Bulgarian Journal of Agricultural Science, 18 (No 2) 2012, 161-165
Agricultural Academy

MODERN HIGH TECHNOLOGY SOLUTIONS FOR QUALITY AND LONG-TERM VEGETABLE PRESERVATION

I. NACHEVA, D. MITEVA, Y. TODOROV, K. LOGINOVSKA and Tsv. TSVETKOV
Institute of Cryobiology and Food Technologies, BG - 1407 Sofia, Bulgaria

Abstract

NACHEVA, I., D. MITEVA, Y. TODOROV, K. LOGINOVSKA and Tsv. TSVETKOV, 2012. Modern high technology solutions for quality and long-term vegetable preservation. *Bulg. J. Agric. Sci*., 18: 161-165

In the publication the authors present the results of the applying of two modern technologies for long term and safe vegetable preservation – freeze-drying and gamma sterilization. The freeze-dried vegetables feature minimum moisture – from 2 – 5% and taste-aroma complex preserved to the highest degree. The carried out gamma sterilization ensures a high microbial purity of the vegetables and guarantees for their long term preservation (up to 5 years) in polymer packing, under usual conditions.

Key words: lyophilization, gamma sterilization, long-term preservation, vegetables

Introduction

Under the conditions of the continuously raising requirements for healthy way of life, one of the leading directions of the contemporary food industry is related to the production of high quality foods by rational using of the nutrition resources and applying of new technologies which preserve the natural properties of the raw products, make them healthier, safer and long-term preservable.

Vegetables occupy a specific place in human nutrition. They are one of the food groups recognized as a leader in healthy nutrition, especially in the environment of industrialization and increased consumption of refined foods, poor in plant fibers and vitamins (Obretenov, 2002).

Vegetables are consumed fresh or processed. They are stored at low temperatures (0-3°C) under refrigeration conditions, by freezing, drying and by traditional preservation. It is known that vegetable preservation by drying and freezing has a number of advantages compared to sterilization. However, the applying of these conventional processing methods does not ensure their reliable and long-term preservation. Besides that, they are also connected with a number of unfavorable changes in the products – disturbances in the taste-aroma complex and structure, denaturation processes which decrease their nutritious and biological value (Obretenov, 2002). The raised requirements of the consumers towards healthy, least processed foods, continuously increases the demand for such products (Nikolova et al., 2003).

This imposes the applying of modern and efficient methods of preservation to prolong the vegetables shelf life with maximum preservation of their quality.

Lyophilization is a process of drying by vacuum sublimation, combining two stages – freezing at a preliminary specified speed to a temperature of hardening and drying under vacuum at temperatures not surpassing the critical, i.e. those which don't disturb the micro- and macrostructure of the product.

This technology allows to avoid the disadvantages of all other methods of preservation as the end products feature preserved initial qualities – color, aroma, nutritious properties, vitamin content, unchanged initial volume, fast rehydratation, and it is a preferred method for preservation of fresh vegetables. The gamma sterilization of foodstuff is identified as a safe technology for decreasing of the risk of spoilage, where elimination or a considerable decrease of the potentially dangerous for the consumers health pathogenic microorganisms, contained in the products, is achieved and their shelf life is substantially prolonged.

Normally, in the process of lyophilization, because of the free water reduction, part of the vegetative forms of the mesophyll microorganisms, part of the yeasts and rarely of the fungi perishes. Part of the bacteria spores, some microscopic fungi and yeasts with a higher resistance to heat and technological treatment can survive after lyophilization. This method by itself is weakly bactericidal and does not inhibit the microorganisms reproduction during storage and rehydratation (Nacheva et al., 2007).

That is why the possibility of combining of this technology with gamma sterilization is of interest. **Main objective of the present work**: Comparative study of the changes in the qualitative and microbiological characteristics of different in type and variety vegetables after lyophilization and gamma ray treatment.

Materials and Methods

The vegetables used in this investigation were bought from the local net of shops and were technologically treated in ICFT (Institute of Cryobiology and Food Technologies, Sofia). The following raw materials were used – tomatoes, green pepper, cauliflower, marrows, carrots, spinach, mushrooms, peas and green beans. The products were subjected to a preliminary selection because their quality defines the regime of lyophilization, packing and storage.

The freezing of the raw materials was done in chambers with natural air circulation at inside temperature –35^{0}C up to –40^{0}C, at average refrigeration speed –0.25^{0}C/min.

The freeze-drying was carried out in TG-16.50 installation of "Hochvakuum" company – Germany with contact plates heating. The main lyophilization parameters – complete hardening temperature, the minimum and maximum meting temperature were determined by the method of measuring of the specific electrical resistance and by the method of differential scanning calorimetry (DSC)

The irradiation of the studied vegetables was done on a gamma-irradiation installation – "Gamma-1300", with radiating source Cs^{137}, and two-dose values-1.5 and 3 кGy/min.

The vegetables treated by the two technological methods – lyophilization and gamma ray irradiation were packed in polymer 3-layer aluminum foil vacuum closed packing bags and stored at temperatures from 0^{o}C – 5^{o}C.

Results and Discussion

The lyophilization of the investigated products was carried out at heating plates temperature – 65^{o}C, total pressure in the sublimation chamber 40-65 Pa and secondary drying temperature up to +35^{o}C. The drying temperature regime should be selected in a way to achieve an optimal correlation between the drying speed and the product quality in order to guarantee high end products quality and good energy efficiency (Gegov, 2003).

Because of the carried out technological trials of the freeze-dried various fresh vegetables we have established the following optimal technological parameters of the process, shown in Table 1.

The lyophilized vegetables were technologically processed by ionizing radiation. Two irradiation doses were applied: 1.5 kGy and 3 kGy. Compared to the other traditional preservation technologies in the case of gamma sterilization the energy consumption is smaller as a result of which the temperature of the irradiated product raises insignificantly and the provoked chemical changes affect a.

Several index groups – residual water content, organoleptics, rehydratation and microbiological purity, assessed the quality of the dried and irradiated.

For obtaining of quality products, it is necessary during the freeze-drying 70-95% of the moisture to be separated at negative temperatures. The residual moisture content is in the range of 2.0 up to 4.5% and is uniformly distributed in the completely dried vegetables volume. The degree of rehydratation of the lyophilized product is calculated on the base of coefficient of rehydratation K_p:

$$K_p = \frac{G_2}{G_1} \quad (1)$$

where: K_p –coefficient of rehydratation, in relative units , expressing the water retaining capacity of the lyophilized product at rehydratation; G_1 – the dry product mass in g; G_2 – the rehydrated product mass – g.

Due to their lyophil nature, the products restitute fast by rehydratation reaching to a maximum degree their initial physical, organoleptic and physiological properties (Tzvetkov et al., 1985).

No substantial changes were observed in relation to the physical-chemical characteristics after technological treatment. The protein content in the dried and irradiated vegetables varies from 2.75% up to 8.10%, of fats from 0.5% up to 3%, of carbohydrates from 65% up to 75% and of minerals – from 3.8% up to 6.9%.

The microbiological status is of a particular importance for the quality of the dried and irradiated vegetables. The freeze-drying technology hampers and inhibits the growth and development of microorganisms because of the free water reduction (Pushkar at al., 1984).

In the process of lyophilization, the free water quantity needed for the growth and development of microorganisms is reduced. In that, connection

Table 1
Technological parameters for freeze-drying of vegetables

Parameters	Tomatoes	Green pepper	Cauliflower	Marrows	Carrots	Spinach	Mushrooms	Peas	Green beans
Thickness of layer – mm	8-12	10-12	12-15	15-17	15-18	12-14	12-15	10-12	14-16
Freezing temperature, ^{0}C	-35	-32	-32	-32	-35	-30	-35	-32	-30
Sublimation temperature,^{0}C	-38	-38	-30	-28	-28	-30	-35	-27	-24
Total pressure, Pa	65	65	55	40	60	45	50	60	55
Terminal temperature of the product, ^{0}C	30	30	32	35	30	35	32	30	30
Duration of the cycle, h	14-15	11-12	15	11-12.5	12-14	10.5-11	14-14.5	11	11-13
Residual humidity, %	2.0-3.0	3.0- 3.5	3.5-4.0	4.0- 4.5	4.0-4.5	2.0-2.8	4.5-5.0	3.5-4.0	2.5-3.0

it has been proved that the index "water activity" of foodstuff determines better the growth limits of the various microorganisms, compared to the index "total water content". That is why water activity was introduced as an important controlling and varying quantity in long shelf life food technologies (Obretenov, 2002).

Most of the bacteria and yeasts in the dried products are in growth stage at a_w = 0.9, and the greater part of the fungi develop at a_w - below 0.80. The water activity of the lyophilized vegetables is between 0.2 – 0.4, which proves their microbial stability (Miteva et al., 2008). The microbiological status of the investigated vegetables is presented in Table 2.

The total number of microorganisms is in the rage of 2.8 – 5.3 logarithms, the highest being in spinach and peas. The found fungi and yeasts are in the admissible norms rates and they are not affected by the freeze-drying. After the gamma ir-

Table 2
Microbiological characteristic of the lyophilized and irradiated vegetables

Parameters	Total number of microorganisms, CFU/g	Coliforms, CFU/g	E.coli, CFU/g	Salmonella, sp.in 25g	Sulfate reducing Clostridii,CFU/g	Coagulase - positive staphylococcus/1g	Fungi, CFU/g	Yeasts, CFU/g
Lyophilized - not irradiated								
Tomatoes	$2.4.10^4$	$1.5.10^2$	$4.3.10^1$	ND	0-2	ND	$2.5.10^2$	< 10
Green pepper	$6.5.10^3$	$2.7.10^2$	$2.4.10^1$	ND	1-3	ND	$1.5.10^1$	< 10
Cauliflower	$2.0.10^4$	$4.3.10^2$	< 10	ND	0	ND	$6.0.10^2$	< 10^2
Marrous	$7.5.10^3$	$3.8.10^1$	< 10	ND	0	ND	$3.2.10^2$	< 10
Carrots	$2.4.10^5$	$7.8.10^2$	$2.0.10^1$	ND	3	ND	$6.5.10^2$	< 10^2
Spinach	$1.4.10^5$	$4.2.10^2$	< 10	ND	0	ND	$7.25.10^1$	< 10^2
Mushrooms	$4.5.10^3$	$3.4.10^2$	$1.8.10^1$	ND	2	ND	$3.7.10^1$	< 10
Peas	$7.5.10^2$	$1.5.10^2$	< 10	ND	0	ND	$2.75.10^2$	< 10^2
Green beans	$4.5.10^3$	$2.5.10^2$	< 10	ND	1-3	ND	$3.0.10^1$	< 10
Lyophilized, irradiated with a dose 1.5kGy								
Tomatoes	$1.4.10^2$	$1.0.10^1$	ND	ND	1	ND	$1.0.10^1$	ND
Green pepper	$2.5.10^1$	ND	ND	ND	1	ND	$1.0.10^1$	ND
Cauliflower	$1.8.10^2$	$1.2.10^1$	ND	ND	ND	ND	ND	ND
Marrous	$2.0.10^1$	ND	ND	ND	ND	ND	ND	< 10
Carrots	$1.7.10^2$	$1.2.10^1$	ND	ND	1	ND	$1.7.10^1$	< 10
Spinach	ND	ND	ND	ND	ND	ND	ND	ND
Mushrooms	$2.6.10^2$	$1.6.10^1$	$1.3.10^1$	ND	ND	ND	ND	< 10
Peas	ND	ND	ND	ND	ND	ND	ND	ND
Green beans	$2.8.10^1$	$1.2.10^1$	ND	ND	1	ND	$1.5.10^1$	MD
Lyophilized, irradiated with a dose 3kGy								
Tomatoes	ND	ND	ND	ND	ND	ND	ND	ND
Green pepper	ND	ND	ND	ND	ND	ND	ND	ND
Cauliflower	ND	ND	ND	ND	ND	ND	ND	ND
Marrous	ND	ND	ND	ND	ND	ND	ND	ND
Carrots	ND	ND	ND	ND	ND	ND	ND	ND
Spinach	ND	ND	ND	ND	ND	ND	ND	ND
Mushrooms	ND	ND	ND	ND	ND	ND	ND	ND
Peas	ND	ND	ND	ND	ND	ND	ND	ND
Green beans	ND	ND	ND	ND	ND	ND	ND	ND

ND- not detected

radiation, we observed a considerable microorganism's reduction. The total number of microorganisms decreases and remains in the range of 1.3 – 2.2 logarithms for the low irradiation dose. Fungi with a higher resistance to irradiation were established. According to Frazier (1988), doses of 1.3 up to 11 kGy are needed to eliminate fungi. In our experiments, a complete reduction of the microorganisms and fungi was achieved in the sample irradiated with 3 kGy.

Our microbiological analyses of the lyophilized and irradiated vegetables also confirm an absence of pathogenic microflora seeding.

In a lyophilized form and after gamma sterilization, packed in vacuum-closed polymer packing, the vegetables can be stored for up to 5 years under usual conditions, while preserving to a considerable degree their organoleptic properties, nutritious and biological value (Tzvetkov at al., 1985).

Conclusions

Freeze-drying is a modern, highly effective technology for quality and long-term vegetable preservation, which preserves to a maximum degree their taste properties and biological value.

The gamma sterilization prolongs the shelf life of the lyophilized vegetables through inactivation of the undesired microflora.

The two preservation methods – lyophilization and gamma-ray irradiation do not cause unfavorable changes in the organoleptic and the physical-chemical characteristics of the vegetables, at the same time increasing their microbiological safety.

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Received August, 2, 2011; accepted for printing February, 2, 2012.