https://dergipark.org.tr/tr/pub/food
OPEN ACCESS JOURNAL
ISSN 2667-5803

FHTI Journal of Food Health and Technology Innovations
December Vol 7, No 15 (2024)

DergiPark AKADEMİK

ResearchArticle

EXTRACTION AND CHARACTERIZATION OF LOQUAT SEED STARCH: A POTENTIAL ALTERNATIVE STARCH SOURCE

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Abstract

The seeds of loquat (Eriobotrya japonica Lindl.), which are often discarded as agricultural waste, contain significant amounts of starch with unique properties. The aim of this study was to extract starch from loquat seeds and investigate its chemical and functional properties as well as its potential to replace wheat starch in traditional desserts such as jelly. The starch from loquat seeds was extracted by alkaline extraction and freeze-drying. The extracted starch had a moisture content of 4.47%, a water holding capacity of 303.2 g/g, an oil holding capacity of 19.21 g/g, a swelling power of 40.8 g/g at 95°C and a water solubility index of 85.7% at 95°C. The color parameters L*, a* and b* were 95.86, 2.02 and 4.79, respectively. Microscopic analysis revealed granules with various shapes, including flat, spherical, hemispherical, ellipsoidal and irregular polygonal and angular morphology. These characteristics make loquat seed starch suitable for various food and industrial applications, especially for the development of functional foods and sustainable gastronomy.

Keywords: Loquat seeds, starch, physicochemical property, sustainability, alternative starch source

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Introduction

Sustainability, a concept that affects many industries, is particularly important for the food sector due to its economic, environmental and social aspects. Sustainability in food means adopting an ecological approach throughout the production and consumption chain that conserves natural resources and is guided by the principles of sustainable development [6]. Sustainable food production relies on several key elements, including good agricultural practices, increased consumer and producer awareness and effective waste management strategies [1]. Fruit and vegetable parts such as peels, stems and seeds, which contain important nutrients and bioactive elements, are often discarded as waste. The recycling of plant waste is considered economically beneficial as its economic value is higher compared to other types of waste [23]. Research has shown that both the powdered and oil extracts from the seeds can be used effectively as dietary supplements and bioactive compounds [21].

Carbohydrates in the human diet are primarily starch, which plays a crucial role both for nutrition and for technological applications in the food industry. Outside the food industry, starch is used in various areas, including pharmaceutical production, fertilizer production, paper production and the formulation of adhesives [3]. Current conventional sources of starch are not sufficient to meet the increasing demand due to population growth. Therefore, alternative sources of starch need to be explored to supplement the existing ones. Recently, researchers have turned their attention to unexplored crops, underutilized plant varieties, agricultural residues and wastes, various plant components and by-products of fruit and vegetable processing with high starch content. Non-traditional starches derived from the utilization of waste and by-products help reduce pollution while supporting the local economy. Some examples of these alternative starch sources are avocado seeds, sweet potatoes, Chinese chestnuts, sago and ramie roots. The industrial usability of these sources is determined by factors such as availability, physicochemical properties and molecular structures [13]. While the search for alternative starch sources continues, the further development and application of non-conventional starch offer a promising solution to meet the challenges posed by the increasing global demand for starch [13]. Starch obtained from loquat seeds is an alternative source of starch.

The evergreen loquat (*Eriobotrya japonica* Lindl.) from the Rosaceae family of the order Rosales is a fruit species that generally grows in subtropical climates between 20-35° north and south latitude [19]. The home of the loquat fruit, also known as Maltese plum, is Japan, China and northern India. In our country, the Mediterranean region is the most widely cultivated region [9]. The country with the highest production of loquat fruit with a total production of 982 thousand tonnes is China with 919 thousand tonnes, which corresponds to 93.6 % of production. This is followed by Spain (28,836 tonnes) and Turkey (16,402 tonnes) as the countries where most cultivation takes place [19]. Loquat seeds are usually discarded as agricultural waste as they account for 20-30% of the weight of the fresh fruit and have no practical use [7]. These seeds contain significant amounts of starch, amygdalin, amino acids and fatty acids. Despite their nutritional content, the seeds are not suitable for human consumption due to their bitter taste [2]. Loquat seed starch has emerged as a promising non-conventional starch source with unique properties and potential applications in various industries. The starch extraction yield from loquat seeds ranges from 30.04% to 45.2%, with high amylose content (>50%) [13, 20].

The aim of this study was to extract starch loquat seed and to investigate the chemical and functional properties of the extracted starch. In addition, the possibility of replacing wheat starch in classic desserts such as jelly with the extracted loquat seed starch was investigated.

Materials and Methods

Materials

The seeds of the loquat were harvested from trees that had grown in the neighborhood garden of Özlüce in Tarsus, a district of Mersin. After the seeds were extracted from the fruit, they were stored at -24°C. All solvents and chemicals were obtained from Sigma Aldrich (St. Louis, MO, USA).

Production of Starch

For starch extraction, loquat seeds were mixed with alkaline water (0.1 % NaOH) in a ratio of 1:2 and soaked at +4°C for 24 hours. The mixture was then ground in a high-speed grinder for 5 minutes before being filtered through steel sieves with a pore size of 80 and 70 micrometres. The sieve residue was rinsed 2-3 times with distilled water and the resulting filtrate was centrifuged at 3000 rpm for 15 minutes. This centrifugation procedure was repeated four times, washing with distilled water between each cycle. After the last centrifugation, the supernatant was collected and frozen at -24°C for 48 hours. The frozen samples were then dried in a freeze dryer (Labconco, NewYork) at -54 °C and 0.250 mbar [18].

Production of Jelly

The jelly was made using traditional methods. Jelly is produced separately from wheat starch and loquat seed starch. The jelly consisted of 200 mL of water and 20 g starch. To make jelly, starch and water were mixed in a bowl and the mixture was heated in a saucepan over medium heat, stirring constantly. Stirring was maintained until the consistency of the mixture increased in viscosity. Once the mixture had reached a jelly-like consistency, it was allowed to cool and then stored in the refrigerator (Figure 1).

Analysis

Moisture contents of loquat seed starch determined by infrared moisture analyzer at 105˚C. The pH measurement was performed with a pH meter. A colorimeter (3NH colorimeter, China) was used for color measurements of (CIE L^*, a^* and b^* values). The granular structure of the starch sample obtained from the loquat seed was examined by microscopy. A minute amount of the dry starch sample was placed on a microscope slide. A drop of distilled water was applied to the dry starch, covered with a coverslip and placed in the microscope apparatus. The granular structure of the prepared samples was observed at 10x, 40x and 100x magnification. To determine the water holding capacity, 0.5 g of the starch sample was mixed with 4 ml of distilled water, and the mixture was shaken for 30 seconds every 10 minutes for a total of 70 minutes. The mixture was then centrifuged for 15 minutes at 25°C and 6000 rpm. After centrifugation, the liquid phase was removed, and the tubes were placed at an angle of 45° to the horizontal plane to facilitate drainage of the remaining liquid phase for 10 minutes. The mass of the solid fraction separated from the liquid phase was determined and the water holding capacity was calculated. The results were expressed in grams of water per gram of sample (g water/g sample) [12]. To determine the oil holding capacity, 0.5 g of the starch sample was mixed with 3 ml of sunflower oil. The mixture was homogenized with a glass rod for 30 seconds at 5-minute intervals for a total of 30 minutes. The homogenized samples were centrifuged at 25°C and 6000 rpm for 25 minutes. After centrifugation, the liquid phase was removed, and the tubes were inverted to allow the remaining liquid phase to drain for 5 minutes. The solid portion was weighed and the weight gain measured. The results were expressed in grams of oil per gram of sample (g oil/g sample). The swelling power (SP, g/g) and water solubility index (WSI, %) were determined according to a method modified by Li et al. [16]. In brief, the sample (0.15 g, db) was weighed into a centrifuge tube with a coated screw cap and 10 mL of deionized water was added. The tubes were then heated to 55◦C, 65◦C, 75◦C, 85◦C, and 95◦C, respectively, with frequent shaking for 1 h before cooling and centrifugation in an ice water bath (6000 rpm, 30 min). The supernatant was poured into an aluminum dish. The remaining solid fraction was weighed (Ws). The supernatant was dried at 100◦C until constant weight (W1). The WSI and SP were calculated as follows:

$$\text{WSI}\ (\%) = \frac{W_1}{W_0} x\ 100 \qquad (1)$$

$$\text{SP}\ (g/g) = \frac{W_S}{W_0 \times (1 - WSI)} \qquad (2)$$

Results and Discussion

The results of the physicochemical and fuctional parameters of loquat seed starch (moisture content, dry matter content, water holding capacity, oil holding capacity, swelling capacity, solubility index, L*, a*, b*, pH value) are shown in Table 1. The moisture content of the starch from the loquat seed was determined to be 4.47 %. Barbi et al. [5] determined the moisture content values of loquat seed starch in the range of 7.92 to 8.29 % in their study. The moisture content of loquat seed starch was lower than that of corn, wheat and quinoa starch and similar to that of canistel starch [15, 17, 23]. The reason for the lower moisture content of the starch obtained in this study is due to the freeze-drying process.

The water holding capacity is defined as the amount of water retained by the starch under certain conditions (temperature, time and mechanical force). The water holding capacity of loquat seed starch was determined to be 303.2 g/g. Inatçı [12] reported the water holding capacity of alkali-treated horse chestnut starch as 234.60 g/g in his study. Inatci [12] determined the water- holding capacity of conventionally treated acorn starch to be 212.88 g/g. The water-holding capacity of starches depends largely on the properties of the amylopectin structure. A long-chain ratio of the amylopectin molecules increases the water-holding capacity of the starch. In addition, the crystal structure of the molecules influences the water holding capacity of the starch and the triggering of the gelatinization process. A high-water holding capacity has a positive effect on properties such as thickening and gelling. It was determined that the data on the water holding capacity of loquat core starch is consistent with the information in the literature.

The oil holding capacity of loquat seed starch was determined to be 19.21 g/g. In comparison, Inatçı [12] found that alkali-treated horse chestnut starch and classically treated acorn starch have an oil holding capacity of 175.26 g/g and 169.38 g/g, respectively. The study by Inatçı [12] concluded that the oil holding capacity of loquat seed starch is significantly lower. The combination of oil and starch affects the physical properties of starch, as oils and fats can form complexes with amylose, which hinder the swelling of starch granules and make gelatinization more difficult [10]. Although starch with a high amylose content has a low oil holding capacity, no definitive correlation between amylose content and oil holding capacity has been established. Charles et.al. (2016) found that oil holding capacity is an indicator of emulsifiability, a critical property for products such as mayonnaise. In addition, high oil absorption properties are essential in various foods such as meat substitutes and extenders, doughnuts, baked goods and soups [4].

The properties of swelling power and solubility index are decisive factors for the industrial use of starch. The gelatinization of starch is caused by the interaction of water and temperature. In addition, factors such as the ratio of amylose and amylopectin, the formation of amylose-lipid complexes, the granule structure, the size, the morphological characteristics and the starch modifications have a significant influence on the swelling capacity of starch. The swelling power of loquat seed starch was determined to be 40.8 g/g at 95 °C. In their study, Kong et al. [13] determined the swelling power of five loquat cultivar seed starches in the range of 25-62 g/g. Koyuncu Aydın [14] reported that the swelling power of domestic quinoa starch is 14.4 g/g. From this, it was concluded that loquat seed starch has a higher swelling power than domestic quinoa starch. Güzel (2009) determined the swelling power properties of starch from kidney beans, beans and chickpeas from legumes to be 8.19, 7.08 and 7.71 g/g, respectively. Chung et al. [8] determined the swelling capacity of starches from three different pea varieties at 90 °C to be 21.7, 19.1 and 18.8 g/g, respectively. Gani et al. [11] extracted starches from four different kidney bean varieties and determined the swelling power values of these starches to be 11.6, 11.3, 10.6 and 11.0 g/g, respectively. The differences in the solubility and swelling power of starch from different sources can be attributed to differences in the morphological structure of the starch granules. In addition, experimental parameters such as starch concentration, centrifuge conditions, mixing and separation methods and granule structure can influence the results. This variability can pose a challenge when comparing the results of different studies [16]. The average value of the water solubility index of loquat seed starch was determined to be 85.7 % at 95 °C. Yaşar [24] reported that the water solubility property of navel starch increases with increasing temperature. According to the results of the analysis, the water solubility was 4.92±0.35 % and 16.86±0.15 % at 60 and 90 °C, respectively. The low solubility of starch at low temperatures is attributed to the semi-crystalline structure of the starch granules and the hydrogen bonds between the hydroxyl groups in the starch molecules. As the temperature increases, the solubility increases due to the disintegration of the starch granules and the increased interaction of the hydrophilic groups with water [24]. Koyuncu Aydın [14] determined that the water solubility index of quinoa seed starch at 95 °C was 89%.

Color is an important factor in determining starch quality. Analysis of the color of the starch sample yielded the parameters L*, a* and b* of 95.86, 2.02 and 4.79, respectively. These results indicate that the starch had high lightness (high L*), minimal redness (low a*) and minimal yellowness (low b*). Yaşar [24] reported L*, a* and b* values for sea flea starch of 90.87, 2.19 and 4.71, respectively. Rafiq et al. [18] reported an L* value of 96.2, with a* (red/green) and b* (yellow/blue) values of 2.43 and 2.77, respectively. Comparison with previous studies shows comparable results. These color parameters also influence the color values of the gelatinized starch. The color of the loquat seed starch darkens during the gelatinization process (Figure 1-b).

The pH value of the starch of loquat seeds was measured at 11.210. Inatci [12] determined the pH of classically treated acorn starch to be 5.63. The pH values of starch extracted from horse chestnuts using alkaline and ultrasound-assisted methods were 9.94 and 10.44, respectively. Although the pH is lower than in this study, it remains alkaline. Careful evaluation of the effects of this pH in application is essential for starch processing and food quality.

Microscopic images of the starch of loquat seeds are shown in Figure 2. The starch granules have smooth surfaces and various shapes, including flat, spherical, hemispherical, ellipsoidal and irregular polygonal and angular morphology, with no visible damage due to isolation conditions. In this study, truncated granules characterized by a flat surface on one side (referred to as truncated ends) were also observed, which is consistent with the results reported for the seed starches of five loquat cultivars [13]. Similarly, Yaşar [24] found in his study that the morphological structures of starch granules of sea voles were irregular, dome-shaped and polygonal as well as agglomerated and discrete.

Conclusion

Loquat seed starch is a promising alternative source of starch with unique properties. In this study, starch was extracted from loquat seeds and its chemical and functional properties were investigated. The extracted starch had a moisture content of 4.47%, a water holding capacity of 303.2 g/g, an oil holding capacity of 19.21 g/g, a swelling power of 40.8 g/g at 95°C and a water solubility index of 85.7% at 95°C. Microscopic analysis revealed granules with various shapes, including spherical, ellipsoidal and irregular morphology. These characteristics make loquat seeds starch suitable for various food and industrial applications, especially for the development of functional foods and the promotion of sustainable gastronomy. In addition, the traditional desserts produced by using loquat seeds, which are considered a waste product, and the use of their starch form, are considered to also support sustainable gastronomy, especially in environmental and social terms. Further research is needed to optimize processing techniques and explore new applications of this promising starch source in the food industry and beyond.

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Table 1. *Properties of Loquat Seed Starch*

Properties	Mean ± Standard Deviation
Moisture Content (%)	4.470 ± 0.248
Water Holding Capacity (g/g)	303.2 ± 7.002
Oil Holding Capacity (g/g)	19.21 ± 0.235
Swelling power (g/g)	40.8 ± 1.888
Water Solubility Index (%)	85.7 ± 0.771
$L*$	95.86 ± 0.530
$a*$	2.02 ± 0.216
$b*$	4.79 ± 0.578
pH	11.210 ± 0.026

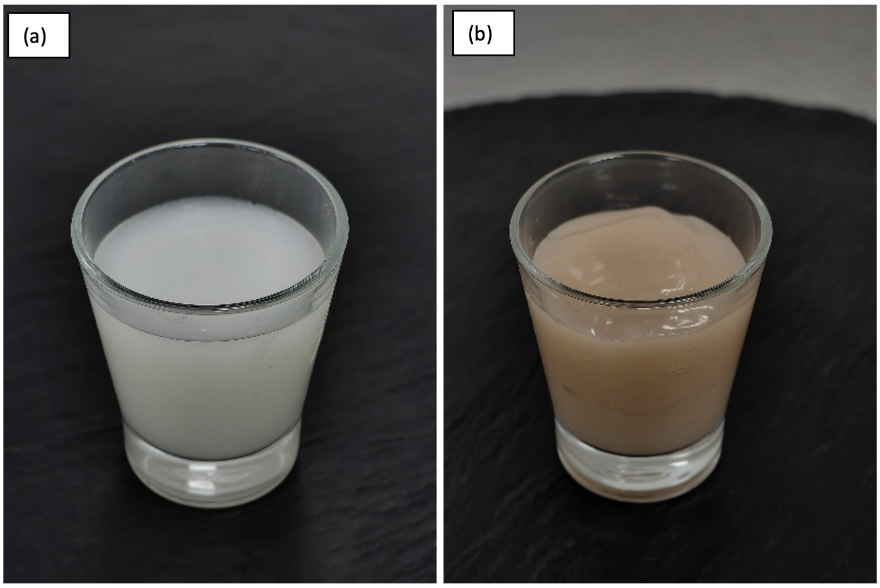

Figure 1. Jelley images, (a): wheat starch jelly, (b): loquat seed starch jelly

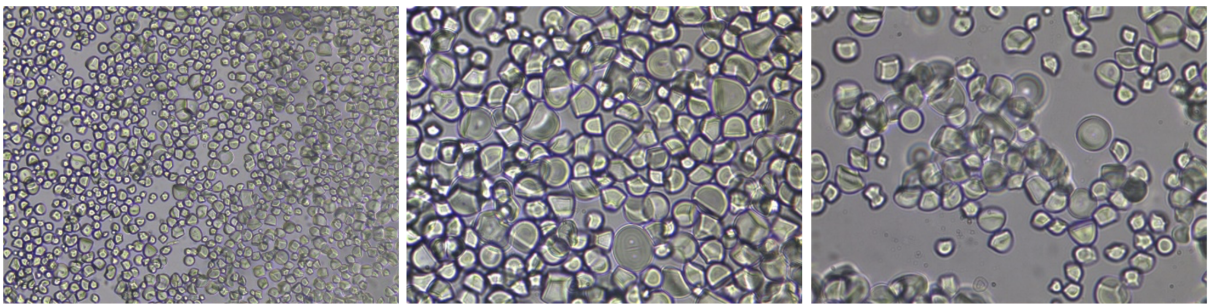
Figure 2. Microscope image of loquat seed starch.