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TRANS-ISOMERIZED FATTY ACIDS IN HYDROGENATED FATS

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A B S T R A C T	K E Y W O R D S
The article outlines ways to improve the quality and ensure the food safety of fats obtained by hydrogenation of cottonseed oil, through the selection of scientifically based highly effective technologies and catalytic systems that allow reducing the content of trans-isomerized fatty acids and regulating the necessary arrangement of fatty acids in triacyl glycerides of edible fats.	Hydrogenation technology, catalysts, isomerization processes, trans-isomerization of fatty acids, target fats

Introduction

Dietary fats are an important food product. According to physiological standards, the recommended fat content in the human diet is 30-33% of the total energy value of food [1].

Fats are necessary not only as a reserve substance and source of energy, but also as a supplier of physiologically active compounds - essential fatty acids, phospholipids, sterols, vitamins involved in the synthesis of cell membranes and other tissues of the body [3].

Improving the quality of fats can be achieved by changing the triglyceride composition of oils and fats using various methods of their modification [4].

Consumption of excessively large amounts of trans isomers leads to dysfunction of the body at the cellular level. It has been established that trans isomers are metabolized in the body much more slowly than natural cis isomers. Unlike cis isomers, which have a curved spatial structure with bends in the carbon chain at double bonds and an angle of about 30°, trans acid molecules are almost straight and resemble the spatial structure of saturated acids [1, 2]. Due to this, during crystallization they can be packed into very dense structures with fairly powerful intermolecular interactions. A higher melting point of transform increases the viscosity of cell membranes, changes their permeability and disrupts the metabolism of the cell as a whole [3].

Relevance

In the world, increasing attention is being paid to research work on the catalytic modification of vegetable oils and fats in order to improve the quality and ensure the nutritional safety of fats for their intended purpose. The creation of a new generation of catalysts for the production of edible fats for special purposes is an urgent problem. In this direction, research work to improve the properties of edible fats for specific purposes, optimize their composition and technological processes is receiving significant development.

Solving problems of the quality and safety of edible fats and their processed products is one of the priority areas in the implementation of the concept of state policy in the field of healthy nutrition for the population of the Republic of Uzbekistan.

Purpose of the Research

The work is aimed at improving the quality and ensuring the food safety of fats obtained by hydrogenation of cottonseed oil, through the selection of scientifically based highly effective technologies and catalytic systems that allow reducing the content of trans-isomerized fatty acids and regulating the necessary arrangement of fatty acids in triacyl glycerides of edible fats.

Objects of Research

Scientific and experimental research was carried out in modern laboratory and pilot production facilities.

Various catalytic systems have been used in experimental studies on the catalytic modification of cottonseed oil. For laboratory hydrogenation, stationary alloy and powder (Nisosel-800 containing nickel and copper salts) catalysts based on nickel, copper and promoting additives were investigated. Stationary alloy catalysts containing one and two promoting additives have been studied [9, 10].

Catalytic hydrogenation of cottonseed oil was carried out in identical technological modes (Table 1), under which the basic properties of stationary alloy catalysts were established.

Table 1 Conditions for assessing the hydrogenation properties of stationary alloy catalysts

Hydrogenation conditions parameters	Unit of measurement	Meaning
Temperature	^0C	200
Pressure	*kPa*	300
Volume flow rate of raw materials	h^{-1}	1
Volumetric flow rate of hydrogen supply	h^{-1}	60
Catalyst capacity	*mL*	1000
Average particle size of catalyst	*mm*	6
Height of the catalyst bed	*mm*	765
Diameter of reactor	*mm*	50

Methods and Materials

To analyze and evaluate the quality, physico-chemical characteristics, food safety of raw materials, intermediate materials, hydrogenated fats and products based on them, modern physical, chemical and physico-chemical methods and mathematical processing of the obtained experimental data were used [7, 8].

Results and Discussion

The degree of trans isomerization depends mainly on the hydrogenation conditions (Table 2): temperature, type, amount and activity of the catalyst, pressure and amount of hydrogen, intensity of stirring. Fully hydrogenated fats do not contain trans isomers. In case of incomplete hydrogenation, the content of trans isomers is determined by thermodynamic cis/trans equilibrium, corresponding to 75% of the total number of double bonds.

Table 2 Characteristics of lard oils obtained by continuous modification of cottonseed oil on a new generation catalyst

Modification conditions			iodine value. % J_2	Trans acid content, %	Acid value, mg KON/g	Melting temperature, ^0C	Firmness g/cm
Temperature, ^0C	Pressure, kPa	Oil supply speed, h^{-1}					
200	300	1,8	74,1	11	0,20	34,5	420
200	300	1,5	72,1	14	0,21	36,1	500
200	100	1,0	64,2	18	0,27	37,2	540
180	100	1,0	63,7	19	0,29	37,1	600
180	100	1,2	66,4	21	0,35	38,3	620

Results and Discussion

The results of studying the influence of temperature and hydrogen supply rate on the isomerizing ability of stationary catalysts are shown in Fig. 1 and 2.

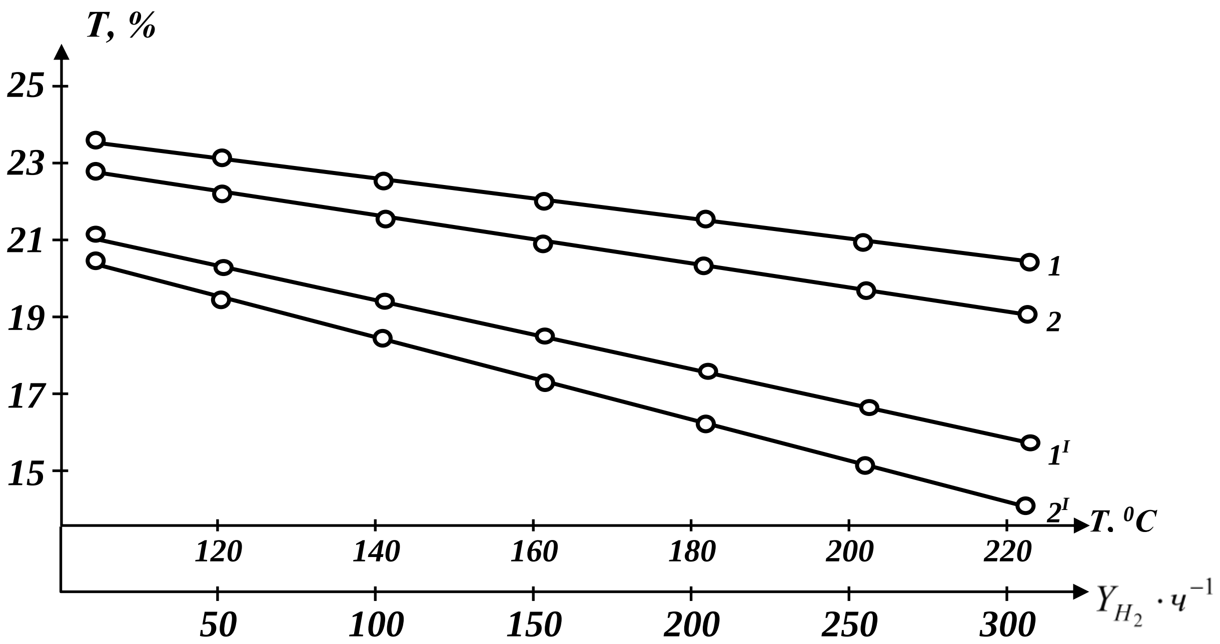

Fig.1. Effect of temperature (1.1^I) and hydrogen supply rate ($2, 2^I$) on the reduction of the content of trans acids in lard on fresh catalysts № 1 (1, 2) and № 2 (1^I, 2^I)

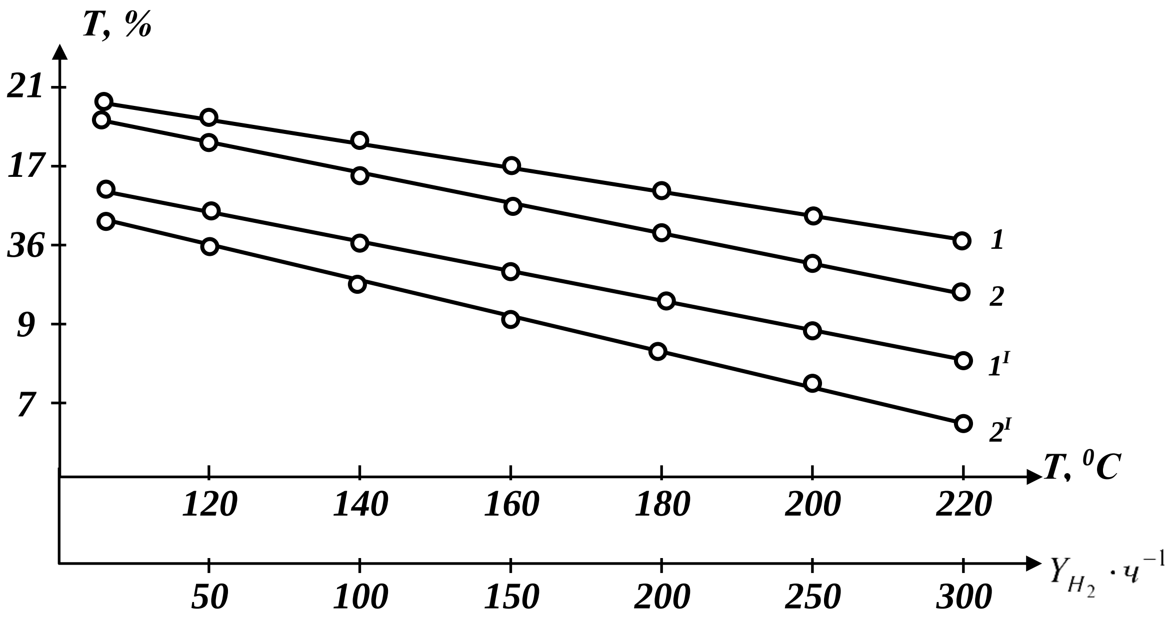

Fig.2. Effect of temperature (1.1I) and hydrogen supply rate (2, 2^I) on reducing the content of trans acids in lard on regenerated catalysts № 1 (1.2) and № 2 (1^I, 2^I)

Increasing the temperature and rate of hydrogen supply leads to a decrease in the accumulation of trans-isomers in oils, and the greatest degree of decrease in isomerizing ability is manifested on regenerated catalysts.

The results of studies with stationary catalysts promoted by additives [9] make it possible to obtain selectively hydrogenated fats with a low content of trans-isomers at temperatures of 180-2000C and hydrogen pressures of up to 300 kPa.

Similar studies were carried out on a catalyst with the addition of the most effective promoter [10]. The results of these studies are presented in Table 3.

Table 3 Production of high-hardness lard on a regenerated and trained (120 h) stationary catalyst

Modification Terms		Fatty acid composition (C),					Selectivity coefficient, %	Trans acid content, %
Pressure, kPa	Oil supply speed, h^{-1}	14:0	16:0	18:0	18:1	18:2		
100	1,6	0,6	22,0	6,9	53,9	16,6	91,2	17
300	1,6	0,6	21,7	8,0	51,4	18,3	90,0	15
300	1,1	1,0	22,4	6,0	63,6	7,0	94,8	13
100	1,1	1,7	22,2	8,2	50,3	18,0	89,3	14

As can be seen from Table 3, food lard, containing a small number of saturated glycerides, completely correlates with the data for lard obtained with a powder catalyst. High-hard fat, which has a higher melting point and significantly greater hardness (Table 4), is also characterized by a higher content of desaturated and triturated glycerides.

Table 4 Characteristics of lard oils obtained by continuous catalytic modification of cottonseed oil on a stationary catalyst regenerated and trained for 800 hours (process selectivity 94-99%)

Modification conditions			iodine value. % J_2	Content of trans acids, %	Acid value, mg KON/g	Melting temperature, ^0C	Firm ness g/cm
Temperature, ^0C	Pressure, kPa	Oil supply speed, h^{-1}					
200	300	1,8	74,1	11	0,20	34,5	420
200	300	1,5	72,1	14	0,21	36,1	500
200	100	1,0	64,2	18	0,27	37,2	540
180	100	1,0	63,7	19	0,29	37,1	600
180	100	1,2	66,4	21	0,35	38,3	620

To ensure high quality and nutritional safety of edible fats, the reduction of trans-isomerized monoenoic fatty acids through the selective and high-temperature hydrogenation process of cottonseed oil was investigated.
The results of the catalytic modification are given in Table 5.

Table 5 Content of trans-isomers of acids during selective catalytic modification of cottonseed oil

Indicators	Iodine number of salomas				
	88	84	73	69	65
Melting temperature, ^0C	25	29	33	34	35
Hardness, g/cm	70	140	270	300	400
	65	65	50	30	15
C, %	98	98	97	95	90
L, %	21	17	5	3	6
(L_o - L)	26	30	42	44	47
T, %	9	11	15	21	24
Calculation	10	12	17	23	26

Under these conditions, the accumulation of trans-isomerized fatty acids, which determine the hardness of selectively modified oils, occurs not only due to the hydrogenation of linoleic acid, but also due to the parallel reaction of cis-trans isomerization of all monounsaturated acids - the original ones and those formed during hydrogenation.
When using a regenerated catalyst, the content of trans isomers in catalytically modified fats is approximately equal to the decrease in the content of linoleic acid (Table 6): $T = L_o - L$.

Table 6 Trans-isomerization during the hydrogenation of cottonseed oil on a regenerated catalyst "Nysosel-800"
(Trans=L_o – L, T = 200^{0}C, 0,08% Ni)

Indicators	Iodine number of salomas			
	80	71	67	63
Melting temperature, ^{0}C	24	26	32	36
Hardness, g/cm	-	-	180	180
L, %	22	17	12	6
(L_o – L)	32	37	42	48
Trans, %	7	9	13	17

Conclusions

The conditions under which the hydrogenation process can be directed along the path of the least formation of trans isomers are low process temperature, high hydrogen pressure and low catalyst concentration in the feedstock.

To produce hydrogenated fats with a low content of trans isomers, it is necessary to change the technological regime of the hydrogenation process, suppress diffusion inhibition of the reaction (hydrogen), transferring it to the kinetic region. For this purpose, it is advisable to use batch autoclaves with an increased rotation speed of the mixing device (more than 120 rpm) at increased hydrogen pressure.

Technological parameters at which the formation of trans isomers is minimal (high hydrogen pressure, high stirring speed, low catalyst concentration) when used together will lead to the production of non-selectively hydrogenated lard with a high content of saturated glycerides, a high melting point and a low content of unsaturated fatty acids. Such lard contains practically no trans isomers, but cannot be directly used for the production of the fatty base of margarine.

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