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Optimising the nutritional and sensory quality of gluten-free flours

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Abstract**—**This study evaluated gluten-free flours made from corn, rice, and sweet potato (SP) for pancake (PC) production targeting celiac and diabetic individuals. Three formulations were tested for their nutritional and sensory qualities. The formulation with sweet potato (PC3) showed the best results in terms of taste, texture, and nutritional value. The findings support the development of innovative gluten-free products for public health.

Keywords**—** Gluten-free flours, sweet potato, celiac disease, sensory quality, food innovation

I. Introduction

The rise in celiac disease and diabetes highlights the need for suitable dietary alternatives. Gluten-free flours combining corn, rice, and sweet potato show great potential [1]. Recent studies have shown that sweet potato enhances the nutritional profile and sensory acceptance of gluten-free products, particularly due to its richness in fiber and antioxidants [2]. This study explores their nutritional and sensory qualities. The aim is to optimize their formulation for the development of innovative and health-oriented food products.

II. MATERIALS AND METHODS

Rice, maize, and SP were purchased from the local market in Tizi Ouzou (Algeria). Rice and maize flours were obtained by grinding the grains using a household coffee grinder, followed by sieving to achieve a fine, homogeneous powder. SP flour was prepared from grated tubers, dried in an oven at 40 °C for 1 to 2 hours depending on moisture content, then ground and sieved. Three formulations were developed using different proportions of these flours

Total ash content was determined by incineration at 550°C in a muffle furnace. The lipid content was determined by Soxhlet extraction with hexane. Crude proteins were evaluated using the [3]. Total sugars were quantified using the Phenol/Sulfuric Acid method [4].

The total polyphenol content was assessed using the colorimetric Folin-Ciocalteu method, based on the protocol of [5] with slight modifications. A volume of 200 µL of each extract was mixed with 1 mL of Folin-Ciocalteu reagent (diluted 10-fold) and 800 µL of sodium carbonate solution (7.5%). After 30 minutes of incubation, absorbance was measured at 765 nm. A calibration curve was established using gallic acid (0–

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1000 µg/mL), and results were expressed as mg gallic acid equivalents per gram of sample (mg GAE/ml extract).

Descriptive sensory analysis was performed by a panel of 8 tasters. The attributes evaluated were color, odor, taste, aroma, and texture. Each attribute was rated on an intensity scale from 0 to 10. All statistical analyses were performed using XLSTAT software version 2019.4.1 (Addinsoft, Paris, France).

All statistical analyses were performed using XLSTAT version 2019.4.1 (Addinsoft, Paris, France). Data were statistically analysed using a one-way analysis of variance (ANOVA) to determine significant differences ($p<0.05$).

III. RESULTS

A. Macronutrient content (%)

The lipid content of the initial flours ranged from 0.53% to 2.07%, while the blends showed values between 1.19% and 1.29%, which fall within the range reported by [6] (1.2%–1.4%). Corn flour exhibited a significantly higher lipid content ($p < 0.05$) compared to the other flours (Table I).

The protein content was relatively low. These contents range from 0.35% to 0.66%, the highest values being observed for the initial rice flour and formulation 3, while the lowest are obtained for the maize flour and formulation 1. The total sugar contents of the initial flours of DP, rice and blend 3 are higher. The high sugar content found in rice flour is perhaps justified by the fact that the rice husks are retained during processing, as the protective part is rich in sugar [7]. The significant difference ($P < 0.05$) between the sugar contents of the blends could be explained by the amount of SP added to each blend (TABLE I).

TABLE I

LIPID, PROTEIN and SUGAR LEVELS in STARTER FLOURS and THEIR FORMULATIONS (%)

	Fat*	Protein	Sugars*
SP Flour	1.24	0.66	5.1± 0.005
Corn flour	2.07	0.35	1.87± 0,21
Rice flour	0.53	0.70	5.63± 0,35
Formulation 1	1.29	0.55	4.02± 0.22
Formulation 2	1.20	0.58	4.34± 020
Formulation 3	1.19	0.61	4.61± 0.14

*$P < 0.05$, between PCs by Tukey ANOVA.

B. Mineral content (ash %)

The average ash content is an indicator of flour purity and is related to its extraction rate and the mineralisation of the grains used for milling. It also defines the commercial types of flour [8]. The initial flours and the different formulations have levels varying between 0.4% and 3.4%, SP flour has a high ash content ($p < 0.05$) compared to other flours the Eriad standard applied to gluten-free bread flour is between 0.55% and 2%, so the values obtained are acceptable and comply with the standards (TABLE II).

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The phenolic compound contents of the initial flours and the different blends varied between 5.56 ± 1.01 mg EAG/ml and 28.99 ± 0.38 mg EAG/ml, recorded for rice flour and sweet potato flour respectively. These results are in agreement with those reported by [9], confirming the richness of phenolic compounds in sweet potato. This high content can be attributed to the natural presence of antioxidants such as phenolic acids and flavonoids in this tuber. The variation observed between flours highlights the importance of selecting raw materials to formulate products with a high functional value.

TABLE II Mineral (ash) and Polyphenols content in initial flours and their formulations

	Ash *(%)	**Polyphenols** mg EAG /ml extract
SP Flour	3.4	28.99 ± 0.38
Corn flour	0.7	11.46± 0.93
Rice flour	0.4	5.56 ± 1.01
Formulation 1	1.12	12.61 ± 0.71
Formulation 2	1.39	14.36± 0.67
Formulation 3	1.96	18.46 ± 0.59

*P < 0.05, between PCs by Tukey ANOVA.

C. The sensory quality of pancake

Sensory quality, also known as organoleptic quality, covers all the characteristics perceived by the senses during tasting. In our study, three pancake formulations (PC1, PC2, PC3) were evaluated by a panel of tasters using a descriptive sheet. Notable differences were observed between the samples.

The orange colour was particularly pronounced in the PC3 formulation, which is explained by the presence of sweet potato, rich in carotenoid pigments, known for their intense colour [10]. Conversely, the brown hue was more pronounced in PC1, probably due to a more intense Maillard reaction or to the nature of the flours used. As for the yellow colour, it followed a decreasing order from PC1 to PC3.

In terms of taste, the PC3 pancake was perceived as the sweetest, an expected and appreciated characteristic, particularly thanks to the sweet potato, which provides natural sugars and a pleasant sweetness [11]. In addition, this formulation was described as less granular and less pasty, reflecting a better creaminess in the mouth, which is an advantage in terms of texture. These results are consistent with other studies highlighting the texturising effect of the natural fibres contained in sweet potatoes.

The PC3 pancake obtained the highest overall scores, reflecting significantly higher sensory acceptability than the other formulations. The higher overall quality intensity of PC3 reflects a successful balance between taste, texture and appearance, and underlines its potential as a viable alternative to conventional wheat-based products.

Another positive point to highlight is the absence of undesirable flavours (bitterness, excessive acidity or metallic taste), despite the use of gluten-free flours which can sometimes alter the flavour profile. Although the formulations are wheat-free, the tasters did not perceive any bitterness, which is a significant advantage in terms of overall acceptability.

We also assessed undesirable sensory descriptors such as chemical impression, oxidised odour or unpleasant smells, but these attributes were rated 0 by the panel as a whole, which is why they were not

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represented in the sensory schema. This result testifies to the stability and good quality of the ingredients used, with no perception of rancidity or degradation

Finally, the specific odours of sweet potato and rice flours were perceived as low to moderate, which is also an advantage. Indeed, according to several studies, consumers generally prefer cereal products with neutral aromas, thus avoiding odours that are considered “strange” or too strong [12]. This aromatic neutrality contributes to the product's versatility, which can be combined with sweet or savoury toppings [13].

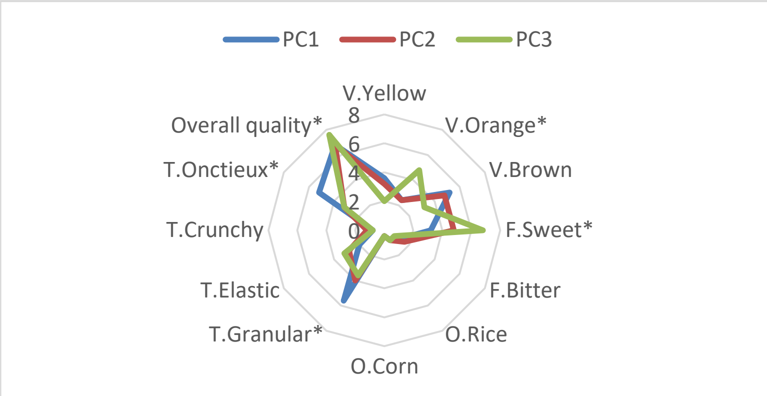

Fig. 1 Web diagram of the three PCs.

Descriptors followed by capital letters V, F, O and T stand for “Visual”, “Flavour”, “Smell” and “Texture” respectively. Asterisks indicate a significant difference, *P < 0.05, between PCs by Tukey ANOVA.

IV. CONCLUSIONS

The addition of sweet potato significantly enhances the nutritional and sensory quality of gluten-free flours by enriching the formulations with bioactive compounds and improving texture.

The balanced lipid profile, particularly in the blends, remains within nutritional recommendations, with corn flour making a notable contribution. PC3 stands out as the most promising formulation, combining functional properties with good sensory acceptability. The results highlight the potential of sweet potato flour as a valuable functional ingredient, particularly due to its high total polyphenol content, for the development of antioxidant-rich food formulations.

These results confirm the relevance of designing enriched gluten-free flours that meet both nutritional and technological expectations. They highlight the potential of combining various plant-based sources to develop innovative, high-value-added products. This approach aligns with strategies aimed at improving the food supply for better public health outcomes.

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