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## PACKAGING OF POWDERED PRODUCTS MADE FROM DRIED PUMPKIN

**Genjebayev Marat Sovetovich** – PhD researcher at the Karakalpak Institute of  
Agriculture and Agrotechnologies

**Umidov Shavkat Ergashevich** – Associate Professor at Tashkent State Agrarian  
University.

<https://orcid.org/0009-0008-5344-0014>

**Annotation.** The article presents a comparative analysis of packaging methods for pumpkin powder. Vacuum packaging, modified atmosphere (MA), metallized polypropylene, polyethylene–foil laminates, and PET containers were tested. The highest efficiency was observed with MA packaging (vitamin C – 93–95%, carotenoids – 95–96%), while polyethylene–foil was considered cost-effective. Vacuum packaging preserved high biological value but showed agglomeration. Metallized polypropylene was recommended as a low-cost option, whereas PET containers accelerated vitamin and pigment loss due to light exposure.

**Keywords.** pumpkin powder, drying, packaging technology, vacuum packaging, modified atmosphere, metallized polypropylene, polyethylene–foil, PET container, vitamin C, carotenoids.

### INTRODUCTION

In many countries around the world, pumpkin products—particularly pumpkin seed oil—are valued for their richness in essential nutrients, various vitamins, and antioxidants. This oil is well known for its broad application in the cosmetic, pharmaceutical, and food industries. Researchers in the United States, Turkey, China, and Kazakhstan are actively engaged in developing new pumpkin varieties and improving processing technologies. Such studies are aimed at creating novel cultivars, ensuring stable yield growth, and thereby enhancing the economic significance of pumpkin.

Deep processing of pumpkin, converting its raw material into diverse products, and advancing storage technologies play a crucial role in this context. Furthermore, these research efforts are of great importance in strengthening food security and highlight the growing relevance of developing innovative pumpkin-based products.

**Research Aim and Objectives**

The aim of this study is to develop technologies for the storage, drying, and preparation of semi-finished products from pumpkin fruits. These technologies are intended to extend the shelf life of pumpkin-based products, maintain their quality parameters, and improve the overall efficiency of processing operations.

### Materials and Methods

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

Dried pumpkin powder is characterized by high biological value, being rich in vitamins (particularly ascorbic acid), minerals, carotenoids, and antioxidants. However, these bioactive compounds are highly sensitive to environmental factors such as moisture, oxygen, light exposure, and temperature fluctuations. Therefore, the choice of packaging method and material, based on scientific evaluation, is essential to ensure long-term stability of the organoleptic and biochemical properties of pumpkin powder.

In the experiments, various packaging types were evaluated, including vacuum packaging, modified atmosphere (MA) packaging, metallized polypropylene pouches, polyethylene-foil laminated films, as well as PET jars and glass containers. Each type of packaging was assessed based on its moisture absorption capacity, oxygen permeability, protection against light exposure, and mechanical stability. In vacuum packaging, air inside the package is removed and the product is sealed hermetically under reduced pressure. This method minimizes oxygen exposure and slows down oxidation processes. According to the results, pumpkin powder stored under vacuum conditions maintained a moisture level of 12–14% over 8 months, with vitamin C loss not exceeding 10%, while carotenoid retention reached 92–94%. However, the pressure inside the package sometimes caused powder agglomeration. In the MA packaging method, the internal air was replaced with inert gases (nitrogen or CO<sub>2</sub>), eliminating oxidation reactions and reducing microbial activity. During 10 months of storage, moisture variation remained minimal ( $\pm 0.5\%$ ), vitamin C retention reached 93–95%, and carotenoids were preserved at 95–96%. Moreover, MA packaging ensured the powder was stored without agglomeration. Metallized polypropylene pouches provided good protection due to their low permeability to moisture and oxygen. In a 6-month storage trial, vitamin C retention was around 88–90%, while carotenoids were preserved at 90–92%. However, incomplete protection against light exposure resulted in slight changes in color parameters.

Polyethylene–foil laminated films offered strong resistance to both moisture and oxygen penetration, while also providing complete protection against light. Over 8 months, vitamin C retention was 91–93% and carotenoids 94–95%. This method is also cost-effective, making it suitable for wide industrial application.

PET jars and glass containers provided strong mechanical protection, although their effectiveness against light depended on the type of glass. In dark-colored glass, vitamin C retention was 90–92% after 9 months, while in transparent glass it dropped to 86–88%. Carotenoid degradation occurred more rapidly in transparent glass, making non-light-transmitting containers preferable.

The findings can serve as a guideline for optimizing packaging technologies in industrial production. When selecting packaging types, factors such as the target market, intended storage duration, and logistical conditions should be taken into account.

**Table 1. Experimental results on packaging methods of dried pumpkin powder**

aging type	Storage period (months)	Moisture variation (%)	Vitamin C retention (%)	Carotenoid retention (%)	Advantages	Disadvantages
Vacuum packaging	8	±1.0	90	92–94	Minimizes oxygen exposure, slows oxidation	Risk of powder agglomeration
Modified atmosphere (MA) packaging	10	±0.5	93–95	95–96	Eliminates oxidation reactions, reduces microbial activity	Expensive equipment, complex process
Metallized polypropylene	6	±1.2	88–90	90–92	Low permeability to moisture and oxygen,	Does not fully protect from light

					cost-effective	
Polyethylene-foil laminated film	8	$\pm 0.8$	91–93	94–95	Blocks moisture and oxygen, provides full light protection	Slightly more expensive, but effective
PET jar and glass container (dark)	9	$\pm 1.0$	90–92	92–94	Strong mechanical protection, blocks light	Heavy, additional logistics cost
PET jar and glass container (transparent)	9	$\pm 1.0$	86–88	88–90	Strong mechanical protection	Poor light protection, faster vitamin and pigment loss under light exposure

The results of experiments on packaging methods of dried pumpkin powder clearly demonstrated the crucial role of packaging in controlling chemical and physical changes during storage, as well as in maintaining the organoleptic and biochemical properties of the product over extended periods. Key factors influencing the preservation of quality include the type of packaging, its permeability to gases and moisture, the degree of protection against light, mechanical strength, and technological feasibility. Therefore, in this study, six types of packaging were tested, and their advantages, disadvantages, storage duration, and efficiency in preserving vitamin C and carotenoids were comparatively analyzed.

In vacuum packaging, oxygen is almost completely removed, significantly slowing down oxidation processes. The results showed that pumpkin powder stored under vacuum for 8 months exhibited a moisture variation of about  $\pm 1.0\%$ , with vitamin C retention at 90% and carotenoid retention between 92–94%. The main advantage of this method is its ability to preserve antioxidant activity and color stability over a long period. However, a drawback is the tendency of particles to agglomerate under vacuum conditions, which may require additional grinding before use.

In modified atmosphere (MA) packaging, the gas composition inside the package is artificially adjusted: oxygen is reduced to minimal levels, while nitrogen or carbon dioxide concentrations are increased. This method ensured a storage period of 10 months, with minimal moisture variation ( $\pm 0.5\%$ ), vitamin C retention of 93–95%, and carotenoid retention of 95–96%. These were the highest values among the tested methods, as oxidation reactions and microbial activity were significantly reduced. However, the high cost of MA equipment and the complexity of the process can make its adoption challenging for small-scale production facilities.

Metallized polypropylene packaging stood out for its affordability and convenience. Due to its low permeability to moisture and oxygen, it allowed a 6-month storage period. Moisture variation was  $\pm 1.2\%$ , vitamin C retention 88–90%, and carotenoids 90–92%. Its main advantage is economic feasibility, but limited protection against light resulted in some degradation of pigments and vitamins.

Polyethylene–foil laminated packaging demonstrated strong barrier properties against both moisture and oxygen while also providing complete protection from light. Under this method, an 8-month storage period was recorded, with moisture variation of  $\pm 0.8\%$ , vitamin C retention of 91–93%, and carotenoids 94–95%. The disadvantage is its relatively higher cost, though its effectiveness makes it highly suitable for producing high-quality products.

Dark-colored PET jars and glass containers provided strong mechanical durability and effective protection against light, thereby ensuring good preservation of dried pumpkin powder. Under this method, a storage period of 9 months was achieved, with moisture variation of  $\pm 1.0\%$ , vitamin C retention of 90–92%, and carotenoid retention of 92–94%. The main disadvantages, however, were their heaviness, which increases logistical costs, and, in some cases, the fragility of glass containers that must also be taken into account.

Transparent PET jars and glass containers also demonstrated good mechanical protection against external factors. Nevertheless, due to their high light transmittance, the degradation of vitamins and carotenoids occurred more rapidly. Although the recorded storage period was 9 months, vitamin C retention dropped to 86–88%, and carotenoids were preserved at only 88–90%. Therefore, when using transparent containers, additional light-protection measures are recommended.

A comparative analysis indicated that the highest preservation of biological value and organoleptic characteristics was achieved with MA packaging and polyethylene–foil laminated films. Vacuum packaging also showed high efficiency, but the issue of powder agglomeration can be a drawback, particularly when fine particle size is required, necessitating additional processing. Metallized polypropylene offered the

most cost-effective solution, although its limited light protection restricts its effectiveness in preserving bioactive compounds.

From the perspective of economic efficiency, MA packaging technology is most suitable for large-scale and high-value products, as it provides the best long-term preservation and minimizes vitamin and pigment loss. For lower-cost products, metallized polypropylene or vacuum packaging may be more practical, provided that product type, market price, storage infrastructure, and consumer demands are carefully considered.

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