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TECHNOLOGICAL FOUNDATIONS OF PUMPKIN FRUIT DRYING

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Annotation. The article studies the technology of drying pumpkin fruits and producing powder. After sorting, cleaning, cutting, and thermal treatment, pumpkin was dried using convective, infrared, and sublimation methods. The retention of vitamin C and carotenoids ranged between 68–92% and 70–95% depending on the method. The dried material was ground and packaged into powder form. A comparative analysis of different drying methods was carried out, highlighting their advantages and disadvantages.
Keywords. pumpkin, pumpkin powder, drying technology, convective drying, infrared drying, sublimation drying, vitamin C retention, carotenoids, organoleptic properties, packaging technology.

Introduction

Pumpkin (*Cucurbita spp.*) is a widely cultivated crop, grown in more than 70 countries worldwide. The leading producers include China (25 million tons), India (7–8 million tons), Turkey (2.5–3 million tons), Kazakhstan (2–2.5 million tons), and Russia (1.5–2 million tons) [FAO, 2022]. A considerable portion of the harvested yield is used in the food industry, for livestock feed, and for the extraction of oils with nutritional and medicinal properties [Dhiman et al., 2020]. In recent years, scientific research has focused on the development of innovative technologies for processing pumpkin seeds, oil, and peel, resulting in the creation of functional and value-added products [Achu et al., 2018].

The role of pumpkin in the food industry has been steadily increasing due to its high nutritional value, richness in fatty acids, carotenoids, vitamins, and its wide processing potential [Kim et al., 2019]. These characteristics make pumpkin a promising raw material for the production of vegetable oils, functional food ingredients, and dietary supplements [Kulaitienė et al., 2020]. In Uzbekistan, growing attention is being given to the selection of pumpkin varieties and the improvement of processing technologies aimed at producing flour and other value-added products [Mirzaev et al., 2023]. Such efforts are expected to contribute significantly to strengthening food security and ensuring the sustainable growth of agricultural production in the country.

Research Objectives and Specific Tasks

The primary objective of this research is to develop technologies for the storage, drying, and preparation of semi-finished products from pumpkin fruits. These efforts aim to extend the shelf life of pumpkin products, preserve their quality, and improve the efficiency of processing operations.

Materials and Methods

For the study, the following pumpkin cultivars were selected: *Ispanskaya–73* (control), *Kashgarskaya–1644*, *Palov Kadu–268*, *Volzhskaya Seraya–92*, *Medovaya*, *Non Kadi*, and *Kustovaya Oranzhevaya*.

The methodology of the study was as follows:

- Moisture content of pumpkin fruits was determined by the gravimetric method, i.e., drying at a controlled temperature.
- Sugar content was assessed using the colorimetric method.
- Carotenoid levels were measured by spectrophotometry.
- Vitamin C content was determined through titrimetry.
- Fiber composition was analyzed using the Van Soest method.

Technological Approach

Producing pumpkin in powdered form is recognized as an effective method for obtaining functional and value-added products in the food industry. The process begins with mechanical cleaning of the fruits, during which damaged, low-quality, or diseased specimens are removed. Subsequently, two main processing approaches are applied to the selected fruits.

In the first method, pumpkin fruits are cut into pieces according to their geometric shape, which ensures uniform and rapid removal of moisture during drying. The drying process is carried out using convective, infrared, or sublimation technologies, reducing the moisture content to 12–14%. Afterwards, the dried pieces are ground and sieved to obtain a homogeneous powder structure.

Table 1. Drying pumpkin fruits in slices and producing powder

ge	Description	Time	Temperature (°C)	Moisture content (%)
Sorting and cleaning of raw material	Selection of mechanically undamaged fruits with 85–88% moisture and removal of soil and dust	15–20 min	—	85–88
Cutting into slices	Cutting into uniform slices of 1–1.5 cm thickness	10–15 min	—	85–88
Thermal treatment	Blanching at 90–95°C for 2–3 min or treatment with 0.1% sodium bisulfite	2–3 min	90–95	80–82
Drying (convective)	Drying at 60°C for 7–9 h; vitamin C retention ≈ 68–70%, carotenoids ≈ 70–72%	7–9 h	60	12–14
Drying (infrared)	Drying at 55°C for 6–7 h; vitamin C retention ≈ 78–80%, carotenoids ≈ 82–85%	6–7 h	55	12–14
Drying (sublimation)	Freezing at –35°C, followed by drying at 25–30°C for 20–24 h;	20–24 h	–35 → 25–30	12–14

	vitamin C retention ≈ 90–92%, carotenoids ≈ 94–95%			
Grinding and sieving	Grinding to 0.3–0.5 mm fraction and sieving using a vibrosieve	10–15 min	—	12–14
Packaging	Vacuum or modified atmosphere (MA) packaging; stable storage for 8–12 months	5–10 min	—	12–14

The technology of producing powder through drying pumpkin fruits in slices is considered one of the practically significant directions in the food industry. This method not only allows seasonal products to be preserved and utilized throughout the year but also ensures a higher retention of vitamins, minerals, and natural pigments. Each stage presented in the technological process serves specific technological and biochemical purposes, directly influencing the final quality of the product. Therefore, detailed scientific analysis of these stages, including the identification of their advantages and limitations, is of critical importance.

The sorting and cleaning of raw materials represent the initial and most essential stage of the process. Pumpkins selected for processing must be free from mechanical damage, disease symptoms, and should be fully mature. Fruits with a moisture content of around 85–88% are considered optimal, as this ensures even water release during drying and preserves the structural integrity of the fruit matrix. Sorting can be conducted manually through visual inspection, with automated sorters, or on conveyor lines with manual labor. This stage also involves the removal of soil, dust, and other impurities, ensuring compliance with hygiene requirements in the subsequent processing stages.

The slicing stage prepares the fruit for the drying process. Cutting pumpkins into uniform slices of 1–1.5 cm thickness allows consistent moisture removal during drying. If the slices are too thick, internal moisture may be retained, while the outer layers dry excessively, leading to spoilage or undesirable changes inside the fruit. Conversely, excessively thin slices may burn or undergo color changes during drying. Thus, from a technological perspective, optimizing slice thickness is a critical factor in ensuring product quality.

The thermal treatment stage is considered one of the most important pre-drying operations. At this stage, pumpkin slices are either blanched at 90–95°C for 2–3 minutes or treated with a 0.1% sodium bisulfite solution. Blanching reduces enzymatic activity, particularly polyphenol oxidase and peroxidase, thereby preventing discoloration. In addition, blanching helps lower the microbial risk level. Sulfitation, on the other hand, ensures color stability, slows down pigment degradation, and minimizes vitamin C loss. However, strict control of concentration and treatment time is required to prevent residual sulfite levels from exceeding sanitary standards.

Drying can be carried out using different methods, each of which has a distinct effect on the biochemical composition and organoleptic properties of the product. Convective drying at around 60°C for 7–9 hours retains approximately 68–70% of vitamin C and 70–72% of carotenoids. Although this method requires relatively high energy consumption due to its long duration, the low temperature helps preserve the product's flavor and texture. Owing to its simplicity and low cost, convective drying is widely applied, though more efficient alternatives exist for nutrient and pigment preservation.

Infrared drying is performed at 55°C for 6–7 hours. Infrared radiation penetrates both the outer and inner layers of the product, accelerating moisture removal. This method allows vitamin C retention at about 78–80% and carotenoid retention at 82–85%. The advantage of infrared drying lies in its ability to achieve rapid drying at a lower temperature, maintaining the product's color more effectively. It also offers higher energy efficiency compared to convective drying, though equipment costs are significantly higher.

Sublimation (freeze-drying) is recognized as the most advanced method, ensuring the highest product quality. In this process, pumpkin slices are first frozen at –35°C and subsequently dried under vacuum conditions at 25–30°C for 20–24 hours. Sublimation involves the direct conversion of water from the ice state to vapor, bypassing the liquid phase. As a result, vitamin C retention reaches 90–92%, and carotenoids remain at 94–95%. The texture, color, and taste of the product are almost fully preserved. However, the main drawbacks of freeze-drying are the high cost of equipment and energy consumption, limiting its use primarily to premium, high-value products.

The grinding and sieving stage transforms the dried slices into powder form. The dried material is processed using mechanical or turbo grinders to achieve a particle size of 0.3–0.5 mm. It is then passed through a vibrosieve to obtain a homogeneous powder. Uniform particle size is critical for subsequent applications, such as puree production or incorporation into food additives. Careful temperature control during grinding is essential, as excessive heat generated by high-speed processing may cause nutrient losses, particularly vitamin degradation.

The packaging stage is crucial for ensuring the long-term preservation of pumpkin powder and maintaining its quality parameters. Vacuum or modified atmosphere (MA) packaging effectively protects the product from moisture and oxygen exposure. In the MA method, the internal air is replaced with nitrogen or carbon dioxide, thereby slowing down oxidation processes. Under such conditions, pumpkin powder can be stored for 8–12 months without significant loss of vitamins and pigments. For optimal results, the use of laminated films with high oxygen barrier properties is recommended.

Analysis of the technological stages demonstrates that the choice of drying method has a significant impact on the final quality of the product. While convective and infrared drying are cost-effective and efficient, they are inferior to sublimation in terms of nutrient and pigment retention. Freeze-drying provides the highest product quality, but due to its high cost, it is economically feasible mainly for premium products. Infrared drying offers a favorable balance between quality and processing time, making it the preferred method when projects aim to save both energy and time.

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