THE LIMITING STORAGE LIFE OF PERISHABLES DURING JOINT TRANSPORTATION

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Abstract: The article presents the research results of the optimal storage period for perishable products, which require specific thermal and temperature-humidity conditions, during joint transportation. A new classification to group perishable products that are subject to joint transportation by moisture and water activity is proposed. The calculations show that perishable goods during joint transportation need the following optimal parameters: an air temperature of the cargo space of −5 to 0 °C, relative humidity of 75 – 95%, and storage life of no more than 10 days while in transit.

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Introduction

Effective transportation, especially in terms of transporting perishable goods optimally through a refrigeration transport chain, is an important component of the production activity of meat processing companies.

The problems relating to delivery of perishables in today's society should be approach rationally. Having created optimal storage conditions for maintaining food quality while minimizing the costs of refrigeration, processing, and transportation, are the main indicators of improvement and optimization of vehicles and their components for the transport of perishables (Tolysbayev & Abilmazhinov, 2007; Bolshakov, 2006).

The maintenance technology of perishables determines the transportation technology.

The continuity of a refrigeration transport chain requires compliance with similar conditions to those set down for stationary refrigerated storage areas and other refrigerated transport. We consider that, currently, the meat processing enterprises of Kazakhstan aim to expand the market realization of products. Also, according to the Statistics Agency of the Republic of Kazakhstan, the volume of transported perishables is increasing at about 6% of the total turnover. Shipment of these products is mainly by road and rail-refrigeration (Law of the Republic of Kazakhstan from "On Automobile Transport", 2003; Rules of goods' transportation by road, 2011; Terms of railway transportation, 2011). The long-haul transportation outside the country is well planned, particularly in countries of Central and Southern Asia. In these areas, there has been widespread introduction of advanced technologies for transportation of perishables in recent years. One such technology is the use of 'container' shipping. The efficiencies in using container shipping largely depend on similar conditions to those that affect joint transportation of foodstuffs and agricultural products, given they are subject to the same transportation requirements.

Materials and methods

In current practice, depending on the requirements, all perishables during joint transportation are grouped into three groups (Ryall & Pentzer, 1982; Gill, 1996; Angelov, 2011).

The inclusion of indicators, such as humidity and water activity of the product, which affect joint transportation, were not considered in the grouping of perishables. Below are the characteristics relating

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to the existing three perishable groups that are relevant for joint transportation. Based on the foregoing, we consider the grading of these indicators for the groups of perishables, as shown in Table 1.

Table 1: Group I — Frozen products. Storage modes: air temperature in the cargo space no higher than −12°C at a relative humidity of 70 – 80%, with moderate circulation at a rate no higher than 0.2 – 0.3 m s^{-1}. Storage life in transit is not more than 30 days.

#	Product	Humidity *W*, %	Water activity, a_w
1	**Frozen beef and mutton**	70 – 75	0.98 – 0.992
2	**Frozen pork**	70 –75	0.978 – 0.986
3	**Frozen offal (tongue, udder, heart, kidneys, and brain)**	80 – 85	0.98 – 0.9891
4	**Meat and offal; frozen in blocks**	70 – 85	0.98 – 0.9891
5	**Frozen poultry**	65 – 75	0.979
6	**Bacon fat**	70	0.977
7	**Butter**	75	0.971
8	**Margarine**	75	0.97

Source: Authors

Table 2: Group II — Frozen and chilled products. Storage modes: air temperature in the cargo space of between −5°C and 0°C. Storage life in transit is not more than 15 days.

#	Product	Humidity *W* (%)	Water activity a_w
1	**Chilled beef and mutton**	65 – 75	0.98 – 0.992
2	**Chilled pork**	65 – 75	0.978 – 0.986
3		85 – 95	0.98 – 0.9891
4	**Frozen culinary products from minced meat (goulash, burgers, steaks, meatballs, and schnitzel)**	65 – 85	0.98 – 0.9891
5	**Sausages (wieners and sausages)**	35	0.9715
6	**Combined meat and cereal products (meat dumplings, etc.)**	-	-
7	**Butter**	75	0.971
8	**Margarine**	75	0.97

Source: Authors

Table 3: Group III — Chilled food. Storage modes: air temperature in the cargo storage area within the range 0 – 6°C at a relative humidity of 70 – 85%. Storage life in transit not more than 10 days.

#	Product	Humidity *W* (%)	Water activity a_w
1	**Pates of meat, liver, and poultry produced by industry**	21	0.9891

2	**Sausages**	24	0.78
3	**Culinary products from minced meat, fried (goulash, burgers, steaks, meatballs, and schnitzel)**	22	0.79

Source: Authors

Finding ways to reduce the loss of perishable goods in transit is inextricably linked to an objective assessment of the quality characteristics. Widespread species loss relating to the quality of the product is linked to shrinkage. It is now scientifically proven that a product contains moisture in three types: strongly bound, free, and loosely coupled. The change in state of moisture in the product depends on many parameters. In particular, the temperature and humidity of air, and change in the water activity of the product itself, greatly affect shrinkage of the product.

The water activity in this case is defined as the ratio of the water-vapor pressure of the product to that of the pure solvent used in establishing thermodynamic equilibrium. Water activity was measured by a manometric method in a suitable machine (Kamerbayev, 2001). The installation of this machine included a differential gauge, a flask with the product and distilled water, a vacuum pump, a trap, a thermocouple, and a potentiometer for testing the temperature of the product.

Water activity is calculated by the formula:

$$a_w = \frac{P_{np}}{P_o} = \frac{P_o - \Delta P}{P_o} \tag{1}$$

where P_{np} – is the partial vapor pressure of meat products; and

P_o – is a steam partial pressure of distilled water.

Shrinkage of the product was determined by way of an experimental stand that remotely measured the time step (h = 1 hour), without breaking the heat and humidity modes (Gill & Phillips, 1993). Moisture evaporation from the model broke the equilibrium state of the sample weights, and forced equal effect on the mass of removed moisture, which was transferred to a steel elastic beam, where four strain gauges (AKA-10.200V, TU25.06, 1382-78) were attached, with each connected to a bridge circuit of 200 ohms. The signal from the strain gauges entered the strain amplifier, “TOPAZ-4”, and then transferred onto the C-75 oscilloscope.

Separate experiments were carried out for samples of meat, which weighed 5.02 kg for beef, 5.135 kg for mutton, and 5.01 kg for preserved meat. Temperature-humidity conditions were set with air temperature ± 30°C and absolute humidity 60 – 95%.

Results and discussion

As it can be seen, the storage life of perishables depends on air temperature. However, the storage life must ensure the preservation of the quality of products. Product quality is determined mainly by the acidity (pH), and water activity (a_w) of the product. The technique of determining the storage life of perishables based on the pH, a_w and storage temperature of the product is proposed (James, James, & Evans, 2006).

The peculiarity of this technique is that you can determine the storage life of a perishable product at any stage of storage and transportation to the next, based on

$$\tau_{xp} = 1{,}15 \cdot A \cdot p_1 \cdot \ln(B \cdot a_w) + C \cdot p_2 \int_a^b \ln(pH)d(pH) \tag{2}$$

In our case, for the following products: meat chilled, cooked sausages and minced meat, the coefficients and constants were empirically determined.

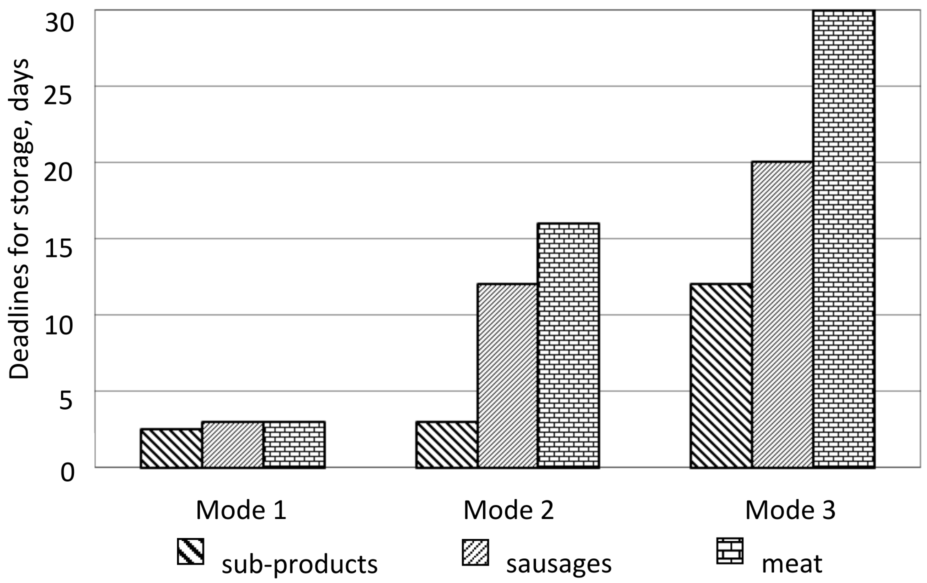
Table 4: Empirical coefficients

The storage of products at the stages of storage in the enterprise and transportation: $[t] = -4$ °C – 0	The storage of products at the stage of realization $[t] = 0 - 8$ °C
$A = 5.5(1-\varphi)e^{-\varphi(t-5)}$	$A = 5.5(1-\varphi)e^{-\varphi\sqrt{(5-t/1.6)}}$
$B = \frac{0.235}{1-\varphi}e^{t^2\varphi}$	$B = \frac{0.235}{(1-\varphi)}e^{\varphi}\sqrt{([t]-t)^3}$
$C = 80 \cdot \varphi^2$	$C = 0.5 \cdot \varphi^2$

Source: Authors

A graph of the perishable products' deadlines in relation to different modes of temperature and humidity is presented in Figure 1.

Figure 1: Deadlines for storage of meat and meat products, in relation to different technological regimes



Mode 1 – air temperature not higher than 6 °C, relative humidity 80 – 95%;

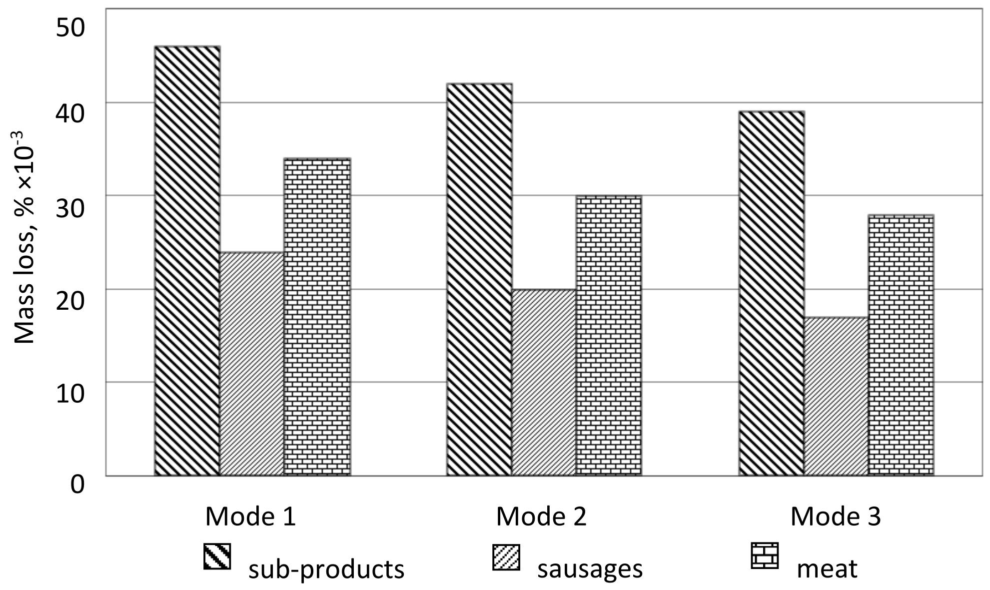
Mode 2 – air temperature not higher than 0 °C, relative humidity 75 – 95%;

Mode 3 – air temperature of −5 °C, relative humidity 75 – 80%.

Source: Authors

Figure 2 shows the weight change of perishable products according to different modes of storage.

Figure 2: The weight loss of perishable products with different modes of storage



Mode 1 – air temperature not higher than 6 °C, relative humidity 80 – 95%;

Mode 2 – air temperature not higher than 0 °C, relative humidity 75 – 95%;

Mode 3 – air temperature of −5 °C, relative humidity 75 – 80%.

Source: Authors

As we can see from Figure 1, the deadlines for storage at air temperatures between 0 ° C and − 5°C are higher than those for storage at 0 – 6 °C. Figure 2 shows that compared to results for air temperatures not higher than 6 °C, weight loss is apparent for temperatures less than 0°C and 5 °C, respectively.

Tables 5, 6, and 7 show the limits of storage for perishable goods, respectively, for the three groups in the proposed grouping for joint transportation.

Table 5: Shelf life of perishable products in the first group (days)

Product	**At the stage of storage in the enterprise and transportation: $[t]$ = −4 – 0 °C**	**At the stage of the realization $[t]$= 0 – 8 °C**
Frozen beef and mutton	30	3
Frozen pork	30	no more than 2
Frozen offal (tongue, udder, heart, kidneys, and brain)	20	1
Meat and offal; frozen in blocks	30	2
Frozen poultry	20	3
Bacon fat	12	1
Butter	20	1
Margarine	20	

Source: Authors

Table 6: Shelf life of perishable goods in the second group (days)

Product	At the stage of storage in the enterprise and transportation: $[t]$ = −4 – 0 °C	At the stage of realization $[t]$= 0 – 8 °C
Chilled beef and mutton	5	3
Chilled pork	5	3
Chilled carcasses of poultry and rabbits	5	3
Frozen culinary products from minced meat (goulash, burgers, steaks, meatballs, and schnitzel)	12	5
Sausages (wieners and sausages)	10	3
Combined meat and cereal products (meat dumplings, etc.)	5	1
Butter	5	2
Margarine	5	2

Source: Authors

Table 7: Shelf life of perishable goods in the third group (days)

Product	At the stage of storage in the enterprise and transportation: $[t]$ = −4 – 0 °C	At the stage of realization $[t]$= 0 – 8 °C
Pates of meat, liver, and poultry produced by industry	15	7
Sausages	15	3
Culinary products from minced meat, fried (goulash, burgers, steaks, meatballs, and schnitzel)	5	1

Source: Authors

Conclusion

The calculations show that perishable goods during joint transportation need the following optimal parameters: an air temperature of the cargo space of −5 to 0 °C; relative humidity of 75 – 95%; and storage life, while in transit, of not more than 10 days.

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