VALORIZATION OF RED ONION SKINS FOR NUTRITIONAL ENRICHMENT OF JAMS

VALORIFICAREA COJILOR DE CEAPĂ ROȘIE PENTRU ÎMBOGĂȚIREA NUTRIȚIONALĂ A DULCEȚURILOR

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Abstract
Fruits and vegetables represents fundamental components of a balanced diet, playing a crucial role in maintaining health. Rich in carbohydrates, vitamins, minerals, and essential acids, they support metabolic processes. However, their perishability requires the use of essential preservation methods such as concentration, acidification, dehydration, etc. An effective way to utilize and preserve chili peppers is by producing chili pepper jam, a product with a long shelf life. This study focuses on the physicochemical and organoleptic of four chili pepper jam samples, homemade products. Additionally, this study aimed to explore the valorization of vegetable waste and its reintegration into the food cycle. Dehydrated white onion peel powder was obtained and used to enhance the sensory qualities of the products and to test consumer acceptability. To assess quality, physicochemical determinations were carried out, including soluble solid content (°Bx), total acidity (g/L citric acid), pH, moisture, and ash content. Organoleptic evaluations were also conducted, assessing the appearance of the jam samples, color, homogeneity, olfactory and gustatory characteristics, aromatic intensity, and persistence in the aftertaste. The results suggest that the products comply with the physicochemical and organoleptic characteristics described in the specialized literature and the technical specifications associated with current legislation. Moreover, the organoleptic analysis highlights that homemade chili pepper jam samples are appreciated to the pleasant sweet-spicy balance and the addition of onion peel powder.
Key words: chili pepper jam, waste valorization, onion peel powder, food preservation.

Rezumat
Fructele și legumele sunt componentele fundamentale ale unei alimentații echilibrate, având un rol important în menținerea sănătății. Bogate în carbohidrați, vitamine, minerale și acizi organici esențiali, acestea susțin procesele metabolice. Cu toate acestea, natura lor perisabilă impune

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utilizarea unor metode de conservare, cum ar fi concentrarea, acidifierea, deshidratarea, etc. O modalitate eficientă de a utiliza și conserva ardeii iuți este obținerea dulceții de ardei iute, un produs cu o durată lungă de valabilitate. Acest studiu se focusează pe analiza caracteristicilor fizico-chimice și organoleptice a patru probe de dulceață de ardei iute, produse în regim casnic. În plus, s-a urmărit valorificarea cojilor de ceapa galbena și reintegrarea acestora în circuitul alimentar. Pudră de coji de ceapă galbenă deshidratată a fost utilizată pentru a îmbunătăți caracteristicile senzoriale ale produselor și pentru a testa acceptabilitatea în rândul consumatorilor. Calitatea produselor obținute a fost evaluata prin determinări fizico-chimice, inclusiv conținutul de substanțe solide solubile (°Bx), aciditatea totală (g/L acid citric), pH-ul, umiditatea și conținutul de cenușă. Evaluările organoleptice efectuate au analizat aspectul eșantioanelor de dulceață, culoarea, omogenitatea, caracteristicile olfactive și gustative, intensitatea aromatică și persistența în postgust. Rezultatele arată că produsele sunt in conformitate cu caracteristicile fizico-chimice și organoleptice descrise în literatura de specialitate și cu specificațiile tehnice asociate cu legislația în vigoare În plus, analiza organoleptică evidențiază faptul că probele de dulceață de ardei iute preparat în casă sunt apreciate pentru echilibrul plăcut între dulce și picant și pentru adaosul de pudră de coajă de ceapă.

Cuvinte cheie: dulceață de ardei iute, valorificarea deșeurilor vegetale, pudră de coji de ceapă, conservarea alimentelor.

INTRODUCTION

Fresh or processed, onions *(Allium cepa* L.) are one of the most widely grown vegetables in the world. However, processing onions produces a substantial amount of agricultural waste, particularly the outer dry peels and skins, which are typically discarded despite containing high concentrations of valuable phytochemicals (Alara *et al*., 2021; Celano *et al*., 2021; Kumar *et al*., 2022). This waste represents both a significant environmental burden and an underutilized source of bioactive compounds for traditional food systems (Bains *et al*., 2023; Bavaro *et al*., 2026).

Large amounts of inedible waste—such as dried skins, roots, and damaged or discarded bulbs—are generated during onion processing. Over 90–100 million tonnes of onions are produced worldwide annually, and industrial processing of these bulbs generates substantial waste streams. For instance, Europe alone produces approximately 0.5–0.6 million tonnes of onion skin waste annually. This figure exceeds one million tonnes of total onion waste when other by-products, such as roots and the basal or top portions of the bulbs from industrial peeling operations, are taken into account (Benítez *et al*., 2011). In addition to being an underutilized source of valuable bioactive chemicals, this massive volume of waste presents environmental disposal challenges. Consequently, circular economy frameworks and sustainable food systems prioritize its valorisation (Jaganmohanrao, 2025; Sagar *et al.,* 2022).

Onions and their by-products are exceptionally rich sources of quercetin. In fact, quercetin and its derivatives constitute approximately 80% of the total flavonoids found in onions and onion waste (Celano *et al*., 2021). Additionally, this waste is a rich source of tannins and enzymes. Bioactive polysaccharides, such as pectins, are also found in onion waste. These pectins exhibit distinct viscoelastic properties and can be utilized as fat replacers in food products to help lower blood lipid levels, or as emulsion stabilizers in fruit juices to extend their shelf life (Prokopov *et al*., 2018; Sagar *et al*., 2022).

The incorporation of onion peel extracts into food formulations to enhance their functional properties is attracting increasing interest (Belgoumri, 2024; Ferreira *et al*., 2026). In addition to demonstrating anti-obesity and anti-carcinogenic properties in experimental settings, previous research has shown that the addition of onion polyphenols can significantly increase the antioxidant capacity of baked, fermented, and dairy-based food products (Bhattarai *et al*., 2026; Kothari *et al*., 2020; Stoica *et al*., 2024). For instance, recent studies have successfully incorporated red onion peel powders and microencapsulated extracts to enhance the nutritional value, phenolic content, and shelf life of cheeses and other lipid-rich food matrices (Ferreira *et al*., 2026; Stoica *et al*., 2024). The utilization of flavonoid-rich extracts in the development of value-added functional foods is steadily growing, driven by increasing consumer awareness regarding the link between diet and health.

The aim of this study was to explore the potential of fruit and vegetable residues, specifically red onion peels, as valuable raw materials for the development of a new, nutritionally enriched food product: hot pepper jam. Furthermore, by reusing these by-products, this research aims to enhance the nutritional profile of food formulations through the incorporation of natural sources of dietary fiber, antioxidants, vitamins, and minerals (Benítez *et al*., 2011).

MATERIAL AND METHOD

The experimental material used for the analyses consisted of four hot pepper jam samples, labeled with roman numerals from I to IV. The samples were prepared under domestic conditions following traditional recipes, as detailed in Table 1.

Table 1

Codification of the analyzed pepper jams

Products	Code samples
Homemade hot pepper jam: Recipe 1	SI
Homemade hot pepper jam: Recipe 2	SII
Homemade hot pepper jam: Recipe 3	SIII
Homemade hot pepper jam enriched with red onion peel powder	SIV

The primary raw materials used for the preparation of the jams included hot peppers, Kapia peppers, and gogosari peppers (local round sweet peppers). The auxiliary materials used were water, lemon juice, sugar, and an agricultural by-product—red onion peel. The latter is a well-documented, rich source of bioactive compounds such as flavonoids, total phenols, and flavanols (Choi *et al*., 2015).

Indeed, comparative literature indicates that onion solid waste is characterized by a high nutritional profile, containing proteins (8.3%–15.6% on a dry weight basis), dietary fibres (169–750 mg/g dry weight), essential minerals (including potassium, calcium, magnesium, and iron), and carbohydrates (66.12%) (Kumar *et al*., 2021).

Beyond its nutritional and functional value, red onion peel serves as an accessible ingredient capable of enhancing the sensory profile of hot pepper jam. The incorporation of red onion peels into hot pepper jam is a novel adaptation of traditional practices that imparts a distinctive deep colour and an exceptional flavour profile. This addition yields a well-balanced sweet, sour, and slightly caramelized taste that complements the natural pungency of the chili peppers (Benítez *et al*., 2011; Stoica *et al*., 2024).

The technological flow for manufacturing the hot pepper jams comprised the following key stages:

Preparation of the peppers: Washing the raw material, removing the seeds, and dicing or slicing them into uniform strips.

Mixing the ingredients: Combining the chopped peppers in a stainless-steel vessel, adding sugar and salt to taste, incorporating the red onion peel powder (for sample SIV), and adding lemon juice to adjust the acidity.

Concentration (Thermal treatment): Simmering the mixture over medium heat under constant stirring until it reaches a thick, syrupy consistency, indicative of optimal soluble solids content (Sagar *et al*., 2022).

Hot filling and packaging: Transferring the hot jam immediately into pre-sterilized glass jars, sealing them hermetically, and allowing them to cool to room temperature.

Storage: Storing the finished products in a cool, dark place prior to analysis.

To achieve the research objectives, the following analytical determinations were carried out on all samples:

Sensory analysis: Evaluated by a panel of assessors using a 10-point hedonic scoring scale (1–10) to determine attributes such as appearance, colour, aroma, taste, and overall acceptability (Stone *et al*., 2020).

Physicochemical analysis: determination of key quality parameters, including soluble solid content (°Brix), titratable acidity (% citric acid), active acidity (pH), total dry matter (%), moisture content (%), and total ash content, following standard official methods for fruit and vegetable products (AOAC, 2016).

RESULTS AND DISCUSSIONS

The sensory analysis aimed to evaluate the essential quality attributes required for the products to be deemed compliant with quality standards. The primary parameters evaluated included appearance, colour, aroma, taste, texture, flavour intensity, and aftertaste persistence.

The obtained results were centralized and are presented in Table 2.

The hot pepper jam enriched with red onion peel powder achieved the highest score, being highly appreciated by the panellists in terms of appearance, and particularly for its taste and aftertaste.

Table 2

Organoleptic characteristics of jam samples

Samples	Parameters							
	Aspect	Colour	Smell	Taste	Consis-tency	Flavour intensity	After taste	Accepta-bility
SI	8.00	8.40	8.60	8.20	8.00	7.90	7.70	8.11

SII	8.70	9.00	9.00	8.90	8.85	8.60	8.50	8.79
SIII	9.40	9.55	9.4	9.55	9.55	9.60	9.60	9.52
SIV	9.80	9.90	9.75	10	10.00	10.00	10.00	9.92

The comparative analysis of the sensory evaluation results, as can be seen in figure 1, reveals significant differences among the four hot pepper jam formulations, depending on the specific product recipe. Sample SI recorded the lowest scores for most of the analysed attributes, with an overall acceptability score of 8.11. This indicates a product of acceptable quality, albeit with a less intense and persistent sensory profile, particularly regarding taste intensity and aftertaste.

For sample SII, an improvement in sensory parameters was observed, with the overall acceptability score increasing to 8.79, accompanied by enhanced scores for appearance, colour, and aroma. Nonetheless, its taste intensity and aromatic persistence remained lower compared to the higher-scoring formulations.

Sample SIII was characterized by high and relatively uniform scores across all evaluated indicators (with an overall acceptability of 9.52). This suggests an optimized recipe that yields a sensorially balanced product with an appropriate consistency and a well-defined flavour intensity.

The best results were recorded for sample SIV, which includes the addition of onion peel powder, reaching an overall acceptability score of 9.92 and achieving maximum or near-maximum values for all evaluated attributes. These findings indicate a positive effect of the added functional ingredient, manifested through colour intensification, enhanced taste and aromatic persistence, as well as the optimization of the product's texture.

Overall, as can be seen in figure 1, the data suggest that incorporating plant by-products, such as onion peels, can significantly contribute to enhancing the sensory quality and consumer appeal of food products.

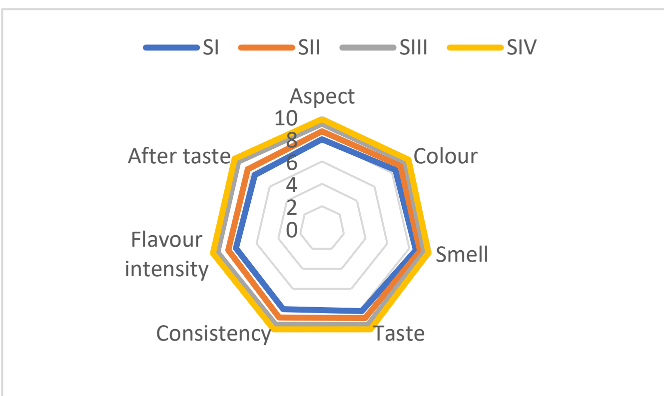

Figure 1. Results of sensory analysis

The comparative analysis of the physicochemical parameters for the four hot pepper jam formulations (Table 3) highlights the significant influence of the recipe on the quality of the final product, particularly in the case of sample SIV, which was enriched with onion peel powder.

The total soluble solids content (°Brix) varied between 34°Bx (SII) and 57°Bx (SIV), indicating significant differences in the concentration of sugars and dissolved substances. Sample SIV exhibited the highest value, suggesting a more concentrated product with superior potential regarding stability and shelf life. In contrast, sample SII recorded the lowest value, which correlated with a higher moisture content (60.56%)—a factor that can negatively influence both texture and preservation capacity.

The titratable acidity, expressed as citric acid equivalent, ranged from 1.62% (SII) to 2.01% (SIV), highlighting a more pronounced acidity in the sample enriched with onion peel powder. This increase in acidity was associated with a lower pH value (3.40 for SIV) compared to the higher pH recorded for SII (3.60), thereby confirming the inverse relationship between pH and titratable acidity. From a technological standpoint, these lower pH values contribute to inhibiting microbial growth and enhancing food safety.

Table 3

Physico-chemical results of jam samples

Samples	Total soluble solids (°Bx)	Total acidity (% citric acid)	pH	Moisture (%)	Total dry matter (%)	Ash (%)	Ascorbic acid (mg/100 g product)
S I	43	1.85	3.48	51.88	48.12	0.65	18.64
S II	34	1.62	3.60	60.56	39.44	0.51	12.52
S III	45	1.74	3.52	48.38	51.62	0.71	20.06
S IV	57	2.01	3.40	36.76	63.24	1.04	25.28

Moisture and total dry matter contents exhibited inverse variations, as anticipated. Sample SIV showed the lowest moisture content (36.76%) and the highest total dry matter (63.24%), indicating a dense, well-bound, and stable product. Conversely, SII presented the highest moisture and the lowest dry matter content (39.44%), suggesting a more fluid consistency and reduced stability.

The ash content, which serves as an indicator of the mineral fraction, reached its maximum in sample SIV (1.04%) and its minimum in SII (0.51%). This trend reflects the additional contribution of mineral compounds provided by the red onion peel powder, which is widely recognized for its high microelement content.

Regarding the ascorbic acid content, a progressive increase was observed from SII (12.52 mg/100 g) to SIV (25.28 mg/100 g). The maximum value recorded for SIV indicates a significant improvement in nutritional value, which may be attributed to the direct contribution of bioactive compounds as well as the protective effect exerted on vitamin C by the natural antioxidants present in the onion peels.

Overall, sample SIV was clearly distinguished from the other formulations by superior values across most of the analysed parameters, including high dry matter and soluble solids, higher acidity, lower pH, increased mineral content, and elevated ascorbic acid levels. These characteristics confirm the positive impact of valorising plant by-products on the physicochemical quality of the food matrix, contributing simultaneously to the enhancement of product stability, safety, and nutritional value.

CONCLUSIONS

An excellent source of both macro- and micronutrients, onion waste can be used directly as a food ingredient or as a source of specific nutrients for extraction and bioconversion. The effective utilization of these waste streams can mitigate both quantitative and qualitative food loss, as well as minimize negative environmental impacts.

The incorporation of red onion skin significantly improved the physicochemical and nutritional properties of the developed jams. Specifically, the sample enriched with onion peel powder exhibited higher total soluble solids and ascorbic acid content, thereby increasing its overall functional value.

Sensory analysis revealed a high level of acceptability for the enriched jams. The colour of the enriched formulation was more intense, while the differences in flavour were subtle yet pleasant.

Utilizing red onion waste in jam production offers clear environmental and economic benefits. It reduces food waste and supports sustainable, cost-efficient manufacturing practices. Overall, red onion skin can be considered a highly valuable ingredient for enhancing both the quality and sustainability of jam products.

This approach not only contributes to the reduction of food waste but also supports the development of innovative, functional food products that promote human health and ecological sustainability.

ACKNOWLEDGEMENTS

The authors are grateful for the technical support provided by the Horticultural Research Centre of the Faculty of Horticulture, Iasi University for Life Sciences "Ion Ionescu de la Brad“.

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