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Research Article

Revalorization of a plum (*Prunus domestica*. L.) kernels: Nutritional characteristics, and cyanogenic glycosides as affected by controlled microwave heat treatment

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Abstract

This paper evaluates the effects of microwave heating (450 W for 2, 4, 6, and 8 min) on compositional characteristics of underutilized and undervalued plum kernels. Compared to the raw sample, microwave-treated samples showed a significant improvement in oil content (4.03%), crude fiber (3.62%), total ash (3.01%), and carbohydrates content (14.92%) at 450W for 6 min. On the contrary, a statistically significant ($p < 0.05$) decrease of 7.61% was observed in crude protein values at the same processing conditions. Microwave heating at 540 W for 6 min showed a considerable reduction of 37.81% in cyanogenic glycosides of plum kernel samples, while the prolonged heating (450 W for 8 min) showed damaging effect (burning spots) on the quality characteristics. The overall findings suggest that the optimum degree and duration of microwave heating from the standpoint of nutritional levels and degradation of cyanogenic glycosides was 450 W for 6 minutes. This novel technological strategy can potentially expand the usage of plum kernels in various diversified food preparations.

Keywords: Plum Kernels; Microwave Heating; Cyanogenic Glycosides; Compositional Characteristics

Introduction

Recycling wastes produced during food processing is a major challenge. Finding innovative recovery techniques and elevating these wastes are top priorities in the food sector [1]. Plums (*Prunus domestica. L*) are a widely consumed fruit crop due to their excellent flavor, enticing aroma, and attractive color, with global production exceeding 12.1 million in 2016 [2]. The majority of the plum harvest is converted into culinary products such as juice, jams, nectars, beverages, and dry fruits, producing a large number of plum kernels as a by-product, which is primarily underutilized and undervalued [3]. The majority of the time, these underutilized kernels are burned or dumped in landfills although they have immense economic potential not just for the pharmaceutical and cosmetics sectors but also for the food sector [4]. These kernels provide a variety of nutritional and health-promoting qualities due to the high concentrations of oils, dietary proteins, carbohydrates, fibers, vitamins, minerals, and other bioactive components [5]. For example, the protein content is about 35.9 percent [6]. and the oil content is about 45.95 percent, with the majority being unsaturated fatty acids [5]. The ranges for crude fiber, ash content, and total soluble sugars are 1.9 to 2.2 percent, 2.2 to 3.5 percent, and 7.3 to 7.6 percent, respectively [7]. Plum kernels are a nutrient-dense fruit that can be used to produce significant amounts of high-quality oils, proteins, and other bioactive substances that may be helpful for the food, cosmetics, and pharmaceutical sectors [8].

Despite having a high nutritional value, plum kernels have not been used to their full potential because they contain significant levels of cyanogenic glycosides such as amygdalin (range 0.1 - 17.5 mg g^{-1}), a naturally aromatic cyanogenic diglucoside compound responsible for the bitterness [9]. Amygdalin is made up of D-mannitol-d-glucoside-6-glucoside, which, when hydrolyzed, releases benzaldehyde and hydrocyanic acid. Since its discovery, amygdalin has been linked to numerous health advantages, including the ability to treat neurological diseases and act as an adjunctive anticancer, immune-regulating, and anti-fibrosis agent [10]. However, amygdalin is believed to be harmless on its own, but when it is broken down by the enzymes glucosidases or hydroxy nitrile lyases, it produces hydrocyanic acid, which may be poisonous [11]**.** More precisely, a lesser dose is good for your health, while a higher dose is poisonous. In order to prevent cyanide toxicity, detoxification has emerged as an important element in the processing of plum kernels [12]. Traditional techniques like soaking, autoclaving, fermenting, and boiling have been employed for ages to minimize the risk of toxicity to acceptable levels [9]. However, there is a large loss of nutritional compounds as a result of these detoxification processes since numerous important nutritional components are transferred to the water. Recently, the revolutionary green detoxification approaches have received a lot of attention [13]. Microwave heating has been studied and is known to lower anti-nutritional components, change the nutritional profile by increasing digestibility produce more palatable flavor compounds, and retain the same levels of exterior color [14]. The availability of plum kernels contributes greatly to the national energy supply and is the best way to promote low-cost energy and the self-sufficiency of the processing industry [15].

In order to achieve the most cost-effective and efficient exploitation of these waste products for the production of proteins and oil, more knowledge on the compositional aspects, anti-nutritional components, and antioxidant ability of plum kernels is needed. This research was motivated by the dearth of information in the literature about the impact of microwave heating on the chemical composition and cyanogenic glycosides of plum kernels.

Materials and Methods

Chemicals and reagents

Amygdalin (> 99.0%) was bought from Hi-media (Mumbai, India). All additional chemicals and reagents (analytical or HPLC grades) required for the analysis were provided by the Department of Food Engineering and Technology, SLIET, Longowal, Sangrur, Punjab, India.

Sampling

Fully ripened, high-quality plum pits were procured from Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu and Kashmir, India. Plum pits were rinsed with tap water to eliminate the dirt and fruit pulp. They were allowed to air dry for two days at ambient temperature. Pits were mechanically broken to get the kernels. The kernels were crushed into a fine powder using a mixer grinder and kept at 4 to 7°C until further investigation.

Methods

Microwave heating

A standard microwave oven (Samsung, MS23K3513AK/T) with a 900 W output at 2450 MHz was employed to conduct heating experiments. Microwave output power was measured according to the method of [4]. A 100g sample was placed in a layer on a 16 cm Petri plate to ensure a 1 cm thickness, placed on the rotary plate of the microwave, and heated at 450 W for 2, 4, 6, and 8 minutes. The pretreated samples were maintained at 4°C in sealed plastic bags until further experiments. The untreated sample was used as a control.

Proximate composition

Standard procedures of AOAC [16] were followed to determine proximate constituents viz: moisture (method 930.15), crude fat (948.22), crude fiber (978.10), ash content (method 942.05), and carbohydrate content (995.13). The crude protein content (method 981.10) was determined by the automatic Kjeldahl method. All the analyses were carried out in triplicate, and final values are presented as their means.

Determination of cyanogenic glycosides

The method described by Sheikh and Saini, [8] was used to analyze the total cyanogenic glycosides in plum kernel samples. In a round bottom flask, one gram of plum kernel sample was mixed with 200 mL of distilled water and left to stand for two hours to induce autolysis. 0.5 gram of tannic acid (an antifoaming agent) was applied to the round bottom flask, followed by distillation. A 250 mL conical flask containing 20 mL of 2.5 percent sodium hydroxide was used to collect the distillate. To 100 mL of distillate, 8 mL of ammonium hydroxide and 2 mL of potassium iodide were added. The solution was mixed and titrated with 0.02 M silver nitrate against a blank sample. Cyanogenic glycoside content of the plum kernel samples was calculated as

$$Cyanogenic\ glycosides\ \left(\frac{mg}{100\ g}\right) = \frac{Titre\ Value\ \times\ 1.08\ \times Exact\ volume}{Aliquot\ Volume\ \times weight\ of\ sample\ (g)} \times 100$$

Statistical analysis

All the assays were carried out in triplicate and were statistically analyzed by calculating the mean and standard deviation. The data were presented as the mean ± standard deviation. Data obtained were subjected to a one-way analysis of variance (ANOVA) to determine the variance among the different samples using SPSS (STATISTICA7.ink). DUNCAN'S multiple range test at $p \leq 0.05$ was used to determine the significant differences among treated samples.

Result and Discussion

Composition of plum kernel flour obtained from different microwave treatments

The effect of microwave heating on the compositional characteristics of native and microwave-treated samples of plum kernel flour is given in table 1. The moisture content of plum kernel flour decreased significantly ($p < 0.05$) with the increasing heating duration compared to the native sample. The samples heated at 450 W for 8 min underwent the highest reduction (59.24%) in moisture content which could be attributed to the evaporation of intercellular water due to volumetric heat generation by microwave radiation [17]. This observation indicates that moisture content was proportional to microwave heating duration. Tian., *et al.* [18] reported that the decrease in moisture content is associated with a volumetric heat generation due to which evaporation of moisture content within the sample is accelerated by the absorption of microwave energy by the water molecules. The experimental values of the moisture content were consistent with the values reported by Hojjati., *et al.* [19] on the roasting of wild almonds. The protein content of native and microwave-heated samples ranged from 35.74 to 33.07%. A statistically significant ($p < 0.05$) decrease was observed in crude protein values with increasing heating duration. The protein content of microwave-treated samples was slightly lower than the native sample, with the highest protein degradation of 7.61% occurring at 450 W for 8 min. These results were in agreement with those of Lenaerts., *et al.* [17], who reported that the decrease in crude protein values during heating may be due to the coagulation of the protein or loss of some nitrogen-containing volatile compounds or may be related to protein denaturation. A similar observation was made by Malgorzata., *et al.* [20], for buckwheat groats during microwave roasting and demonstrated an increase in the FAST index (fluorescence of advanced Maillard reaction products and soluble tryptophan) and FIC (fluorescence intermediary compounds) during thermal processing indicates deterioration of protein quality. Al Juhaimi., *et al.* [19] concluded that microwave roasting increases crude protein digestibility without altering the amide I to amide II ratio. The crude oil content of microwaved plum kernel flour was found to be higher than that of the native sample. The extraction yield of oil from native and microwaved samples varied from 46.03 to 48.62%, with the highest (48.42%) for those microwaved at 450 W for 8 min. The microwave heating significantly ($p < 0.05$) increased the oil content of the plum kernel flour; however, no significant increase in oil yield with an increase in heating time was observed. The extraction yield of the oil is related to various factors such as temperature and moisture content. The lower oil yield of the native sample was due to high moisture content and intactness of cell wall during extraction, while after microwaving or heat processing, oily cells are ruptured, moisture content and oil viscosity are reduced, and a permanent change in porosity; these effects facilitate the easy flow of oils [21,22]. The increase in crude fat values as a result of microwave heating is in line with the observation of an earlier report by Li., *et al.* [23]. The results indicate that microwave pretreatment before oil extraction had an enormous influence on oil yields. The highest yields of crude fiber, total ash, and carbohydrates of 2.86%, 2.42%, and 10.87% were afforded by the sample heated at 450 W for 8 min, respectively, whereas the lowest values of 2.76%, 2.32%, and 8.31% were observed for native sample respectively. The possible reason for significant ($p < 0.05$) fluctuations in crude fiber, total ash, and carbohydrates may vary due to the changes in other macronutrients resulting from microwave heating [24]. The results were in agreement with the literature results of Wani., *et al.* [14]. Overall, the results suggest that the plum kernel might be utilized as a source of essential nutrients (proteins, lipids, minerals, fibers etc.), and microwave pretreatment (450 W for 6 min) has a positive impact on the contents of compositional characteristics when compared with the untreated sample.

			450 W		
Parameter	**Raw**	**2 min**	**4 min**	**6 min**	**8 min**
Moisture Content %	5.03 ± 0.39^{a}	4.04 ± 0.27^{b}	3.59 ± 0.33^{b}	3.04 ± 0.18^{c}	2.05 ± 0.22^{d}
Protein content %	35.74 ± 0.44^{a}	34.31 ± 0.56^{b}	34.12 ± 0.41^{b}	33.98 ± 0.26^{b}	33.02 ± 0.29^{c}
Crude Fat %	46.03 ± 0.67^{d}	47.09 ± 0.71^{bc}	47.75 ± 0.42^{ac}	48.01 ± 0.16^{ab}	48.42 ± 0.29^{a}
Crude Fibre %	2.76 ± 0.11^{d}	2.79 ± 0.13^{cd}	2.82 ± 0.09^{bc}	2.86 ± 0.11^{b}	2.93 ± 0.07^{a}
Total Ash %	2.32 ± 0.09^{b}	2.35 ± 0.03^{b}	2.39 ± 0.06^{a}	2.41 ± 0.04^{a}	2.42 ± 0.03^{a}
Carbohydrates %	8.31 ± 0.56^{c}	8.98 ± 0.34^{bc}	9.23 ± 0.61^{b}	9.55 ± 0.23^{b}	10.87 ± 0.53^{a}

Table 1: Compositional characteristics of raw and microwave treated plum kernel flours.

Values are means ± SD of triplicate determinations. Different superscript letters within the same row indicate significant differences ($p \leq 0.05$) among the microwave and hydrothermal treatments tested.

Effect on cyanogenic glycosides

Cyanogenic glycosides are widely dispersed throughout the kingdoms of plants and act as a form of plant defense by thwarting insect and pest-caused damage [25]. They are water-soluble compounds that are maintained in specific sites in entire cells [26]. The production of hydrocyanic acid after tissue damage is the fundamental property of cyanogenic glycosides [27]. Different cyanogenic substances produce varying amounts of hydrogen cyanide depending on their chemical makeup, such as amygdalin, which releases 59 mg HCN per g cyanogenic molecule [28]. The Commission Regulation (EU) (2017/123712) set the maximum limits for HCN at 50 mg/kg for nougat, marzipan, or its substitutes, or 5 mg/kg for canned stone fruits, and 35 mg/kg for alcoholic beverages. Compared to the raw sample, microwave treatments significantly ($p < 0.05$) decreased the amount of cyanogenic glycosides in samples of plum kernels (Figure 1). The mean amount of cyanogenic glycosides in the raw plum kernel sample was 680.41 mg/100g, while the amount in the sample heated at 450 W for 8 min was 385.12 mg/100g. The percentage reduction of 12.82, 25.14, 37.81, and 43.39% in the content of cyanogenic glycosides was observed during microwave treatments of plum kernel samples at 450 W for at 2 min, 4 min, 6 min, and 8 min, respectively. The reduction of cyanogenic glycosides during microwave treatment could be ascribed to the severe heat stress induced by non-ionizing radiation that caused the elimination of the released hydrogen cyanide through volatilization [29]. The amounts of cyanogenic glycosides in the samples of native and differently treated plum kernels showed a time-dependent reduction. Similarly, Feng., *et al.* [30] reported that microwave heating at 400 W for 4 min 50 sec was perfect for lowering the HCN concentration in flaxseed below the permitted limits. The higher reduction in the level of cyanogenic glycosides during microwave heating at 450 W for 8 min could be attributed to the severe heat stress that causes thermal degradation of cyanogenic glycoside compounds of plum kernel samples [31]. Overall results of the present study demonstrated that the extent of reduction was dependent on the process conditions

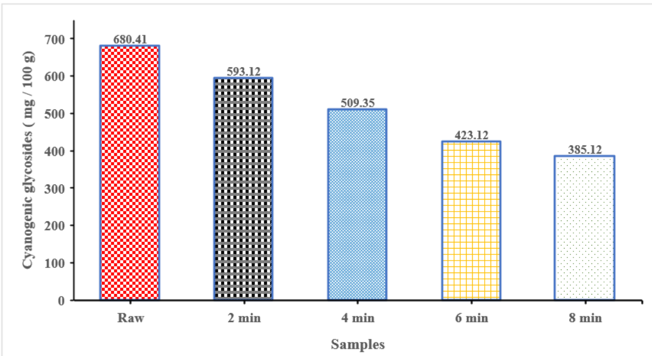

Figure 1: Cyanogenic glycosides of raw and microwave treated plum kernel samples at 2 min, 4 min, 6 min, and 8 min.

Conclusion

The present study revealed that microwave heating exhibited pronounced effects on nutritional and cyanogenic glycosidic components of the plum kernels samples. Compared to the raw sample, microwave-treated samples showed a significant improvement of 4.03% in oil content, 3.62% in crude fiber, 3.01% in total ash, and 14.92% in carbohydrates content at 450W for 6 min. A considerable reduction of 37.81% was noticed in cyanogenic glycosides of plum kernel samples microwaved at 540 W for 6 min. In contrast, the prolonged heating (450 W for 8 min) showed a damaging effect (burning spots) on the quality parameters. To conclude, this investigation revealed that controlled microwave heating at 450 W for 6 min might be a valuable strategy for reducing the cyanogenic glycosides in addition to improving the nutritional profile of the plum kernel samples and may potentially provide the basis for a sustainable process of integrated exploitation of plum kernels for the food industries.

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