ^{a}

The same letter in superscript within the column indicates homogeneous groups as established via ANOVA ($p < 0.05$). Rice flour (RF) and rice grits (RG).

As can be seen, RG presented a higher volume mean diameter (D[4,3]) than did the RF (348 and 186.2 µm, respectively), corroborating the above-mentioned results. In total, 50% of RF presented a particle size of less than 178.9 µm; however, only 10% of RG presented a particle size of less than 170 µm. Likewise, 90% of the RF particles had a particle size smaller than 313.9 µm, while only 50% of the RG particles had a particle size smaller than 331 µm. These differences in particle size explain the existence of significant differences ($p < 0.05$) in D[4,3] and the standard percentiles between RF and RG.

3.2. Microwaving Expansion Kinetics and Sectional Expansion Index (SEI)

Figure 2 shows the evolution of the SEI of dry 3G rice pellets with respect to the microwave processing time applied for both samples and the three compression ratios. In the two initial times of the process (10 and 30 s), the expansion of the dried pellets did not occur. At 60 s, all samples began to expand. Samples extruded with a 3:1 CR showed stable SEI values, presenting only slight fluctuations from 60 s to 110–120 s. However, samples extruded with a 2:1 CR required more time to reach their maximum expansion (approximately 80 s). In the case of the RF samples expanded with a 1:1 CR, their maximum expansion was reached at 90 s, in contrast to that of RG at a 1:1 CR, whose SEI values showed stability at 60 s. Moreover, in addition to the fact that the 1:1 and 2:1 CR samples took longer to stabilize (with the exception of the 1:1 RG samples), their SEI values are lower than those obtained with a 3:1 CR. Petrova et al. [12] found that starch gelatinization increased with an increasing screw compression ratio, which favored the expansion of extrudates [13]. Also, a higher CR increases die pressure, which, as indicated by Gat et al. [14], is related to higher expansion.

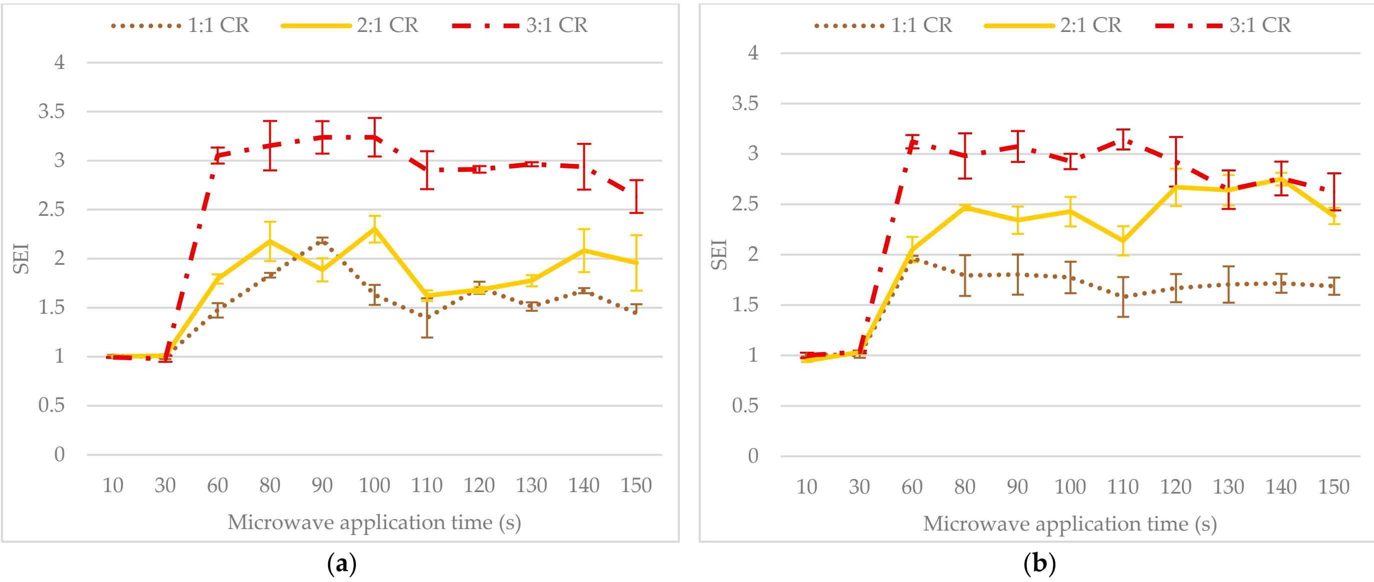
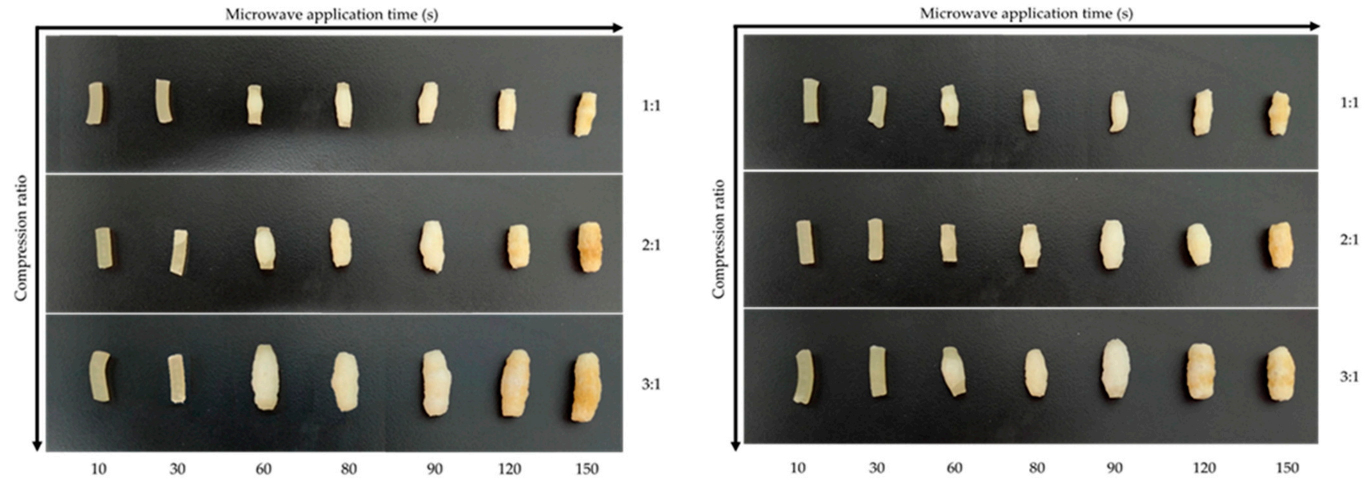


Figure 2. Evolution of SEI as a function of the duration of the microwave treatment of rice flour (RF) and rice grits (RG) expansions for the three compression ratios (CR; 1:1, 2:1, and 3:1). (**a**) Rice flour. (**b**) Rice grits.

Regarding the effect of particle size on SEI, ANOVA statistical analysis showed that there are no significant differences ($p > 0.05$) in the SEI of the samples obtained with a 3:1 CR, as observed in the work conducted by Desrumaux et al. [10]. However, there are significant differences ($p < 0.05$) in the SEI related to particle size in the case of using a 1:1 and 2:1 CR.

These results indicated that when the extruder works with a 3:1 CR, this screw allows a larger and faster expansion of the pellets, and the effect of particle size is attenuated. In cases where the expansion is slower, as when working with a 1:1 and 2:1 CR, the effect of particle size on SEI predominates. When 3:1 CR is applied, sample composition is likely to have more of an impact on snack expansion than particle size is (flour moisture [15] and the presence of fiber and protein [16], among others, affect SEI).

On the other hand, Figure 3 shows the evolution of snacks with the application of microwaves. At 90 s of microwave treatment, RF samples acquired a slight brownish hue, indicating that the sample was starting to burn, as is the case in other studies presented by Acurio et al. [4] on beetroot-enriched snacks. At 120 s, all samples showed browner coloration, while at 150 s, this tone was more evident, showing that the samples had burned. These facts reaffirmed that a 3:1 CR was more interesting for producing these snacks since microwave applications have a margin of 60–90 s where maximum expansion can be achieved without burning the product.



(**a**) (**b**)

Figure 3. Evolution of snack expansion as a function of the duration of the microwave treatment of rice flour and rice grits pellets for the three compression ratios (1:1, 2:1, and 3:1). (**a**) Rice flour. (**b**) Rice grits.

4. Conclusions

The 3:1 compression ratio resulted in a higher SEI than the 1:1 and 2:1 CRs did. This is because a higher compression ratio favors greater starch degradation and higher pressure at the extruder outlet, which favors the expansion of samples. However, the similarity in the composition of samples predominated over the difference in particle size between rice flour and rice grits extruded with a 3:1 CR. The effect of particle size only was significant when the expansion of pellets was smaller, such as when 1:1 and 2:1 CR were used. In view of the results obtained in this work, it can be concluded that the compression ratio of 3:1 resulted in a greater and faster expansion of the snacks, the composition of the samples being more related to expansion than the particle size of the flours was when using this CR.

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