The effect of primary drying temperature on the antioxidant activity of jackfruit, melon and banana in yogurts

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Abstract. Main patterns of interrelationship between parameters of vacuum freeze-drying and the preservation of antioxidants in final product at different primary temperatures were determined in this article. Jackfruit, melon, and banana were frozen in pieces. The process of freeze-drying of the fruit raw material was at the primary temperature (from minus 10 to minus 30 °C) at an appropriate vacuum. At the secondary drying, the temperature was always the same, equal to 38-40 °C. Freeze-dried fruits were added at the stage of preparation of the mixes of yogurts. The total integral antioxidant activity was measured in the finished products by coulometric titration. The research demonstrated that vacuum freeze-drying at increasingly lower primary drying temperatures leads to a preservation the more content of antioxidants. It has been determined that the addition into yoghurt freeze-dried fruit powder leads to rise total antioxidant activity by 11.3-14.7 %. Our data have shown that there is the possibility of choosing, in agreement with potential consumers, the desired quality of the finished product and this can effect on total cost of process.

1. Introduction
Yoghurts are traditionally included in the structure of modern healthy diet, since they not only allow normalizing of the gastrointestinal tract microflora, but are also attractive in terms of taste preferences [1,2]. The range of yoghurts is expanding every year globally. One of the promising directions of increasing the complex of their useful properties is the introduction of fruits into their formulation [3-7]. Fruits like jackfruit, melon and banana enjoy the most widespread popularity [8-10]. Their use in yoghurt formulation can significantly enhance the vitamin composition and enrich its with dietary fibres that are good prebiotics [11,12]. Furthermore, they have better nutritional value than without fruits as the protein digestibility rised during fermentation. The chemical changes which take place during fermentation with the addition of jackfruit to milk are therefore of great interest as overall protein turnover becomes faster, influencing the nutritional status and flavour altogether [3,13,14].

The use of fruits in yoghurt formulations is associated with the seasonality of their maturation and harvesting. The need to preserve them fresh for long term also causes significant problems in the context of industrial production [14]. These problems can be solved by using the technology of high-quality vacuum freeze-drying preservation. This technology assumes two stages: the preliminary freezing stage of vegetative raw materials and the subsequent freeze-drying. In turn, freeze-drying also consists of two
stages. At the first stage, the bulk of the frozen out moisture is removed by the "ice-vapour" phase transition, the remaining physically bound moisture is removed by evaporation at the drying completion stage at positive temperatures. It is known, that the preservation of antioxidants and other useful components depends on the temperature at which the "ice-vapour" phase transition takes place. The general rule is that the lower the temperature of the phase transition, the higher the content of antioxidants preservation [15]. However, a lower temperature of the phase transition leads both to an increase in the drying time and to rise in the total energy consumption for the dehydration process [16]. For this reason, the determination of the numerical relationships between the antioxidants content and the primary temperature, in addition to being of scientific interest, is also of great practical importance.

2. Materials and methods

2.1. Sample preparation
Jackfruit, melon and banana (Vietnam) were raw material. Jackfruit and melon were cleared of seeds, the banana was peeled. Then the fruits were cut into slices and thickness of slices was 10 ± 2 mm, then fruits were put on trays in layers. The temperature sensors were previously installed in the slices of fruit. Then the trays were moved to freezing

2.2. Freezing
The fruits were frozen at -20 °C in a freezer for 5 - 7 hours. It has been experimentally established that this time interval was sufficient to freeze most of the moisture in the raw materials. Then freezing raw material were placed in the lab scale freeze dryer [17].

2.3. Vacuum Freeze-Drying
Process was carried out in each experiment at various primary temperatures from (-10 °C ) to (-30 °C). The temperature at the secondary drying remained the same, 38-40 °C. The total time of the process and the time of the primary drying were measured by the temperature changes in the layer of the raw material being dried. The total drying time was varied from 8 to 24 hours. The total quantity of dried samples was 15: jackfruit, melon and banana, dried at a freeze-drying temperature minus 10 °C, minus 15 °C, minus 20 °C, minus 25 °C, minus 30 °C.

2.4. Preparation of Yoghurt
Yogurt was prepared according to the following process. Freeze-dried fruits were added in an amount of 3 % at the stage of preparation of the mixes. The mixes were pasteurized at 85 ± 2 °C for 15 minutes and cooled to 40 ± 2 °C, before being fermented. The composition of the starter included S. thermophilus and L. delbrueckii subsp. Bulgaricus. Yoghurt samples were fermented at 40 ± 2 °C until a clot was formed and then cooled to 4 ± 2 °C.

2.5. Determination of Total Antioxidant Activity
Total antioxidant activity was determined by coulometric titration [18].

2.6. Sensory evaluation of yoghurts
The sensory evaluation included colour, aroma, taste, texture and overall acceptance. The panelists evaluated each attribute using a five-point scale to compare traditional yoghurt without fruits.

2.7. Statistical Analysis
All experiments were performed in 5 replicates and the average value was calculated

3. Results and discussion

3.1. Vacuum freeze-drying of fruits
Table 1 shows the process parameters of vacuum freeze-drying in our researches.
Table 1. Parameters of vacuum freeze-drying of fruit raw materials in lab scale freeze dryer.

| Primary drying temperature, °C | Average temperature on the surface of condenser, °C | Time, h | Total | Primary drying | Intensity of moisture removal at the primary drying, kg/hr *m² |
|-------------------------------|-----------------------------------------------|---------|---------|----------------|----------------------------------------------------------|
| 1                             | 2                                             | 3       | 4       | 5              | 1.72                                                     |
| -10                           | -20                                           | 8       | 6.5     |                | 1.72                                                     |
| -15                           | -26                                           | 11      | 9       |                | 1.21                                                     |
| -20                           | -30                                           | 14      | 11      |                | 0.95                                                     |
| -25                           | -38                                           | 18      | 14      |                | 0.82                                                     |
| -30                           | -44                                           | 24      | 18      |                | 0.64                                                     |

The data on the primary temperature in our experiments are presented in column 1, and average temperatures on the surface of condenser corresponding to the primary temperatures are in column 2. The results demonstrated that reducing of the primary temperature is accompanied by rising the total time of the process (column 3) and primary drying time (column 4). Lowering the primary temperature leads to a proportional reduce in the intensity of moisture removal at the primary drying.

The freeze-dried fruit slices retained their colour and flavour (figure 1). The final moisture content of the dried samples was 1.7 - 2.0 %. They were easily crushed and turned into powder.

![Figure 1](image1.png)

**Figure 1.** Freeze-drying fruits at primary drying temperature of minus 20°C: a) jackfruit, b) melon, c) banana.

The colour of the dried samples did not depend significantly on the primary drying temperature in the tested temperatures in all dried fruits. The aroma of dried samples had changed significantly. In samples dried at higher primary drying temperatures, a significant reducing in the intensity of the flavour specific for each fruit was determined. In samples dried at a primary drying temperature of minus 25°C to (minus 30°C), the flavour corresponded to the flavour of the raw material. The aroma had a similar dependence on primary temperature.

3.2. Total Antioxidant Activity of the yoghurt

Since substances possessing antioxidant activity are by their nature thermolabile components, this property strongly depends on the temperature effects. Thus, it can be used to evaluate the parameters of freeze-drying, and it is clearly correlated with other indicators of the quality of products [12,13].

The data of the antioxidant activity of jackfruit, melon and banana are presented in figure 2.
The data in the figure 2 indicate that at a primary temperature of -10 °С the antioxidant activity only rose by 10\% compared with the control. At primary temperatures lower (from (-15 °С) to (-20 °С)), the values of this indicator were 0.116 - 0.119 mg/g dry matter. At a primary temperature of (-25 °С) to (-30 °С), the values rose by 14.7% and amounted to 0.12 mg/g dry matter. The addition of freeze-dried fruit to yoghurts leads to a rising of antioxidant activity by 11.3-14.7 % compared to the control and demonstrates sufficiently high preservation of antioxidant substances. Lowering the primary temperature leads to a higher preservation of antioxidant substances. Similar data were obtained for all yoghurts containing freeze-dried melon and banana.

The rise in the content of antioxidant with reducing primary drying temperature is explained by the following reasons. It is known that antioxidants include anthocyanins, catechins, leucoanthocyanins, polyphenols, flavonols and other substances that are highly volatile. Reduction of primary temperature increases the amount of frozen liquid in plant materials. This leads to their better preservation in the finished product and their better activity. Unfrozen moisture is removed by evaporation along with water-soluble volatile components.

3.3. Sensory evaluation of yoghurts
The results of the sensorial evaluation of the tested yoghurts are demonstrated in table 2.

| Attribute         | Traditional yoghurt without jackfruit (control) | Yoghurt with freeze-dried jackfruit primary drying temperature, °С |
|-------------------|-----------------------------------------------|---------------------------------------------------------------|
|                   |                                               | -10   | -15   | -20   | -25   | -30   |
| Colour            | 5.0                                           | 4.8±0.4 | 4.8±0.4 | 4.9±0.3 | 4.9±0.3 | 4.9±0.3 |
| Aroma             | 5.0                                           | 4.2±0.5 | 4.2±0.4 | 4.7±0.5 | 5.0±0.1 | 5.0±0.1 |
| Flavour           | 5.0                                           | 4.2±0.4 | 4.3±0.5 | 4.6±0.5 | 4.9±0.3 | 5.0±0.1 |
| Texture           | 5.0                                           | 4.5±0.5 | 4.5±0.5 | 4.7±0.5 | 4.8±0.4 | 4.9±0.3 |
| Overall acceptance| 5.0                                           | 4.4±0.5 | 4.5±0.5 | 4.7±0.5 | 4.9±0.3 | 5.0±0.1 |

The yoghurt with jackfruit acquired a pleasant light shade of cream colour evenly distributed throughout the volume of the product. The different primary drying temperatures did not significant
effect the colour intensity of the yoghurt samples. Panelists evaluated the yoghurts as same as the control in this attribute.

Panelists noted that the addition of freeze-dried jackfruit, dried at lower temperatures, led to the fact that the samples had a more pronounced pleasant smell and aroma like as of fresh. Since after vacuum freeze-drying these fruit samples had a more pronounced aroma, their aroma remained more pronounced when added to the yoghurt as well.

In yoghurt with jackfruit dried at higher primary temperatures, the aroma was barely noticeable. These data correlate with their antioxidant activity. In samples with a more pronounced aroma and flavour of the fruit, a higher antioxidants content was found. Participants noted a similar dependence in taste.

The jackfruit powder dried at various primary temperatures had insignificantly effected on the texture of the products. The panelists noted that it had become slightly thicker while remaining homogeneous and without lumps.

Overall acceptance was given to the samples with fruits dried at lower primary temperatures.

Similar data were obtained for the yoghurts with melon and banana. Sensory analyses showed a trend: yoghurts with fruits freeze-dried at lower primary temperatures received higher panelist’s ratings.

4. Conclusion
The accomplished tests allowed drawing a conclusion that the primary drying temperature has a significant effect on content of antioxidants. Lower freeze drying temperatures lead to more significant preservation of antioxidant substances, which are saved even when the freeze-dried fruit is further used in dairy engineering. This regularity holds true for all other products of plant origin subjected to freeze-drying, i.e., the lower the primary drying temperature, the higher the content of components.

It is shown, that the primary temperature minus 20 °C and the secondary temperature 40 °C for the tested fruits are the rational parameters. This mode provides a balance of the total antioxidant activity, the time of the process and intensity of moisture removal at the primary drying.

It has been determined that the addition into yoghurt of 3 % freeze-dried fruit powder after the fermentation stage leads to rise antioxidant activity by 11.3-14.7 % compared to traditional yoghurt, besides to increasing its shelf life.

In addition, it has been shown that the primary temperature also effects on the sensorial characteristics of yoghurts. Thus, it is possible to control the quality of dry freeze-dried fruits and products containing them by changing primary temperatures. This data give rise to the prospect of being able to select, upon agreement with consumers, a preset quality of the finished product, which is closely interrelated with the total cost of freeze-drying.

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