DAIRY PRODUCTS QUALITY MANAGEMENT

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Abstract

One of the most important economic tasks is the provision of the population with safe high-quality food products. Milk and dairy products are socially significant products in the population diet. Social-economical programs of the development of

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food processing industry target primarily small-scale processing industry. Taking into account geographical peculiarities and climate conditions in Russia, the studies on the improvement and development of new technologies of milk and dairy-containing preservatives with enhanced nutritional value and long shelf life have high priority. The first aspect provides the main properties of products, the second – preserves them during all the period of storage with minimum risk of quality reduction.

The evaluation of the quality and safety of preserved dairy products is performed by a number of organoleptic, physicochemical, and microbiological parameters. Taking into account constant improvement of the existing and the development of new innovative technologies, the increase in the range of the produced products, the strengthening of the requirements to shelf life, and other factors, the evaluation criteria of the quality and safety are constantly expanding and new methods are developed, which are introduced into the official registration documentation for new types of products.

The analysis of the grounds for the development of dairy products with an extended shelf life showed that there are still ways to improve the traditional technologies for the increase in their effectiveness. Besides, the problem of the improvement of the stability of preserved dairy products is acute because of the increase in the volume of milk-containing preservatives and the increase in the self-cost and the deficit of natural dairy sources.

The development of new products provided the required conditions of their production and storage: a fine method of dehydration, optimization of the content and technological modes, stabilization of fatty bases with antioxidants, correction of fatty acids content, and sealed packaging. The developed technologies of the production of preserved milk and milk-containing products allow for the adaptation of the chosen method for the development of safe preserved milk products and the prognosis of their economic, social, and strategic significance.

Keywords: High-fat dry cream powder, flavonoid antioxidants, antioxidant complexes, inhibition, quality parameters, secondary products of lipid oxidation, shelf life

I. Introduction

In modern conditions of economic development, the issues of food products quality improvement are acute. One of the most important issues is the development of products with a long shelf life. The storage of fats leads to the synthesis of compounds that cause their spoilage and change in the quality parameters [VII, VI].

One of the most widespread types of preserved milk products storage is lipid oxidation under the influence of oxygen contained in the air. In dry milk powder that contains a lot of air, this process is especially intensive. The presence of inhibitors in fats prevents milk fat from oxidation. Still, this inhibition is insufficient because milk processing decreases the inhibitors' activity [VIII, IX]
The processes of oxidation of fats are described in Engler-Bach peroxide theory. It says that the primary products of oxidation of organic and non-organic substances are peroxides. Any oxidation process can be slowed down with inhibitors. The search for substances that inhibit oxidation processes were started by Murault and Dufres at the beginning of the 1920s. The researchers studied and tested more than 500 inhibitors of oxidation processes. Since then, thousands of new antioxidants were discovered. The most efficient inhibitors are primarily aromatic compounds. The high inhibiting effect is exerted by other antioxidants as well.

The choice of an antioxidant depends on fat composition, conditions of its storage after the inhibition, etc. Highly-efficient antioxidant should possess the following properties: actively inhibit oxidation processes, consistently spread in the fat base, be neutral in terms of smell and taste, do not exert a harmful effect on the organism, be easily synthesized, and have low self-cost of production.

Dry preserved milk-containing products look like cream powder with milky or sour milky flavor and smell.

Traditionally, such food products are stored at (4±2)°C and (83±2)% relative air humidity. In such conditions, the shelf life cannot exceed 12 months.

It is established that after 6-8 months of storage, quality parameters worsen and organoleptic, physicochemical, microbiological, and safety properties decrease, and nutritional value is lost [VII, VI, V].

When dry milk powder products, especially high-fat, are stored at high temperatures, the processes of oxidation in them are very intensive. Polyunsaturated fatty acids (PUFA), groups of vitamins and phospholipids oxidize actively. High temperature activates the reaction of melanoidin synthesis. As a result, products turn brown and get the flavor of caramelization, their solubility decreases and the time of hydration increases [X, XIV, XVI].

For the stabilization of products, primarily natural antioxidants are used that prolong products shelf life [XIV, XII, XI, XV]. Chemical inhibitors have a limited range of application for obvious reasons [XIV, XII, XI, XV, XVIII, XIX].

Natural antioxidants are the substances of plant origin, including bioflavonoids [XX, II]. Flavonoid compounds (quercetin, dihydroquercetin (DHQ)) are natural inhibitors that are used as antioxidants in food products. In comparison with synthesized compounds, they are obtained from available plant sources, not toxic, and exert PP vitamin activity, which increases the nutritional value of food products [III].

One of the main representatives of this group of antioxidants is dihydroquercetin that also exerts vitamin activity. Presently, dihydroquercetin is one of the most efficient known antioxidants. It is obtained from a lemon tree and Siberian larch [I].

Taking into account that one antioxidant cannot exert high antioxidant effect [XIII, XVII], the authors developed antioxidant complexes that consist minimum of two monoantioxidants.
The development of antioxidant complexes for the stabilization of dry milk products was performed for high-fat dry cream powder because this product has the highest fat content (fat in dry matter is 75%) and contains only milk fat in its composition without plant fat additives. It is known that milk fat is highly prone to oxidative spoilage.

II. Materials and Methods

For the prolongation of shelf life of preserved dry milk products, the authors studied the effects of DHQ produced by “Evalar” company according to technical conditions TU 9100-241-21428156-11.

DHQ is white powder, sometimes with cream tint, that has low solubility in water. During the study, DHQ was used as a 40% water-spirit solution that amount was not more than 0.03% to the fat content in the normalized mixture. DHQ was introduced into the mixture after the process of evaporation. Ascorbic acid was used as a synergist in the amount of 0.02% to the fat content in the mixture to be concentrated.

The obtained product was used for the analysis of chemical content and quality parameters. The products were left for long-term storage. The storage of the test and control samples was performed in the following conditions: (3±2)°С and (20±3)°С and relative air humidity not more than 75%. The higher the content of DHQ left in the produced product, the better is the antioxidant effect in preserved dry milk products.

III. Results and Discussion

The evaluation of the influence of technological conditions, in particular, temperature, on the antioxidant activity of DHQ showed that the concentration of DHQ changed insignificantly because the increase in the temperature does not influence the stability of this antioxidant during thermal treatment of milk (Table 1).

| Temperature, °C | Exposure time, min | DHQ content, % |
|----------------|--------------------|----------------|
| 65             | 5                  | 91.13          |
| 85             | 5                  | 92.54          |
| 105            | 3                  | 92.49          |
| 125            | 2                  | 92.50          |
| 145            | 1                  | 92.16          |
| 165            | 1                  | 92.15          |
| 185            | 1                  | 92.61          |
| Control        | -                  | 91.25          |
Antioxidant effect of DHQ and other antioxidants is explained by its ability to interrupt the chains of fat auto-oxidation during the storage. High stability of DHQ is observed in preserved dry milk products. After the exposure of the mixture to 185°C for 1 minute, DHQ content remained at the same level as after the exposure to 65°C and in the control sample.

It was established that DHQ decreased the level of the accumulated oxidation products in preserved dry milk products during the storage.

For the evaluation of the antioxidant activity of DHQ, the authors studied its effect in the doses of 0.01-0.02% to the fat content in combination with ascorbic acid (0.02% to the fat fraction). The concentration of 0.02% to the fat content was optimal, i.e. the antioxidant effect of DHQ at the concentration of 0.02% to the fat content is not lower than in the higher concentration (0.03%), which is proved by the data on the quality parameters of the product (Tables 2 and 3).

**Table 2: Quality parameters of freshly produced high-fat dry cream powder.**

| Number of sample | Antioxidant dose, % | Fat content, % | Moisture content, % | Solubility index, ml | Solvent content of free fat, % | Period of induction, hour | Peroxide number, mmol (½ О)/kg | Acidity value, °К | Thiobarbituric numbers, Absorbance units |
|-----------------|---------------------|----------------|--------------------|-----------------------|-----------------------------|--------------------------|-------------------------------|----------------|-----------------------------------|
| 1               | 0                   | 75±±1.0         | 1.4±±0.10          | 103.8±±0.5            | 0.10±±0.01                 | 64.0±±0.5                 | 0.015±±0.0001                 | 1.07±±0.01     | 0.025±±0.0001                     |
| 2               | 0.01                | 75±±0.9         | 1.67±±0.10         | 102.8±±0.5            | 0.10±±0.01                 | 67.0±±0.5                 | 0.013±±0.0001                 | 1.04±±0.01     | 0.03±±0.0001                      |
| 3               | 0.02                | 75±±1.1         | 1.207±±0.1         | 99.0±±0.1             | 0.10±±0.01                 | 69.0±±0.5                 | 0.010±±0.0001                 | 1.06±±0.01     | 0.02±±0.0001                      |
| 4               | 0.03                | 75±±1.0         | 1.74±±0.20         | 100.0±±0.5            | 0.11±±0.01                 | 78.0±±0.6                 | 0.009±±0.0001                 | 1.06±±0.01     | 0.02±±0.0001                      |

**Table 3: Quality parameters of freshly produced high-fat dry cream powder.**

| Number sample of sample | Consistency | Taste |
|-------------------------|-------------|-------|
| 1-4                     | Dry powder with easily broken clumps | Pure, slightly sweet without additional flavors and smells |
Table 2 shows that at the beginning of the storage, the product contained not more than 75% of fat, moisture content was 2%, and the index of solubility was within 0.1 ml.

The flavor of preserved dry cream powder was pure, sweetish, without foreign flavor and smell. The introduction of DHQ did not influence the taste of the final product. The consistency of preserved dried cream powder was dry, fluffy powder with easily broken small lumps.

The authors monitored the quality of the product in the dynamic for 12 months of storage at different temperature.

The changes in the quality of the product that contained inhibitors are presented in Table 4.

Table 4: Dynamics of the quality of high-fat dry cream powder.

| Number of sample | Storage temperature (4±2), °С | 6 months after | 12 months after | Values that exceeded critical |
|------------------|--------------------------------|----------------|-----------------|-----------------------------|
|                  | Moisture content, % | Solubility index, ml | Titratable acidity, °Τ | Content of free fat, % | Moisture content, % | Solubility index, ml | Titratable acidity, °Τ | Content of free fat, % |
| 1                | 1.328±0.100 | 0.10±0.01 | 109.04±0.50 | 54.44±0.60 | Values that exceeded critical |
| 2                | 1.501±0.100 | 0.10±0.01 | 108.41±0.50 | 55.89±0.60 | 1.400±0.100 | 0.22±0.010 | 112.15±0.50 | 68.97±0.70 |
| 3                | 1.151±0.100 | 0.10±0.01 | 101.76±0.40 | 54.48±0.60 | 1.560±0.100 | 0.20±0.010 | 110.00±0.50 | 66.19±0.70 |
| 4                | 1.655±0.200 | 0.11±0.01 | 102.72±0.40 | 50.35±0.50 | 1.580±0.100 | 0.18±0.010 | 117.24±0.50 | 62.25±0.60 |

Storage temperature (20±3), °C

| 1                | 1.23±0.100 | 0.20±0.01 | 100.00±0.50 | 54.04±0.60 | Values that exceeded critical |
| 2                | 1.497±0.100 | 0.15±0.01 | 109.02±0.50 | 53.98±0.50 | 1.484±0.100 | 0.3±0.010 | 113.09±0.50 | 54.19±0.70 |
| 3                | 1.069±0.100 | 0.15±0.01 | 102.24±0.40 | 53.79±0.5 | 1.570±0.100 | 0.25±0.010 | 113.00±0.50 | 57.86±0.8 |

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Table 4 shows insignificant changes in the acidity in the test samples and some increase in the control sample, especially, in the uncontrolled conditions (Sample 1).

The samples that got stabilized with antioxidants accumulated acidity slower, which is explained by the inactivation of acid residues of fatty acids by DHQ.

The solubility worsened both in the control and test samples. The worst solubility was observed in samples in uncontrolled conditions of storage: from 0.1 ml of raw residue at the beginning of the storage to 0.3 ml at the end of the storage. Moisture content in product during the storage at (20±3)°C decreased.

The analysis of the test samples showed that the product stabilized with antioxidants did not change significantly its quality during the storage in both refrigerators and uncontrolled conditions (Table 4).

However, the fat that was isolated from preserved dry cream powder underwent more significant changes. Thus, there was an increase in the level of hydroperoxides and substances that reacted with thiobarbituric acid (Table 5).

Table 5: Dynamics of the changes in the quality parameters of high-fat dry powder cream during the storage

| Number of sample | After 6 months | After 12 months |
|------------------|----------------|----------------|
|                  | Peroxide numbers, (½ O)/kg | Thiobarbituric numbers, Absorbance units | Induction period, hours | Peroxide numbers, mmol (½ O)/kg | Thiobarbituric numbers, Absorbance units | Induction period, hours |
| 1                | 0.0312±0.001 | 0.063±0.004 | 38.0±0.5 | Values that exceeded critical |
| 2                | 0.0268±0.001 | 0.060±0.004 | 63.0±0.5 | 0.0812±0.001 | 0.067±0.004 | 35.0±0.4 |
| 3                | 0.0161±0.001 | 0.060±0.004 | 70.0±0.5 | 0.0639±0.001 | 0.065±0.004 | 42.0±0.4 |
| 4                | 0.0124±0.001 | 0.057±0.004 | 80.0±0.6 | 0.0602±0.001 | 0.060±0.004 | 56.0±0.5 |

Storage temperature (3±2), °C
Table 5 shows that the stability of preserved dry cream powder was better in the samples with antioxidants by the parameters of primary and secondary oxidation products, which is shown graphically in Figures 1, 2(a) and 2(b).

Table 5 (Continue):

|    | 1       | 2       | 3       | 4       | 5       | 6       | 7       |
|----|---------|---------|---------|---------|---------|---------|---------|
| 1  | 0.0521± 0.001 | 0.065±0.004 | 58.0±0.4 | Values exceeded critical |
| 2  | 0.0324± 0.001 | 0.063±0.004 | 65.0±0.4 | 0.1021± 0.001 | 0.068±0.004 | 32.0±0.5 |
| 3  | 0.0193± 0.001 | 0.060±0.004 | 66.0±0.6 | 0.0924± 0.001 | 0.068±0.004 | 40.0±0.5 |
| 4  | 0.0125± 0.001 | 0.058±0.003 | 75.0±0.5 | 0.0782± 0.001 | 0.062±0.004 | 50.0±0.5 |

**Fig. 1:** Induction period (IP) of milk fat in freshly produced high-fat dry cream powder
Figure 1 shows that DHQ at the concentration of 0.03% in combination with 0.02% of vitamin C stabilized milk fat and significantly prolonged the period of induction of the test samples in comparison with the control. Figure 2(a) showed that after 9 months of storage at (20±3) °C, the induction period in the control sample was 32 hours and in the test sample with 0.01% of DHQ – 52 hours, 0.02% of DHQ – 60 hours, 0.03% of DHQ – 70 hours.

**Fig. 2(a):** Dynamic of the induction period of milk fat in freshly produced high-fat dry cream powder at the temperature storage (3±2) °C

**Fig. 2(b):** Dynamics of the induction period of milk fat in freshly produced high-fat dry cream powder at the temperature storage (20±3) °C

Figure 1 shows that DHQ at the concentration of 0.03% in combination with 0.02% of vitamin C stabilized milk fat and significantly prolonged the period of induction of the test samples in comparison with the control. Figure 2(a) showed that after 9 months of storage at (20±3) °C, the induction period in the control sample was 32 hours and in the test sample with 0.01% of DHQ – 52 hours, 0.02% of DHQ – 60 hours, 0.03% of DHQ – 70 hours.
During the storage in refrigerators, the rate of oxidation of \( \beta \)-carotene (extinction) in milk fat was lower because of a longer period of induction, although the consistency in their changes was the same as in the uncontrolled conditions (Figure 2(b)).

The kinetics of the oxidation process can be characterized by the accumulation of peroxide and thiobarbituric numbers.

Fig. 3(a) and 3(b) show the accumulation of peroxide compounds in preserved dry cream powder with antioxidants during the storage at different temperature.

**Fig. 3(a):** Dynamics of the changes in peroxide numbers in high-fat dry cream powder at the storage temperature (20±3)°C.

**Fig. 3(b):** Dynamics of the changes in peroxide numbers in high-fat dry cream powder at the storage temperature (20±3) °C.
The test and control samples showed that peroxide numbers indicated the high quality of milk fat. No oxidation processes were going in these samples.

The stage of peroxide synthesis is the initial stage of fat oxidation. During the first 6 months, there was no significant accumulation of peroxides, which correlated with the induction period, when natural antioxidants contained in fat (β-carotene) prevented its oxidation. After the end of the induction period, the process of oxidation accelerated. The inhibiting effect was expressed as a slowdown in the accumulation of peroxide compounds. In all the samples, there was a difference in peroxide numbers in the test and control samples. The sample that was not stabilized with DHQ exceeded critical values of the peroxide numbers by the 9th month of the refrigerator and uncontrolled storage. It was more than 0.1 mmol (1/20/kg).

In the fat phase of high-fat dry product stabilized with antioxidants, the increase in the level of peroxides slowed down, in particular, in the sample with 0.03% of DHQ to the fat fraction. The content of peroxide compounds increased by the end of the storage but did not reach the borderline limits. Taking into account the existing characteristics, the studied samples were identified as “fresh” but not suitable for further storage.

Degree of oxidation characterized by the peroxide number does not describe the changes in the fat fraction objectively enough because peroxides can both accumulate and degrade.

More objective characteristics of the degree of oxidation can be given by thiobarbituric number (TBN) that highly correlates with organoleptic evaluation. TBN depends on the quantitative and qualitative composition of the fat phase. Fat cannot be stored when TBN reaches 0.067 absorbance units.

Figures 4(a) and 4(b) show the changes in the oxidation rate due to the increase in TBN during the storage at different temperature: refrigerated at (3±2)°C and in the uncontrolled conditions (20±3)°C.

**Fig. 4(a):** Dynamics of the changes in TBN in high-fat dry cream powder at the storage temperature (3±2) °C
In freshly obtained milk fat, TBN depended on the concentration and type of the antioxidant from 0.02 to 0.03 absorbance units. A significant increase in the degree of oxidation was observed when temperature increased. In samples with antioxidants, secondary products of oxidation accumulated slower depending on the concentration of the antioxidant. Thus, after 9 months of storage at = (3±2)°С, the control sample and the sample with the minimum content of DHQ had TBN within 0.07 absorbance units, while the sample with 0.02% of DHQ had such TBN only after 12 months of storage. In the samples that contained a minimal concentration of DHQ, TBN did not exceed 0.06 absorbance units by the 12th months of storage. The changes in TBN during the storage at (20±3)°С were similar to the changes at (3±2)°С but less intensive (Figure 4(b)).

The changes in the levels of secondary products of oxidation correlated with the worsening of organoleptic properties of high-fat dry cream powder during the storage (Table 6).

**Table 6: Changes in the organoleptic evaluation of high-fat dry cream powder during the storage.**

| Number of samples | Amount of introduced additives, % | Score |
|-------------------|-----------------------------------|-------|
|                   | DHQ                               |       |
|                   | Vitamin C                         |       |
|                   | Storage (3±2) °C                  |       |
|                   | temperature                       |       |
|                   | Storage (20±3) °C                 |       |
|                   | temperature                       |       |
|                   | For 6 months                      |       |
|                   | For 9 months                      |       |
|                   | For 12 months                     |       |
|                   | For 6 months                      |       |
|                   | For 9 months                      |       |
|                   | For 12 months                     |       |
High-fat dry cream powder that was not stabilized with antioxidants had the degree of oxidation that could be tasted. It was removed from storage after 9 months.

High-fat dry powder cream stabilized with antioxidants (0.01-0.03% to the fat fraction) met the requirements by the organoleptic parameters during 12 months of storage.

It should be mentioned that 0.03% of DHQ did not influence significantly the stability of the product in comparison with 0.02% of DHQ. This, this concentration is considered optimum.

Thus, the inhibiting effect of antioxidant complex that consisted of bioflavonoid DHQ at the concentration of 0.02% to the fat phase in the combination of ascorbic acid at the concentration of 0.02% to the fat phase was the most effective.

The results of the conducted study were used to determine the shelf life of the developed product according to the MU 4.2.1847-04 with a reserve coefficient 1.15 that is used for preserved food products intended for therapeutic and preventive diet with the periodicity of quality check after 12, 18 and 24 months of storage at (3±2)°C and (20±3)°C.

Based on the complex study of all the controlled parameters (organoleptic, physicochemical, microbiological, and safety), the authors established the guaranteed shelf life for high-fat dry cream powder stabilized with antioxidant complexes that was 18 to 24 months at (20±3)°C and (3±2)°C, respectively.

The elements of the technology of the use of antioxidant complexes in the production of high-fat dry cream powder were tested in the facilities of the milk processing company ONO “VNIMI-Sibir” of the Russian Agricultural Academy and were approved for the development of technical documentation for a new type of preserved high-fat dry cream powder.

IV. Conclusion

It was established that

- Natural bioflavonoid dihydroquercetin was effective in the stabilization of high-fat milk-containing product during the storage;

- It was more feasible to use antioxidant complexes that consisted minimum of two antioxidants;

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The composition dihydroquercetin in combination with ascorbic acid at the concentrations of 0.02% to the fat fraction of the product was the most efficient for the inhibition of the oxidation processes in high-fat dry cream powder;

The inhibiting effect of the antioxidant complex prolonged the shelf life of high-fat dry cream powder to 18 months at (20±3)°C and 24 months at (3±2)°C.

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