

Technical feasibility of grape pomace flour in dry *gomiti rigati* pasta

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ABSTRACT: Grape pomace (GP) is a by-product of the winemaking process, making it possible to incorporate it into bakery products. This research obtained dry pasta-type *gomiti rigati*, partially replacing wheat flour (WF) with grape pomace flour (GPF). The GPF was obtained by drying, crushing, and sieving the Isabel grape pomace (*Vitis Labrusca*) derived from grape juice production. The current results suggested that the addition of GPF caused an increase in the dough's water absorption capacity (WAC), a decrease in resistance to extension (RES), and extensibility (EXT) to a level of 21.04%. The cooking quality parameters demonstrated that the level of 14.18% provided a shorter optimal cooking time (OCT), while the 13.33% concentration resulted in a lower cooking loss (CL) ($P < 0.05$). These results showed that GP can be successfully incorporated into pasta, making applying it in pasta viable.

Key words: agro-industrial waste, rheological properties, food fiber, sustainability.

Viabilidade técnica da farinha de bagaço de uva em macarrão seco tipo *gomiti rigati*

RESUMO: O bagaço de uva (BU) é um subproduto oriundo do processamento de uvas na indústria vitivinícola, sendo possível a incorporação em produtos de panificação. O presente estudo objetivou a obtenção de macarrão tipo *gomiti rigati*, substituindo parcialmente a farinha de trigo (FT) por farinha de bagaço de uva (FBU). A FBU foi obtida por meio da secagem, trituração e peneiramento do bagaço de uva Isabel de espécie *Vitis labrusca* oriunda do processo de produção de suco. Os resultados atuais sugerem que a adição de FBU ocasionou o aumento na capacidade de absorção de água da massa (CAA), a diminuição da resistência à extensão (RES) e da extensibilidade (EXT) até o nível de 21,04%. O teste de qualidade do macarrão demonstrou que a concentração de 14,18% de FBU proporcionou um menor tempo ótimo de cozimento (TOC), enquanto a concentração de 13,33% uma menor perda de sólidos (PS) ($P < 0,05$). Esses resultados mostram que BU pode ser incorporado com sucesso à massa, sendo viável a sua aplicação na produção de massa alimentícia.

Palavras-chave: resíduos agroindustriais, propriedades reológicas, fibra alimentar, sustentabilidade.

INTRODUCTION

Grapes are among the most cultivated fruits in the world, and their production, known as viticulture, represents around 75 million tons per year (ANTONIĆ et al., 2020; FAO, 2005). According to TOLVE et al. (2021), grape processing generates a large volume of waste, representing about 20% of the mass of the total processed grapes. Grape pomace (GP), the main residue from the winemaking process and juice production, consists of seeds, skin, and stalk fragments (GAITA et al., 2020) and is considered a promising by-product due to its high nutritional value (TOLVE et al., 2021; IUGA & MIRONEASA, 2020).

GP is rich in dietary fiber (DF), mineral salts, such as potassium, phosphorus, calcium,

magnesium, manganese, iron, zinc, copper, aluminum, strontium, and sulfur, as well as phenolic compounds, with significant antioxidant capacity. In addition, GP could be used as a functional ingredient in human food to prevent several chronic diseases, such as cardiovascular disorders, type 2 diabetes, obesity, and certain types of cancer (TOLVE et al., 2021; IUGA & MIRONEASA, 2020). In this context, grape by-products become a viable alternative for use in other industrial processes, due to the high volume generated in agro-industries and because they are a cheap source of antioxidant compounds and dietary fiber (GAITA et al., 2020; IUGA & MIRONEASA, 2020; SIMONATO, 2021). Therefore, this study investigated the feasibility of using grape pomace flour (GPF), obtained from the processing of grape juice, in the production of dried *gomiti rigati* pasta.

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MATERIALS AND METHODS

Grape pomace (GP) from Isabel grapes (*Vitis labrusca*), a red variety widely used for juice production (2021 harvest), was kindly provided by the winery Adega Bianchetti Tedesco (Lagoa Grande - PE). The grape pomace flour (GPF) was obtained by drying the GP in a tray-type dryer at 55 °C for 4 h, until a final moisture of 10%. Next, the GP was ground in a knife mill (Model TE-651 Tecnal), with a 20-mesh sieve. Subsequently, the GPF was preserved in the polyethylene packaging at room temperature (24 ± 4 °C) until analyzed.

Physical and physicochemical analysis

Grape pomace flour (GPF)

The particle size distribution of the GPF was determined according to the approved method 66-20 (AACC, 2000). Moisture, water activity (a_w), pH, and titratable acidity were measured according to the method described by INSTITUTO ADOLFO LUTZ (2008). Ash analysis was determined according to approved method 01-08 (AACC, 2000). The micro Kjeldhal method determined the nitrogen content and converted it into protein using a factor of 6.25 according to the approved method 46-10 (AACC, 2000). The total dietary fiber (TDF) content was determined by the enzymatic-gravimetric method 985.29, described by AOAC (2016). The lipid content was determined using method 30-25 of the AACC (AACC, 2000), with direct extraction in a Soxhlet apparatus. The carbohydrate content was determined by difference from the other components, according to INSTITUTO ADOLFO LUTZ (2004).

Mixed flour (GPF and WF)

The color of mixed flour (GPF and WF) at levels of 0, 5, 10, 15, 20, 25, and 30% GPF was measured by a reflectance colorimeter (KONICA MINOLTA CR-410) based on the color system CIE – $L^* a^* b^*$, according to the procedure described by UNGUREANU-IUGA et al. (2020). Water absorption capacity (WAC) was analyzed as proposed by SOSULSKI (1962).

Rheological analysis of mixed flour (GPF and WF)

Extensography analyses were performed using a TA-XT.plus Texture Analyser equipped with the A/KIE accessory, according to the procedure described by BAGDI et al. (2014). A whole pasta strand was placed perpendicular to the blade for each analysis, according to the methodology described in AACC 16-50 (2000), with some modifications. Doughs with the following GPF concentrations were prepared:

0, 5, 10, 15, 20, 25, and 30%, using WF and a saline solution (2.5% NaCl). The test was performed under the following conditions: pre-test speed: 2.0 mm s⁻¹; test speed: 3.3 mm s⁻¹; and post-test speed: 10.0 mm s⁻¹.

Pasta preparation

Pasta was formulated to contain final grape pomace flour (GPF) levels of 0, 4, 8, 12, and 16%, by partially substituting WF with GPF (Figure 1). The concentrations were established to achieve the minimum fiber content for a “high in fiber” claim, corresponding to 5 g of dietary fiber per reference portion (20% of the Daily Reference Value, DRV of 25 g/day for adults) according to ANVISA (Brazilian Health Regulatory Agency) in IN (Normative Instruction) n° 75/2020 (BRASIL, 2020). Based on the fiber content of the grape pomace flour used, 13.8 g of GPF per portion was required to meet this criterion, while also considering the rheological properties of the flour blends. The ingredients used to prepare the dough were: WF (100%), GPF (0, 4, 8, 12, or 16% of the total WF amount), water (75% of the water absorption capacity, due to preliminary test results), soybean oil (2%), and salt (0.5%).

The dough was prepared using a professional pasta machine, being considered 75% of the WAC, due to preliminary test results. Therefore, WAC was obtained according to the mathematical model $WAC = 0.3689 [FBU] + 50.9$, with $R^2 = 0.9349$. Then, the dough was extruded and cut in an Indian extruder series 372707 to obtain the *gomiti rigati* shaped pasta. The pasta was dried according to the methodology of BERGMAN et al. (1994).

Pasta cooking properties and texture analysis

The American Association of Cereal Chemists Official Method 66-50.01 (AACC, 2010), with some modifications, was used to determine pasta cooking properties. The analysed parameters were: optimal cooking time (OCT), water absorption index (WAI), swelling index (SI) (CRUZ & SOARES, 2004), and cooking loss (CL).

Texture analysis was performed according to the methodology of CHEN et al. (2011), with some modifications. A TA-XT plus Texture Analyser in double-cycle compression, with a knife blade probe, was used for the firmness and shear strength test, according to AACC-approved method 16-50 (AACC, 2000), with some modifications.

Statistical Analysis

The experiment followed a completely randomized design with three replicates. Data



Figure 1 - Dry pasta (*gomiti rigati*) prepared from wheat flour (WF) and grape pomace flour (GPF) premixes, before and after optimal cooking time (OCT). From left to right: control pasta with 0% GPF, and pasta containing 4%, 8%, 12%, and 16% GPF, respectively. Top row: uncooked pasta. Bottom row: cooked pasta (after OCT).

was analyzed by ANOVA and regression at a 5% significance level using SAS software (Statistical Analysis System), version 9.1.

RESULTS AND DISCUSSION

Analysis of grape pomace flour (GPF)

The particle-size distribution of GPF showed that around 67.99% of the particles have a diameter similar to WF. According to ANVISA (Brazilian Health Regulatory Agency), in IN (Normative Instruction) n° 08/2005, WF must contain around 95% of particles with diameters below 0.25mm (BRASIL, 2005).

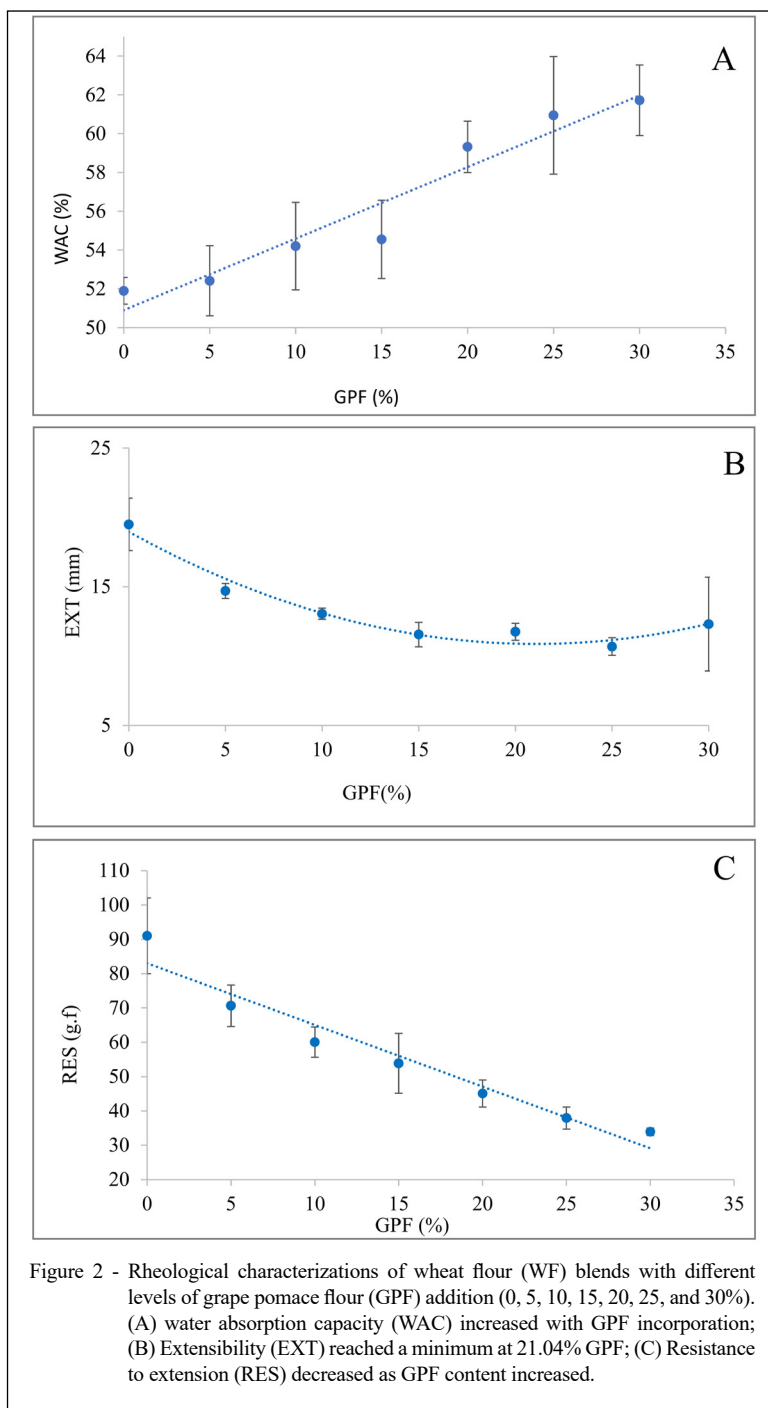
The chemical composition of the GPF was as follows: total dietary fiber (TDF) (45.22%), ash ($7.94\% \pm 0.27$), protein ($11.88\% \pm 0.26$), lipid (7.86%), carbohydrates (17.09%), moisture ($10.01\% \pm 0.10$), water activity (a_w) (0.54 ± 0.03), total titratable acidity ($0.44\% \pm 0.03$ g of acid tartaric acid/100 g) and pH (3.62 ± 0.01). The present findings agree with the literature, except for the ash and lipid values, which were considerably higher. The TDF content reported in the present study was high, which makes its use in bakery products promising. About ash, grape pomace is rich in

mineral salts, which justifies the increase in the ash content (IUGA & MIRONEASA, 2020; ANTONIĆ et al., 2020).

Analysis of mixed flour (GPF and WF)

According to the mathematical model ($P < 0.05$), $L^* = -0.7866[\text{FBU}] + 89.962$, $R^2 = 0.90$, the lightness (L^* -values) decreased with the increasing level of GPF in the WF. This behavior could be associated with the presence of the polyphenols responsible for the dark GPF pigmentation (ANTONIĆ et al., 2020). The model ($P < 0.05$), $a^* = 0.2081[\text{FBU}] + 0.4917$, $R^2 = 0.93$, indicated that redness increased 0.2081 times while yellowing had an initial tendency towards color blue up to a certain level, and then to yellow, as indicated by the model ($P < 0.05$), $b^* = 0.0085[\text{FBU}]^2 - 0.3111[\text{FBU}] + 8.7762$, $R^2 = 0.70$. The difference of color (ΔE^*) of the samples to the standard, 0% GPF, according to the model ($P < 0.05$), $\Delta E^* = 0.582[\text{FBU}] + 10.476$, $R^2 = 0.99$, increased by 0.582 times, demonstrating that the difference in color of the sample to the standard increased with the increasing level of GPF.

The water absorption capacity (WAC) of the flour mixes (Figure 2A) could be explained



by the model ($P < 0.05$), $WAC = 0.3689[FBU] + 50.9$, $R^2 = 0.93$. According to this model, there was an increase of 0.3689 times in the WAC. Similar results have also been reported by KUČTOVÁ et al. (2018) and OPREA et al. (2018), where the WAC increased with the addition of grape skin flour (GSF). This could be explained by the presence of

hydroxyl groups in the structure of the fibers, which leads to greater interaction in the protein matrix through hydrogen bonds (KAUR et al., 2012; IUGA & MIRONEASA, 2020). In addition to the effect of fiber, ash content is another important factor influencing WAC. According to PACHECO et al. (2015), ash content is the main influencing factor

in water absorption, strongly contributing to the increase in moisture, a preponderant factor in water absorption during cooking.

The extensibility (EXT), which reveals the ability of the dough to expand without breakdown, decreased (Figure 2B) to the level of 21.04% of GPF, as indicated by the model ($P < 0.05$), $EXT = 0.0183[FBU]^2 - 0.77[FBU] + 18.99$, $R^2 = 0.96$. The dough extensibility values found in the present study were following other studies. In the study by SAMOHVALOVA et al. (2016), it was observed that there was a gradual decrease in extensibility with the addition of up to 20% of grape seed flour (GSF) in biscuit dough, a desirable factor for making pasta.

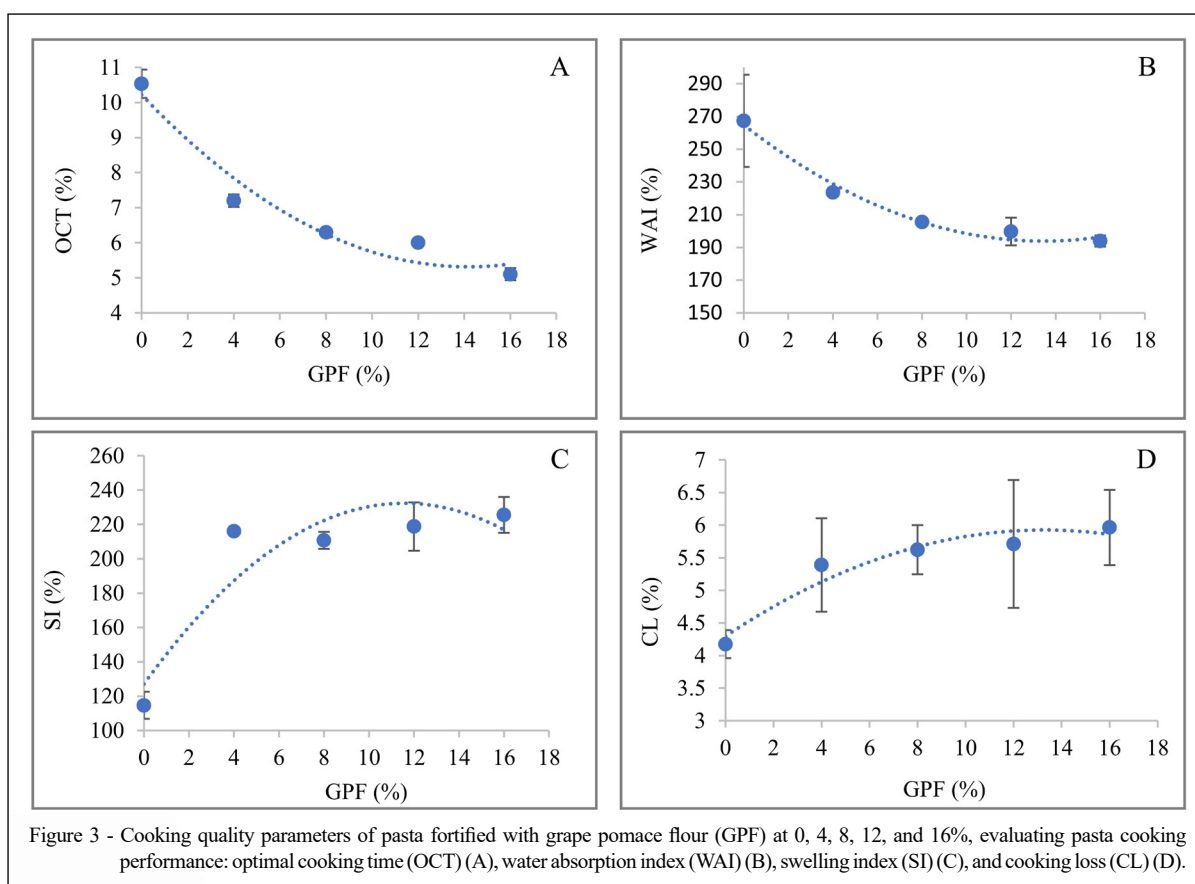
Resistance to extension (RES) (Figure 2C) decreased significantly with the increasing level of GPF, according to model ($P < 0.05$), $RES = -1.80[FBU] + 83.03$, $R^2 = 0.94$. The development of gluten is influenced by the presence of fibers derived from fruit processing by-products, which compete with gluten-forming proteins for water during dough mixing. This competition reduces protein hydration and intermolecular interactions,

thereby impairing the formation of a cohesive and functional gluten network. Moreover, the ash content in GPF amplifies this effect, since mineral components also interact with the available water, further contributing to the structural weakening of the protein matrix (IUGA & MIRONEASA, 2020; KUMAR & PRABHASANKAR, 2015).

Analysis of pasta dough

The optimal cooking time (OCT) analysis (Figure 3A) shows that the 14.18% of GPF provided a shorter optimal cooking time (5.31 minutes), according to the model ($P < 0.05$), $OCT = 0.0244[FBU]^2 - 0.6921[FBU] + 10.221$, $R^2 = 0.9475$. According to TOLVE et al. (2020), this could be due to the high amount of fiber compared to starch in mixed flour, which induces early starch gelatinization and consequent OCT reduction.

For the water absorption index (WAI) parameter (Figure 3B), model ($P < 0.05$), $WAI = 0.3928[FBU]^2 - 10.557[FBU] + 264.8$, $R^2 = 0.9814$, the lowest value was at 13.43% of GPF, which increased the weight of the pasta by 1.93 times, a



value considered optimal, close to 2 to 3 times, as recommended by HUMMEL (1966). The study of TOLVE et al. (2020) also verified a reduction in WAI in the dough with increasing levels of GPF.

For the swelling index (SI) (or volume increase) of cooked pasta (Figure 3C), the model ($P < 0.05$), $SI = -0.7862[FBU]^2 + 18.191[FBU] + 127.11$, $R^2 = 0.8407$, indicates that the maximum was obtained at 11.57% GPF, with an absorption value equivalent to 232.32%, or 2.32 times its volume. According to HUMMEL (1966), good quality dry pasta should increase 3 to 4 times its volume. Moreover, this decreasing SI behavior may be a consequence of the reduction in starch content due to the addition of non-starchy material.

Measurement of cooking loss (CL) (or solid loss) is an important parameter in assessing its overall quality. An increasing trend was observed in CL with GPF level increase (Figure 3D), according to the model ($P < 0.05$), $CL = -0.0092[FBU]^2 + 0.2454[FBU] + 4.2968$, $R^2 = 0.9313$. The maximum quantity found was 5.93% for a level of 13.33% of GPF, which characterizes high technological quality pasta. According to HUMMEL (1966), dry pasta to be considered very good must have CL of up to 6%, regular, up to 8%, and above 10%, it is considered bad. Therefore, it can be affirmed that the *gomiti rigati* pasta developed in this study can be classified as very good technologically.

For the pasta firmness (F) parameter as a function of different levels of GPF, the significant mathematical model was obtained ($P < 0.05$): $F = -0.3142[FBU]^2 + 6.8152[FBU] + 108.81$, $R^2 = 0.9777$. According to the model, the maximum point found was 10.85% of GPF with an F value equivalent to 145.76 g. Conversely, for Shear Force, the model was not significant ($P > 0.05$) with the addition of grape pomace flour (GPF).

CONCLUSION

The use of grape pomace (GP), a winemaking by-product available at low cost in great amounts, may represent an alternative in the preparation of pasta, due to the possibilities of improving the nutritional and technological pasta quality. The results of this study showed that the addition of grape pomace flour (GPF), from grape juice processing significantly influenced the dough's technological properties. Therefore, making it a great alternative for reusing this waste.

The addition of grape pomace flour (GPF) influenced the rheological properties of the dough,

resulting in less extensible and less resistant pasta. This effect is attributed to the dilution of gluten proteins and competition for water, which reduces the formation of the gluten network. Increasing GPF levels in wheat flour led to higher water absorption capacity of the blends, indicating that fiber and ash content significantly affect the hydration properties of the mixtures.

Regarding pasta quality parameters, the lowest value for optimal cooking time (OCT) was observed, which was considered satisfactory. Although, cooking loss (CL) increased, the maximum values remained acceptable, indicating a pasta of high technological quality. In conclusion, the preparation of dry *gomiti rigati* pasta with the addition of 14.18% of GPF is technically viable for application in pasta. This level of incorporation meets most of the parameters evaluated in this study (extensibility, resistance to extension, optimal cooking time, and cooking loss), while also allowing the product to claim a "high dietary fiber" content.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare that there is no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analysis, or interpretation of data; in writing the manuscript, and in deciding to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and writing of the manuscript. All authors critically revised the manuscript and approved the final version.

DATA AVAILABILITY STATEMENT

The raw data underlying the described research are available from the corresponding author upon reasonable request.

DECLARATION OF USE OF ARTIFICIAL INTELLIGENCE

The authors declare that artificial intelligence tools were not used to write the manuscript, nor to replace the authors' activities and skills at any stage of the study. All analyses,

interpretations, and preparation of the manuscript were performed exclusively by the authors.

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