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Impact on antioxidant activity of including grape peel flour in a novel sorghum-based extruded food

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Abstract

The aim of this study was to evaluate the effect of combining grape (*Vitis vinifera* L.) peel flour (GPF) and the colored sorghum BR305 (brown) flour (CSF) by extrusion and the consequent impact on antioxidants in the final product. The physical properties and bioactive compounds of both raw GPF and blended GPF/CSF extruded materials were investigated. The results before extrusion of raw materials, the antioxidants by ORAC the CSF was 89.111 ± 0.25; GPF before drying 321.033 ± 0.21; GPF flour after drying was 311.022 ± 0.30 µmol Trolox.g^{-1}, respectively. Considering the different treatments (10, 15 and 20% of GPF), the highest values of the compounds obtained: Antioxidant activity, ORAC, was 37.889 ± 0.32 (µmol Trolox.g^{-1}); with 15% of GPF, at 120 °C and 17% moisture processing. ABTS, 12.222 ± 0.14 (µmol Trolox.g^{-1}); with 20% GPF at 140 °C and 19% moisture processing as best processing conditions. Anthocyanins 138.31 ± 0.11 (mg cyanidin-3-glucoside 100 g^{-1}); Total phenolic 307.95 ± 0.11 (mg catechin.100 g^{-1}). The water absorption index was 38.99 ± 0.19, g of gel.(g dry matter)$^{-1}$ perhaps are sufficient for the preparation of beverages for breakfast or in porridge in order to contribute to the health of the consumer.

Keywords: colored sorghum; grape peel flour; extrusion-cooking; antioxidants; pre-cooked flours.

Practical Application: Mixed flour that can be used as an input in the preparation of other foods. Alternative for use in preparing gluten-free foods. Depending on the degree of processing, it can be used in the porridges preparation or drinks in general.

1 Introduction

Sorghum is a versatile grain generally consumed in Asian and African countries but which is gaining interest in the United States due to its gluten-free and bioactive compound-enriched health benefits (Davis et al., 2019). In Brazil, the predicted production in 2021 is nearly 25.9454.000 tons (Companhia Nacional de Abastecimento, 2020). Therefore, colored sorghum is utilized in many gluten-free products, as it has good acceptability and an attractive neutral taste and color (Di Cairano et al., 2018).

Mixing ingredients can not only be an advantage but also a unique way to make feasible the consumption of certain powder products such as grape peel flour; each ingredient can contribute to improving the sensory characteristics of the final product, making the product appealing (Di Cairano et al., 2018).

There are several reasons why the use of agro-industrial by-products is interesting. First, due to the conditions of use, it can contribute to a reduction in environmental pollution; second, many by-products contain significant amounts of nutrients, some having a good protein content, or being a good source of fiber, bioactive compounds, other mineral profiles, etc. The third point is that value is added, not only from an economic point of view but also as a health aggregator, which in some cases is greater than the raw material itself (Di Cairano et al., 2018; Matejová et al., 2016).

Grapes (*Vitis* spp.) are one of the most consumed fruits in the world. The winemaking industry generates a lot of waste like peel, seeds, and stems. This waste is called grape pomace and has an economic and environmental impact (Fontana et al., 2013). It contains many bioactive compounds and can be used in added-value products (Sánchez-Tena et al., 2013).

Today, food extrusion technology is one of the most important ways of transforming a wide variety of food types into ready-to-eat foods, whether for human consumption or as animal feed. This is because in the formulation of these foods it is possible to incorporate different raw materials, of animal, vegetable, or mineral origin. All of this is to satisfy the specific needs of a specific consumer. In addition, according to the characteristics imposed in the process, it is possible to incorporate higher levels of dietary fiber or significant percentages of protein, or simply to improve the characteristics of acceptability and sensorial preferences (Román et al., 2017). This technology is also used to improve food by-products (Offiah et al., 2019) and to develop dietary fiber-enriched foods (Leonard et al., 2020).

A large number of products have been developed using food extrusion technology, mainly due to the possibility of using different raw materials, creating texture properties that are highly acceptable to consumers. The technology also has high productivity, low operating costs, and minimal energy costs. From a nutritional point of view, foods produced by this

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type of processing have greater bioavailability and digestibility. For these reasons, it has become one of the most used tools in the formulation of new products derived from agro-industrial by-products (Brennan et al., 2011).

It is very important to note that it is not feasible to consume many inputs derived from agro-industrial by-products due to their own characteristics, for example grape skin powder, shrimp powder, etc. In this sense, there is a need to associate these raw materials with starchy sources, such as flours from rice, corn, wheat, cassava, potatoes, etc., to be processed later by extrusion. Matejová et al. (2016) added grape pomace to gluten-free biscuits. Alves et al. (2018) extruded passion fruit shell and colored sorghum flour. Other combinations explored are extruded colored sorghum flour and apple pomace (Mehraj et al., 2018); cereal breakfast extrudates with colored sorghum and pomelo rind (Shi et al., 2017); sugar replacement using citrus fiber extracted from orange pulp in wheat-corn extrudates (Pitts et al., 2016); cherry pomace and direct expanded corn starch (Wang et al., 2017); and cassava-soy composite with grape pomace (Oladiran & Emmambux, 2018).

Following the tendency for heathier products, sustainable development, and gluten-free foods, the combination of colored sorghum and grape peel by extrusion cooking is a good alternative to formulate new products based on these extruded flours. The aim of this work was to develop mixed colored sorghum and grape peel flours by extrusion cooking, evaluate the corresponding impact on antioxidant content, and consider the usefulness of the mixture for future possibilities.

2 Material and methods

2.1 Raw materials

A sorghum genotype with varied pericarp color, BR305 (brown), was produced by Embrapa Milho e Sorgo (Sete Lagoas, Brazil) at the agricultural experimental field located at 19° 28′ south latitude, 44° 15′ 08″ west longitude and an altitude of 32 m. The grape pomace was supplied by Embrapa Semiárido, Petrolina, PE, -Brazil (in the Municipality of Petrolina, PE, 09° 09′ south latitude, 40° 22′ west longitude and an altitude of 365.5 m). The pomace was submitted to drying oven with air circulation SL102 (SOLAB, São Paulo, Brazil) at 45 ± 0.5 °C and 1.0 m/s of air velocity until reaching constant weight, using stainless steel mesh trays, containing layers of bagasse 0.6 cm high for 48 consecutive hours, reaching constant weight, with a moisture near of 8,00%.

Colored sorghum and grape peel were ground, separately, in a Lab Mill 3600 disc mill (Perten Instruments, model 3600, Kungens Kurva, Sweden). Colored sorghum flour (CSF) and grape peel flour (GPF) with a particle size of less than 450 μm were used.

2.2 Extrusion cooking process

A single-screw Brabender 20DN DSE extruder coupled to a module 330 torque rheometer (Duisburg, Germany) was used. The screw speed and feed rate of 2.5 kg.h^{-1} were constant throughout the process at a pressure of 8.5 ± 10 MPa. The screw configuration was L/D 1:3 (compression ratio, Figure 1) and included a circular die 3 mm in diameter. The proportion of grape peel flour, barrel temperature, and moisture content were the independent variables described in the experimental design. After extrusion cooking, the extrudates were dried in a forced-air drier (Fabble-Primar, São Paulo, Brazil) at 60 °C for 4 h to obtain a moisture range of 4-7 g.100 g^{-1}. In the extrusion assays, flours were ground in a disc mill with a 0.8 mm sieve size. The extruded flours were maintained under refrigeration (5-8 °C) until further analysis.

2.3 Experimental design

The experimental design was based on a central composite rotatable design (CCRD) for two levels and three independent variables. The experiment was conducted with 19 runs with 8 factorial points, 6 axial points, and 5 central points. Independent variables were X_1: proportion of grape peel flour, X_2: barrel temperature, and X_3: moisture content; the coded and decoded levels studied are shown in Tables 1 and 2, respectively. The moisture content of the mixed raw materials was calculated in order to equalize the moisture (X_3) according to the real values used in the experimental design (Table 1 and 2) using Equation 1.

$$W = \left(\frac{M_f - M_0}{100 - M_f}\right) \times G \tag{1}$$

where W is the amount of water to be added, M_0 is the initial moisture (%) of the mixture determined by the method of the Association of Official Analytical Chemistry (2010), M_f is the

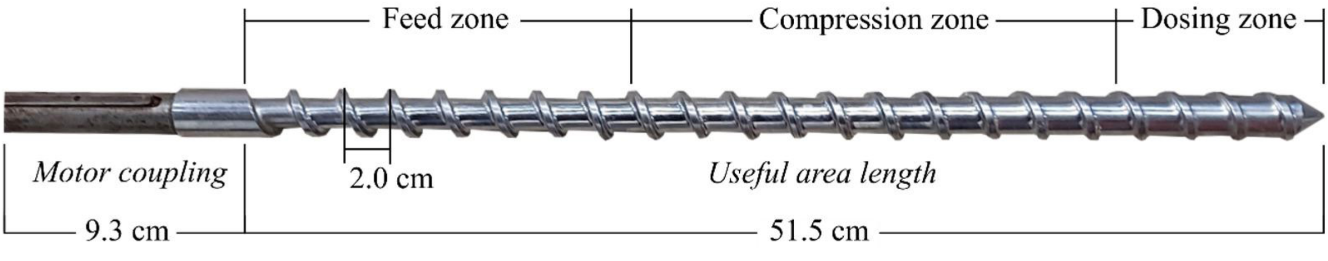

Figure 1. Brabender® extruder screw with 3:1 compression ratio.

Table 1. Real values used in experimental design for the production of products extruded from mixtures of colored sorghum and grape peel flours.

Independent variable	Coded level				
	−1.682	−1	0	+1	+1.682
X_1 : Proportion of grape peel flour (%)[a]	6.6	10	15	20	26.4
X_2 : Barrel temperature (°C)	113.2	120	130	140	146.8
X_3 : Moisture content (%)[b]	13.6	15	17	19	20.4

[a]dry basis; [b]wet basis.

Table 2. Experimental design and responses for proximate composition, pasting properties, and expansion properties of colored sorghum-grape peel extrudates and raw ingredients.

Run	Experimental design			Proximate composition[a]				Pasting properties[b]		Expansion properties			
	X_1	X_2	X_3	*ASH*	*PRO*	*LIP*	*CHO*	*BDV*	*STV*	*BD* kg.m^{-3}	*REI*	*LEI*	*VEI*
1	10	120	15	1.11	6.91	1.99	89.99	301	355	250.02	7.701	0.766	5.899
2	10	120	19	1.33	6.23	1.84	90.60	358.5	377.5	410.01	4.601	0.688	3.165
3	10	140	15	1.26	6.22	1.88	90.64	611	310.5	205.22	7.675	0.799	6.132
4	10	140	19	1.15	6.25	2.22	90.38	501	471	412.01	4.602	0.688	3.166
5	20	120	15	1.88	6.8	2.11	89.21	330	128.5	236.11	6.306	0.898	5.663
6	20	120	19	1.79	5.64	2.6	89.97	478.5	222.5	426.61	3.501	0.779	2.727
7	20	140	15	1.83	5.68	2.95	89.54	396.5	177	236.02	6.205	0.923	5.727
8	20	140	19	1.71	5.53	2.88	89.88	452	211.5	369.25	3.612	0.944	3.41
9	6.6	130	17	1.04	7.52	1.78	89.66	669	320	251.07	6.25	0.821	5.131
10	23.4	130	17	2.1	4.96	2.97	89.97	338.5	170.5	326.01	4.311	0.877	3.781
11	15	113.2	17	1.65	5.25	2.79	90.31	508.5	277.5	309.27	5.79	0.701	4.059
12	15	146.8	17	1.94	4.89	2.98	90.19	381.5	227	266.55	5.289	0.865	4.575
13	15	130	13.6	1.36	5.22	2.76	90.66	318.5	164.5	180.01	6.876	0.917	6.305
14	15	130	20.4	2.39	5.48	2.85	89.28	578.5	345.5	435.33	3.989	0.806	3.215
15	15	130	17	2.77	5.52	2.79	88.92	481.5	225	288.87	5.499	0.788	4.333
16	15	130	17	2.6	5.45	2.96	88.99	429.5	226	256.1	6.081	0.845	5.138
17	15	130	17	2.59	5.28	2.98	89.15	427.5	255.5	248.07	5.201	0.899	4.676
18	15	130	17	2.56	5.09	2.61	89.74	525.5	271	283.2	5.213	0.811	4.228
19	15	130	17	2.68	5.7	2.86	88.76	514.5	249	271.11	5.391	0.844	4.55
Raw materials			*MOIST*	*ASH*	*PRO*	*LIP*	*CHO*						
Grape peel flour			8.12	2.55	11.65	4.76	72.92						
Colored sorghum flour			8.17	1.82	9.59	2.17	78.32						

X_1 : proportion of grape peel flour; X_2 : barrel temperature; X_3 = *MOIST* : moisture content; *ASH* : ash content; *PRO* : protein content; *LIP* : lipid content; *CHO* : carbohydrate content; *BDV* : breakdown viscosity; *STV* : setback viscosity; *BD* : bulk density; *REI* : radial expansion index; *LEI* : longitudinal expansion index; *VEI* : volumetric expansion index. [a]g.100 g^{-1} dry basis; [b]mPa or cP.

feed moisture (X_3, %), fixed according to the levels of Table 1 and 2, G is the mass of mixture to be moistened.

2.4 Determination of proximate composition

Analysis of moisture, lipids, and ash was based on Association of Official Analytical Chemistry (2010) methods.

The total carbohydrates were obtained by difference, subtracting from 100 the values obtained for moisture, proteins, lipids, and ash (Instituto Adolfo Lutz, 2008). The results of the proximate composition were expressed in g.100 g^{-1}.

The total crude fiber content of pre-cooked mixed colored sorghum and grape peel flour was determined according to the enzymatic-gravimetric method (Association of Official Analytical Chemistry, 2010), using a Sigma enzyme kit. This method is based on the non-hydrolyzed portion of the food that resists sequential enzymatic digestion with α-amylase, protease, and amyloglucosidase.

2.5 Determination of physical properties

The melt expansion of extruded product is related to its degree of porosity, which affects mechanical and transport properties such as the shear rate and the diffusion of aromas (Włodarczyk-Stasiak & Jamroz, 2009).

Pasting properties

Pasting properties were analyzed using a Rapid Visco Analyser (RVA Super-4 model, Newport Scientific Pvt. Ltd, Australia). The particle sizes of the samples used were between

125 and 250 µm. The samples (3.0 g in 25 g of water) were corrected for moisture (14%), adding water to achieve a total weight of 28 g. The pasting profile was held at 25 °C for 2 min and heated to 95 °C. It was stabilized at this temperature for 3 min and then cooled to 25 °C. The test was performed in 20 min. The initial viscosity, maximum viscosity, final viscosity, and setback viscosity were used to evaluate the cooking degree of each sample and were expressed in Pascal-seconds (Pa.s).

Expansion properties

The radial expansion index (REI), longitudinal expansion index (LEI), and volumetric expansion index (VEI) of the extruded snack products were determined for each treatment with the aid of a digital caliper (ZAAS Precision, Curitiba, Brazil). To determine the EI (Equation 2), the diameter at the beginning, middle, and end of each extrudate was measured, to obtain the average diameter (D).

LEI and VEI were calculated using Equations 3 and 4, respectively.

$$REI = \left(\frac{D}{D_0}\right)^2 \quad (2)$$

$$LEI = \left(\frac{\rho_d}{BD}\right)\left(\frac{1}{REI}\right)\left(\frac{1-M_d}{1-M_e}\right) \quad (3)$$

$$VEI = REI \times LEI \quad (4)$$

where ρ_d is the density of the molten product inside the extruder before it leaves the die, considered to be 1400 kg.m^{-3} (density of starch); BD is the density of the extruded product; M_d is the moisture content of the wet mass of the molten product inside the extruder; and M_e is the moisture content of the extruded product, as described by Alvarez-Martinez et al. (1988).

The bulk density (BD), in kg.m^{-3}, was calculated according to Fan et al. (1996), using Equation 5.

$$BD = \frac{4M}{\pi D^2 L} \quad (5)$$

where M is the mass, in g; L is the length of extrudate, in m; and D is the extruder diameter, in m. The analysis was performed with 15 replicates of each treatment.

Water solubility and water absorption indices

The water solubility index (WSI) and water absorption index (WAI) of the samples were determined in quadruplicate as described by Anderson et al. (1969). WSI is the sample mass in the supernatant divided by sample mass, and WAI is the sample mass with absorbed water divided by the sample mass. The WAI was calculated using Equation 6, while the WSI was calculated using Equation 7, modified by Doğan & Karwe (2003). The results are expressed in g of gel.(g dry matter)$^{-1}$ and percentage, respectively.

$$WAI = \frac{WRC}{Ws - WRE} \quad \text{g of gel.}\left(\text{g dry matter}\right) - 1 \quad (6)$$

$$WSI = \frac{WRE}{Ws} \quad (\%) \quad (7)$$

where WRC is the weight of the centrifuge residue, in g; Ws is the sample weight, in g; and WRE is the weight of the evaporation residue, in g.

2.6 Determination of antioxidant capacity and phenolic compounds in grape skin flour and extruded products

Antioxidant capacity was determined using removal of the peroxyl radical (ORAC – oxygen radical absorbance capacity) and the ability to remove the organic radical ABTS (2,2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid). The total phenolic compounds were determined using the Folin-Ciocalteu assay, which is the most widely used rapid reaction procedure for the quantification of phenolic compounds in plants. The complete analytical procedure was performed as previously described by Georgé et al. (2011).

Extract Preparation: To determine the antioxidant capacity, an extract was used for the ABTS and ORAC analysis. For grape skin flour, 0.1 g was weighed, and for extruded mixed flours, 0.5 g was put, in triplicate, into centrifuge tubes; 10 mL of 50% methanol was added to the tubes, then the mixture was homogenized in a vortex mixer (Genie 2 Scientific Industries, Bohemia, NY, USA) and left to stand for 60 min at room temperature and protected from light. The tubes were then centrifuged in a Universal 320R centrifuge (Hettich, Tuttingen, Germany) at 2000 rpm for 15 min and the supernatant content was transferred to 25 mL amber volumetric flasks; 10 mL of 70% acetone was added to the residues from the first extraction, homogenized, and left to stand for 60 min at room temperature and protected from light. The tubes were centrifuged again (under the same conditions) and the supernatant content was collected and next to the supernatant from the first centrifugation. The balloons were filled with distilled water.

The extracts were then transferred to Eppendorf tubes, frozen at −10 °C, and kept away from light to be used to analyze antioxidant capacity.

ABTS method

The antioxidant capacity equivalent to Trolox was estimated according to the procedure proposed by Re et al. (1999), with some modifications. The ABTS•+ radical was prepared from the reaction of 7 mM ABTS aqueous solution with 140 mM potassium persulfate, leaving the mixture at room temperature for 16 h, in the absence of light. Soon the ABTS solution was diluted with ethanol, in order to obtain a level of absorbance of 0.70 ± 0.05 at 734 nm. Aliquots of 30 µL of the samples were added to 3 mL of the diluted ABTS solution, and the absorbance of the mixture was recorded after 6 min. The antioxidant capacity was calculated using a standard Trolox curve (100 to 2000 µM) and respective percentage inhibition, and the test results were expressed in µmol of equivalent Trolox per gram of fresh weight (µmol TE.g^{-1} PF).

ORAC method

ORAC was analyzed as proposed by Dávalos et al. (2004). In microplates, aliquots of 25 μL of the extracts were mixed with 150 μL of the fluorescein solution (40 nM) and incubated at 37 °C for 30 min, before adding 25 μL of the AAPH solution (153 nM). All reagents were prepared in phosphate buffer (75 mM, pH 7.1). The fluorescence intensity (excitation at 485 nm and emission at 525 nm) was monitored every minute, for 60 min, in a Sinergy Mx microplate reader (BioTeK, Winooski, VT, USA). The standard curve was prepared with Trolox solution (6.25 to 100 mM), and the results were expressed in μmol equivalent of Trolox per gram of fresh weight (μmol Trolox.g^{-1} PF).

Determination of total phenolic compounds

Quantification of the total phenolic content of the extracts and products was carried out as recommended by Georgé et al. (2005). The reading was performed at 720 nm, after reduction of the reagent by the phenolic compounds. The results were expressed in mg of catechin per 100 g of grape skin flour and in the extruded product, in order to evaluate the effect of extrusion on the content of total phenolic compounds.

Determination of total anthocyanins

pH difference methodology was used to determine total anthocyanins in the extracts, according to Lee et al. (2005). Two buffer solutions were made, one of potassium chloride/hydrochloric acid of pH 1.0 (0.025 M), another of sodium acetate/hydrochloric acid of pH 4.5 (0.4 M). The samples were diluted in these buffer solutions, and the concentration of the sample at pH 1.0 showed a reading between 0.2 and 1.4 AU, as it is the linearity range of the spectrophotometer. Readings were taken at 520 nm and 700 nm, in both pH 1.0 and pH 4.5 buffer. The 700 nm reading was performed to discount the sample turbidity. The final absorbance (A) value was calculated using Equation 8.

$$A = \left(A_{520nm} - A_{700nm}\right) pH\,1.0 - \left(A_{520nm} - A_{700nm}\right) pH\,4.5 \tag{8}$$

The total concentration of monomeric anthocyanins was expressed in terms of cyanidin-3-glucoside, according to Equation 9.

$$MA = A \times MW \times DF \times \frac{100}{\varepsilon - 1} \tag{9}$$

where MA corresponds to monomeric anthocyanins, in mg.100 g^{-1}; A corresponds to absorbance; MW is the molecular weight; DF is the dilution factor; and ε corresponds to molar absorptivity.

The determination was carried out on the grape skin flour sample and on the extruded flours, in order to evaluate the effect of extrusion on the total anthocyanin content.

2.7 Statistical analysis

The responses of the extrudates (Table 2) obtained as results of the rotating central composite design 2^3 were subjected to a second order polynomial regression analysis shown in the Equation 10:

$$\hat{Y} = \beta_0 + \sum_{i=1}\beta_i X_i + \sum_{i=1}\beta_i X_i^2 + \sum_{i=1}\sum_{j=i}\beta_{ij} X_i X_j \tag{10}$$

where $\hat{Y}$ is the predict response (proximal composition, paste properties, and expansion properties); X_i , X_i^2 , and $X_i X_j$ are the linear, quadratic, and interaction effects, respectively, of the factors that influence the response ($\hat{Y}$); and β_0 , β_i , and β_{ij} are the coefficients of the model to be determined. Analysis of variance (ANOVA) test was carried out using the Statistica software version 12.0 (StatSoft, Tulsa, USA) with 5% of significance.

3 Results and discussion

3.1 Proximate composition

The proximate composition (in g.100 g^{-1} on a dry matter basis) of colored sorghum flour (CSF) and grape peel flour (GPF) and the different tests provided for in the experimental design are shown in Table 2. GPF showed a high fiber content and ash content although the physical and chemical properties of grapes vary according to the climate, soil, variety, and cultivar (Osorio & Silveira, 2013). As an example, the mineral composition may vary according to edaphological conditions, climatic factors, and the use of fertilizers and herbicides among other factors (Bampi et al., 2010). The protein content of the grape depends on the cultivar and its proteins are present mainly in the grape pulp. Crushing of grapes by applying pressure, depending on the intensity can lead to a decrease in the content of soluble proteins in the GPF. At the end of the fermentation process, many proteins precipitate with tannins, mainly in the making of red wine (Jackson, 2020). The data according to the experimental design, with regard to mixed colored sorghum extrudates containing 15%, 20%, and 25% GPF, are presented in Table 2.

The protein content varied between the different treatments from 4.89 to 7.52 g.100 g^{-1} of sample (d.b). These values are reasonable considering the composition of the mixtures. The lipid content varied from 1.43 to 2.59 g.100 g^{-1}. This component is mainly associated with the seeds and, as the flour is made from the grape skin, there may be some remaining seed, presenting a value closer to that for the skin fraction. The lipid content of the grape skin fraction in this study is included among the values found by Romero et al. (2013), which was 4.76 g.100 g^{-1}.

Carbohydrates were the most abundant components in pre-cooked mixed CSF and GPF flour. Although the protein and lipid content is close to that of cereals in general, the mixture has an interesting contribution of nutrients in its consumption.

3.2 Physical properties

The pasting properties determined in the RVA indicate significant degrees of conversion after extrusion. Table 3 shows the results of the different treatments for pasting properties, bulk density, REI , LEI , and VEI for the different tests described in the experimental design. In general, the addition of material containing a significant amount of fiber to the formulations causes lower expansion values. Significant number of train jobs demonstrated this effect; consequently, as GPF is added, lower expansion values are observed. This is because the links are

Table 3. Regression coefficients (in coded levels) of adjusted models for proximate composition, pasting properties, and expansion properties of colored sorghum-grape peel extrudates using independent variables: proportion of grape peel flour (X_1), barrel temperature (X_2), and moisture content (X_3).

Coeff.	Proximate composition				Pasting properties		Expansion properties			
	ASH	PRO	LIP	CHO	BDV	STV	BD	REI	LEI	VEI
β_0	2.65**	5.39**	2.85**	89.11**	452.71**	262.37**	286.95**	5.48**	0.84**	4.52**
β_1	0.3**	−0.46**	0.34**	-	−49.08*	−75.12**	-	−0.6**	0.05*	−0.23^{ns}
β_{11}	−0.41**	0.42**	−0.24**	-	-	-	-	-	-	-
β_2	-	−0.18*	0.13*	-	20.08^{ns}	-	−12.6^{ns}	-	0.04*	-
β_{22}	−0.33**	-	-	0.39*	-	-	-	-	−0.02^{ns}	-
β_3	0.09*	−0.11^{ns}	-	-	43.11*	45.1**	82**	−1.2**	−0.03*	−1.18**
β_{33}	−0.34**	0.11^{ns}	-	0.29*	-	-	15.28*	-	-	-
β_{12}	-	-	-	-	−51.56*	-	-	-	-	-
β_{13}	-	-	-	-	-	-	-	-	-	-
β_{23}	-	0.22^{ns}	-	-	-	-	-	-	-	-
LoF	0.052^{ns}	0.053^{ns}	0.108^{ns}	0.174^{ns}	0.077^{ns}	0.067^{ns}	0.163^{ns}	0.581^{ns}	0.415^{ns}	0.525
R^2	0.931	0.7	0.711	0.614	0.446	0.808	0.902	0.925	0.718	0.903

ASH : ash content; PRO : protein content; LIP : lipid content; CHO : carbohydrate content; BDV : breakdown viscosity; STV : setback viscosity; BD : bulk density; REI : radial expansion index; LEI : longitudinal expansion index; VEI : volumetric expansion index; **significant at $p < 0.01$. *significant at $p < 0.05$; ^{ns}: not significant.

increasingly smaller, due to the blocking of cellulose structures in the formation of hydrogen bridges. Figure 2 shows the response surface plots for expansion properties: (a) BD (kg.m^{-3}); (b) REI ; (c) LEI ; and (d) VEI . All three of the independent variables had a significant effect on the expansion properties at $p < 0.01$ (Table 3); this can be seen in Figure 2a in which the apparent density is plotted with the process temperature and moisture content. It is evident that as the moisture content increases, there is an increase in pellet density. The reverse phenomenon occurs with a decrease in temperature, but with less impact.

On the other hand, as shown in Figure 2b, the plot of REI plot versus the proportion of GPF and moisture content, both variables have a significant effect on radial expansion. Figure 2c, the plot of LEI versus the proportion of GPF and moisture content, shows a linear inverse behavior, that is, the lower the moisture content, the higher the value of LEI and the lower the content of GPF more than LEI . An equivalent phenomenon is shown in Figure 2d, with VEI plotted against the proportion of GPF and moisture content. The starch content of sorghum flour is sufficient to cause high expansion values when extruded without any other ingredient. Thus, the levels of GPF substitution used (10%, 15%, and 20%) were sufficient to observe how, as the levels of expansion increase, they also decrease significantly.

Due to the interaction of GPF, mainly with sorghum starch carbohydrates, in the melting and expanded formation of a single product, it is understandable that there is a decrease in the level of expansion, considering the high levels of fiber that grape peel contains. A similar work by Diez-Sánchez et al. (2019), used blackcurrant pomace rich in polyphenols and dietary fiber, the extrusion treatment of the flour caused the disruption of the starch granules, and affected starch characteristics such as water binding capacity and swelling, this causes the expansion properties in general to be affected due to the fiber content contained in the study material.

In extruded mixed flours, there was a considerable reduction in viscosity values throughout the profile. In the first phase of the viscosity test, a certain water absorption capacity was observed, being characteristic of starch processed by thermoplastic extrusion and which has undergone shearing. The mixture with the highest moisture content, 20.4%, showed a sharp viscosity peak in the temperature increase phase, which may indicate the presence of starch with a certain molecular integrity capable of swelling with the temperature increase, typical of crude starch. According to Khanal et al. (2009), extrusion processing can be used to increase the procyanidin monomer and dimer content in grape seeds and pomace. Table 3 shows the regression coefficients of adjusted models for the proximate composition, pasting properties, and expansion properties of colored sorghum-grape peel extrudates using the independent variables proportion of GPF (X_1), barrel temperature (X_2), and moisture content (X_3), showing that in most events they had a significant effect on the physical properties (pasting and expansion properties).

It is important to emphasize that, the data recorded in Table 3, referring to expansion and density values, pasting properties

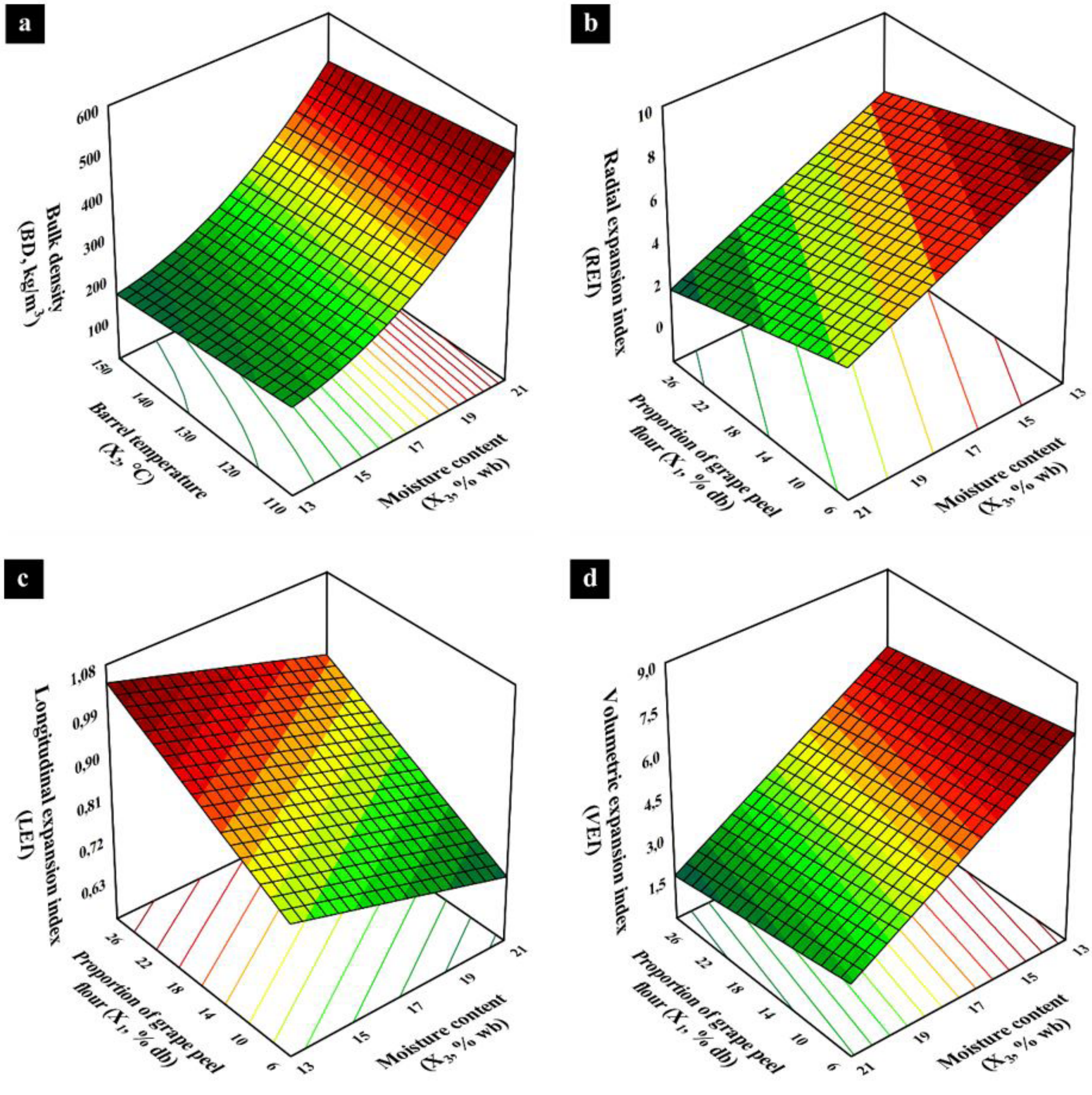

Figure 2. Response surface plots for expansion properties: (a) bulk density (*BD* , $kg.m^{-3}$); (b) radial expansion index (*REI*); (c) longitudinal expansion index (*LEI*); (d) volumetric expansion index (*VEI*).

allow the possibility of use for a given product, for example, tests with a high degree of expansion, can be used for beverage formulation, that of low expansion, can be used to compose porridge formulations, or use them in pastes or bakery products.

3.3 Antioxidant capacity and phenolics in grape skin flour and extruded products

Table 4 shows the results for antioxidant capacity determined by the ORAC and ABTS methods, anthocyanin content, and total phenolic content of pre-cooked mixtures of CSF and GPF, water absorption, and solubility index. The antioxidant values for GPF are considered high so that when fused by the extrusion process with CSF, the product obtained has sufficient quality of antioxidants compared to the available food supplement flours (Shi et al., 2017). Procyanidins in grape by-products have many health benefits, but most are present as large molecular weight compounds, which are poorly absorbed. Extrusion processing appears to be a promising technology to increase the levels of bioactive low molecular weight procyanidins (Khanal et al., 2009). According to this premise, it is considered that during the

Table 4. Antioxidant capacity determined by ORAC and ABTS methods, anthocyanin content, total phenolic content, water absorption, and solubility indices of pre-cooked blended colored sorghum and grape peel flours.

Run	Antioxidant activity		Phenolics		Water absorption and solubility indices	
	ORAC	ABTS	Anthocyanins	Total phenolics	WAI	WSI
1	16.040 ± 0.10	4.501 ± 0.11	108.23 ± 0.07	287.66 ± 0.11	18.94 ± 0.12	13.58 ± 0.11
2	28.633 ± 0.12	2.005 ± 0.10	112.43 ± 0.17	297.16 ± 0.16	10.49 ± 0.22	10.41 ± 0.16
3	16.312 ± 0.11	6.991 ± 0.13	109.13 ± 0.03	285.22 ± 0.26	18.45 ± 0.31	12.78 ± 0.21
4	10.715 ± 0.13	5.005 ± 0.10	111.03 ± 0.44	288.19 ± 0.33	15.22 ± 0.05	8.77 ± 0.31
5	29.351 ± 0.21	6.109 ± 0.14	118.53 ± 0.06	298.17 ± 0.13	12.13 ± 0.19	15.16 ± 0.24
6	37.627 ± 0.11	8.990 ± 0.10	122.01 ± 0.12	295.28 ± 0.91	12.15 ± 0.32	10.11 ± 0.21
7	34.570 ± 0.15	11.661 ± 0.11	126.21 ± 0.21	288.19 ± 0.33	20.12 ± 0.51	11.77 ± 0.33
8	32.263 ± 0.10	12.222 ± 0.14	125.90 ± 0.05	281.08 ± 0.72	17.05 ± 0.32	10.05 ± 0.19
9	09.324 ± 0.11	10.433 ± 0.12	95.05 ± 0.03	101.18 ± 0.12	21.56 ± 0.14	13.11 ± 0.25
10	37.122 ± 0.12	10.987 ± 0.10	138.31 ± 0.11	307.95 ± 0.11	19.41 ± 0.24	11.76 ± 0.28
11	24.311 ± 0.15	4.669 ± 0.10	101.27 ± 0.08	277.61 ± 0.22	14.55 ± 0.16	11.94 ± 0.41
12	25.541 ± 0.30	4.644 ± 0.12	112.23 ± 0.11	267.26 ± 0.07	39.89 ± 0.22	11.15 ± 0.42
13	32.335 ± 0.35	6.298 ± 0.10	100.32 ± 0.22	259.61 ± 0.22	38.99 ± 0.19	15.11 ± 0.33
14	18.777 ± 0.32	6.666 ± 0.14	128.21 ± 0.44	285.11 ± 0.04	38.72 ± 0.13	10.14 ± 0.21
15	31.776 ± 0.31	9.276 ± 0.12	110.11 ± 0.22	280.17 ± 0.04	17.88 ± 0.28	11.09 ± 0.41
16	37.889 ± 0.32	10.601 ± 0.16	109.93 ± 0.06	283.99 ± 0.55	16.91 ± 0.13	12.54 ± 0.51
17	33.679 ± 0.28	10.006 ± 0.12	111.88 ± 0.11	281.16 ± 0.07	19.89 ± 0.08	11.33 ± 0.13
18	33.666 ± 0.30	11.127 ± 0.11	112.25 ± 0.05	284.22 ± 0.66	12.93 ± 0.09	10.17 ± 0.41
19	33.176 ± 0.19	9.267 ± 0.16	111.66 ± 0.27	281.99 ± 0.19	16.77 ± 0.14	11.59 ± 0.14
Raw materials	ORAC	ABTS	Anthocyanins	Total phenolics		
Colored sorghum flour	89.111 ± 0.25	32.147 ± 0.19	71.66 ± 0.27	4.09 ± 0.19	-	-
Grape peel flour[a]	321.033 ± 0.21	49.567 ± 0.15	2098.7 ± 0.12	1821.3 ± 0.13	-	-
Grape peel flour[b]	311.022 ± 0.30	44.666 ± 0.10	1822.2 ± 0.02	1669.3 ± 0.03	-	-

ORAC: oxygen radical absorbance capacity (μmol Trolox.g^{-1}); ABTS: 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (μmol Trolox.g^{-1}); anthocyanins (mg cyanidin-3-glucoside 100 g^{-1}); total phenolic compounds (mg catechin.100 g^{-1}). [a]before drying; [b]after drying.

extrusion process, mainly during melt rather formation in the fusion of the two ingredients, CSF and GPF, part of the molecular structure could be exposed, so that in the determinations appear. On the other hand, considering that extrusion is an HTSH-type thermal process, its effect on the content of antioxidants is not so drastic, mainly because it takes a very short period, that is, approximately 20 to 30 s, in this sense, Pokorný & Schmidt (2010) commented that extrusion usually occurs at temperatures above 100 °C, but the residence time is very short, therefore the decomposition of antioxidants is relatively small, these authors cited an experiment with wheat flour Saracen, where they were extruded at 120 ± 200 °C. in which they observed that the content of phenolic acids increased by the release of their binding to proteins and the sum of polyphenols decreased. Considering GPF as a raw material before the mixing procedure for the extrusion procedure, at the end of Table 4, the values of antioxidants (ORAC, ABTS, total anthocyanins, and phenolic) were added, to verify the influence of the exposed time the drying of the grape skin at a temperature of 45°C before and after drying. In which there was a decrease in the values of antioxidants, ORAC, and ABTS, of 3.2%, and 10%, respectively, in the case of Total anthocyanins and phenolics, 13.18%, and 8.35%, respectively. As an example of losses in cooking activities, during steaming cabbage cooking losses are about 21 ± 23% in ascorbic acid and total phenols about 10%. The antioxidant activity of Trolox decreased by 5 ± 20% and the phenolic compounds increased the pea antioxidant capacity, due to the phenol ± protein interaction. Hydroxycinnamic acids (such as ferulic, coumaric, and caffeic acids) were the most active ingredients (Pokorný & Schmidt, 2010). Considering the work of Nayak et al. (2011) who used the extrusion process for a mixture of purple potato and yellow pea flour the losses in the total phenolic (TP) content of the formulations under extrusion are expected to occur, due to breaking down of complex polyphenols to other phenolic or non-phenolic compounds, because of high-temperature conditions. However, the effect of the extrusion die at temperatures, 130 and 140 °C, was not significant ($p > 0.05$) on the TP content of the extrudates. On the other hand, Moreno et al. (2017) corroborate what was described above, in which several studies have shown that extrusion and process conditions affect the phytochemical content and antioxidant activity of cereal grains, showing that important losses can occur in the Bioactive compounds due to thermal effect and chemical changes can occur during extrusion since phenolic compounds are highly dependent on the parameters, moisture content, temperature and residence time in the extrusion system.

In another work, researchers (Neder-Suárez et al., 2021) used a blend of blue corn, black beans and sweet chard by extrusion in the production of a type of third-generation snacks, considering that these ingredients contain phytochemical and polyphenols compounds. They concluded that despite thermal processes, anthocyanin retention was high (29.08 mg of cyanidin-3-glucoside equivalents/100 g) under the optimal process conditions of 122 °C, 133 rpm, and 25% of moisture content. Screw speed and moisture content had the largest effects on the physical responses, while moisture content had the largest effects on total anthocyanin. The highest expansion index, water absorption and water solubility indexes, and hardness were obtained at high screw speed and low extrusion temperature. At low extrusion temperature and moisture content, the highest total anthocyanin was generated.

Among the possibilities of using GPF, Baldán et al. (2021) used this flour; processed at 75 °C (15 and 25%) improved the nutritional composition of the muffins as their content increases, highlighting protein and rude fiber content. Likewise, these had a good level of acceptability by consumers. Taking into account grape pomace is a by-product discarded by wineries, it has a potential benefit and is feasible to use as an ingredient for gluten-free muffins. It should be considered that these authors used GPF without mixing, and not processed by extrusion. In the case of the present study, however, we have the mixture, in the percentages established in the experimental design (10, 15 and 20% of GPF) with the difference of colored sorghum flour. This condition, with the starch material fused to GPF, can contribute to better performance in the elaboration of products, as the functional characteristics like absorption and water solubility can be modified only with variations in the extruder process parameters and meet specific functional properties.

4 Conclusion

These results indicated that extrusion of sorghum colored and grape peel flours produces acceptable extrudates. Changing process conditions affected the physical and functional properties of produced expanded products. However, this impact is not very drastic, making the products resulting from the CSF/GPF mixture have significant values of antioxidants and phenolic compounds. Under these conditions, this resulting mixture with considerable amounts of antioxidants and phenolic compounds can be used as porridge, food formulations among other alternatives. In any case, the resulting products can contribute to the health of the consumer.

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References

Alvarez-Martinez, L., Kondury, K. P., & Harper, J. M. (1988). A general model for expansion of extruded products. *Journal of Food Science*, 53(2), 609-615. http://dx.doi.org/10.1111/j.1365-2621.1988.tb07768.x.

Alves, P. L. S., Berrios, J. D. J., Pan, J., & Ascheri, J. L. R. (2018). Passion fruit shell flour and rice blends processed into fiber-rich expanded extrudates. *CYTA: Journal of Food*, 16(1), 901-908. http://dx.doi.org/10.1080/19476337.2018.1503618.

Anderson, R. A., Conway, H. F., Pfeifer, V. F., & Griffin, E. L. (1969). Gelatinization of corn grits by roll and extrusion cooking. *Cereal Science Today*, 14(1), 4-12.

Association of Official Analytical Chemistry – AOAC. (2010). *Official methods of analysis* (18th ed.). Gaithersburg: AOAC International.

Baldán, Y., Riveros, M., Fabani, M. P., & Rodriguez, R. (2021). Grape pomace powder valorization: a novel ingredient to improve the nutritional quality of gluten-free muffins. *Biomass Conversion and Biorefinery*. In press. https://doi.org/10.1007/s13399-021-01829-8.

Bampi, M., Bicudo, M. O. P., Fontoura, P. S. G., & Ribani, R. H. (2010). Chemical composition of fruit, concentrated extract and flour from "Japanese grape.". *Ciência Rural*, 40(11), 2361-2367. http://dx.doi.org/10.1590/S0103-84782010001100018.

Brennan, C., Brennan, M., Derbyshire, E., & Tiwari, B. K. (2011). Effects of extrusion on the polyphenols, vitamins and antioxidant activity of foods. *Trends in Food Science & Technology*, 22(10), 570-575. http://dx.doi.org/10.1016/j.tifs.2011.05.007.

Companhia Nacional de Abastecimento – CONAB. (2020). *Grãos: acompanhamento da safra brasileira* (Vol. 8 – Safra 2020/21, No. 1 – Primeiro Levantamento). Brasília. Retrieved from https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos

Dávalos, A., Gómez-Cordovés, C., & Bartolomé, B. (2004). Extending applicability of the oxygen radical absorbance capacity (ORAC-fluorescein) assay. *Journal of Agricultural and Food Chemistry*, 52(1), 48-54. http://dx.doi.org/10.1021/jf0305231. PMid:14709012.

Davis, H., Su, X., Shen, Y., Xu, J., Wang, D., Scott Smith, J., Aramouni, F., & Wang, W. (2019). Phenotypic diversity of colored phytochemicals in sorghum accessions with various pericarp pigments. In R. R. Watson (Ed.), *Polyphenols in plants: isolation, purification and extract preparation* (pp. 123-131). London: Academic Press. Elsevier. http://dx.doi.org/10.1016/B978-0-12-813768-0.00008-6.

Di Cairano, M., Galgano, F., Tolve, R., Caruso, M. C., & Condelli, N. (2018). Focus on gluten free biscuits: Ingredients and issues. *Trends in Food Science & Technology*, 81, 203-212. http://dx.doi.org/10.1016/j.tifs.2018.09.006.

Diez-Sánchez, E., Quiles, A., Llorca, E., Reiβner, A.-M., Struck, S., Rohm, H., & Hernando, I. (2019). Extruded flour as techno-functional ingredient in muffins with berry pomace. *LWT*, 113, 108300. http://dx.doi.org/10.1016/j.lwt.2019.108300.

Doğan, H., & Karwe, M. V. (2003). Physicochemical properties of quinoa extrudates. *Food Science & Technology International*, 9(2), 101-114. http://dx.doi.org/10.1177/1082013203009002006.

Fan, J., Mitchell, J. R., & Blanshard, J. M. V. (1996). The effect of sugars on the extrusion of maize grits: I. The role of the glass transition in determining product density and shape. *International Journal of Food Science & Technology*, 31(1), 55-65. http://dx.doi.org/10.1111/j.1365-2621.1996.22-317.x.

Fontana, A. R., Antoniolli, A., & Bottini, R. (2013). Grape pomace as a sustainable source of bioactive compounds: Extraction, characterization, and biotechnological applications of phenolics. *Journal of Agricultural and Food Chemistry*, 61(38), 8987-9003. http://dx.doi.org/10.1021/jf402586f. PMid:24004377.

Georgé, S., Brat, P., Alter, P., & Amiot, M. J. (2005). Rapid determination of polyphenols and vitamin C in plant-derived products. *Journal of Agricultural and Food Chemistry*, 53(5), 1370-1373. http://dx.doi.org/10.1021/jf048396b. PMid:15740008.

Georgé, S., Tourniaire, F., Gautier, H., Goupy, P., Rock, E., & Caris-Veyrat, C. (2011). Changes in the contents of carotenoids, phenolic compounds and vitamin C during technical processing and lyophilisation of red and yellow tomatoes. *Food Chemistry*, 124(4), 1603-1611. http://dx.doi.org/10.1016/j.foodchem.2010.08.024.

Instituto Adolfo Lutz – IAL. (2008). *Analytical standards of the Instituto Adolfo Lutz: physicochemical methods for food analysis* (1020 p.). São Paulo: IAL.

Jackson, R. (2020). *Wine science: principles and applications* (5th ed.). London: Academic Press.

Khanal, R. C., Howard, L. R., & Prior, R. L. (2009). Procyanidin content of grape seed and pomace, and total anthocyanin content of grape pomace as affected by extrusion processing. *Journal of Food Science*, 74(6), H174-H182. http://dx.doi.org/10.1111/j.1750-3841.2009.01221.x. PMid:19723202.

Lee, J., Durst, R. W., & Wrolstad, R. E. (2005). Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: collaborative study. *Journal of AOAC International*, 88(5), 1269-1278. http://dx.doi.org/10.1093/jaoac/88.5.1269. PMid:16385975.

Leonard, W., Zhang, P., Ying, D., & Fang, Z. (2020). Application of extrusion technology in plant food processing byproducts: An overview. *Comprehensive Reviews in Food Science and Food Safety*, 19(1), 218-246. http://dx.doi.org/10.1111/1541-4337.12514. PMid:33319515.

Matejová, S., Fikselová, M., Čurlej, J., & Czako, P. (2016). Application of by-products in the development of foodstuffs for particular nutritional uses. *Journal of Central European Agriculture*, 17(4), 1306-1319. http://dx.doi.org/10.5513/JCEA01/17.4.1850.

Mehraj, M., Naik, H. R., Reshi, M., Mir, S. A., & Rouf, A. (2018). Development and evaluation of extruded product tion of extruded product of rice flour and apple pomace. *International Quarterly Journal of Life Sciences*, 1(13), 21-26.

Moreno, C. R., Fernández, P. C. R., Rodríguez, E. O. C., Carrillo, J. M., & Rochín, S. M. (2017). Changes in nutritional properties and bioactive compounds in cereals during extrusion cooking. In S. Z. Qamar (Ed.), *Extrusion of metals, polymers and food products*. London: IntechOpen. https://doi.org/10.5772/INTECHOPEN.68753.

Nayak, B., Berrios, J. D. J., Powers, J. R., & Tang, J. (2011). Effect of extrusion on the antioxidant capacity and color attributes of expanded extrudates prepared from purple potato and yellow pea flour mixes. *Journal of Food Science*, 76(6), C874-C883. http://dx.doi.org/10.1111/j.1750-3841.2011.02279.x. PMid:22417485.

Neder-Suárez, D., Quintero-Ramos, A., Meléndez-Pizarro, C. O., Jesús Zazueta-Morales, J., Paraguay-Delgado, F., & Ruiz-Gutiérrez, M. G. (2021). Evaluation of the physicochemical properties of third-generation snacks made from blue corn, black beans, and sweet chard produced by extrusion. *LWT*, 146, 111414. http://dx.doi.org/10.1016/j.lwt.2021.111414.

Offiah, V., Kontogiorgos, V., & Falade, K. O. (2019). Extrusion processing of raw food materials and by-products: a review. *Critical Reviews in Food Science and Nutrition*, 59(18), 2979-2998. http://dx.doi.org/10.1080/10408398.2018.1480007. PMid:29787291.

Oladiran, D. A., & Emmambux, N. M. (2018). Nutritional and functional properties of extruded cassava-soy composite with grape pomace. *Starch*, 70(7-8), 1700298. http://dx.doi.org/10.1002/star.201700298.

Osorio, D. A., & Silveira, J. F. S., Jr. (2013). *Composição centesimal e perfil de ácidos graxos de farinha obtida do bagaço de uva cv. 'Concord' (Vitis labrusca L.) sob dois métodos de cultivo: convencional e orgânico.* Universidade Tecnológica Federal do Paraná, Francisco Beltrão. Retrieved from http://repositorio.utfpr.edu.br/jspui/handle/1/11658

Pitts, K. F., McCann, T. H., Mayo, S., Favaro, J., & Day, L. (2016). Effect of the sugar replacement by citrus fibre on the physical and structural properties of wheat-corn based extrudates. *Food and Bioprocess Technology*, 9(11), 1803-1811. http://dx.doi.org/10.1007/s11947-016-1764-4.

Pokorný, J., & Schmidt, Š. (2010). Effects of processing and storage on antioxidant efficacy in foods. In E. A. Decker (Ed.), *Oxidation in foods and beverages and antioxidant applications: understanding mechanisms of oxidation and antioxidant activity* (pp. 368-393). Oxford: Woodhead Publishing. http://dx.doi.org/10.1533/9780857090447.2.368.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology & Medicine*, 26(9-10), 1231-1237. http://dx.doi.org/10.1016/S0891-5849(98)00315-3. PMid:10381194.

Román, L., Martínez, M. M., Rosell, C. M., & Gómez, M. (2017). Changes in physicochemical properties and in vitro starch digestion of native and extruded maize flours subjected to branching enzyme and maltogenic α-amylase treatment. *International Journal of Biological Macromolecules*, 101, 326-333. http://dx.doi.org/10.1016/j.ijbiomac.2017.03.109. PMid:28341177.

Romero, P., Gil-Muñoz, R., del Amor, F. M., Valdés, E., Fernández, J. I., & Martinez-Cutillas, A. (2013). Regulated deficit irrigation based upon optimum water status improves phenolic composition in Monastrell grapes and wines. *Agricultural Water Management*, 121, 85-101. http://dx.doi.org/10.1016/j.agwat.2013.01.007.

Sánchez-Tena, S., Lizárraga, D., Miranda, A., Vinardell, M. P., García-García, F., Dopazo, J., Torres, J. L., Saura-Calixto, F., Capellà, G., & Cascante, M. (2013). Grape antioxidant dietary fiber inhibits intestinal polyposis in ApcMin/+ mice: Relation to cell cycle and immune response. *Carcinogenesis*, 34(8), 1881-1888. http://dx.doi.org/10.1093/carcin/bgt140. PMid:23615403.

Shi, N., Narciso, J. O., Gou, X., Brennan, M. A., Zeng, X. A., & Brennan, C. S. (2017). Manipulation of antioxidant and glycaemic properties of extruded rice based breakfast cereal products using pomelo fruit by-product material. *Quality Assurance and Safety of Crops & Foods*, 9(4), 489-495. http://dx.doi.org/10.3920/QAS2017.1084.

Wang, S., Kowalski, R. J., Kang, Y., Kiszonas, A. M., Zhu, M. J., & Ganjyal, G. M. (2017). Impacts of the particle sizes and levels of inclusions of cherry pomace on the physical and structural properties of direct expanded corn starch. *Food and Bioprocess Technology*, 10(2), 394-406. http://dx.doi.org/10.1007/s11947-016-1824-9.

Włodarczyk-Stasiak, M., & Jamroz, J. (2009). Specific surface area and porosity of starch extrudates determined from nitrogen adsorption data. *Journal of Food Engineering*, 93(4), 379-385. http://dx.doi.org/10.1016/j.jfoodeng.2009.01.041.