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Comparative Analysis of the Physiological Value of Lecithins Obtained From Different Types of Raw Materials

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Abstract
The article provides comparative data describing the chemical composition and characteristics of the physiologically functional properties of the lecithins derived from plant and animal raw materials. The results of the clinical studies of the sunflower lecithin are presented, which show its hepatoprotective lipid-lowering and antioxidant properties. The quick and beneficial impact of the sunflower lecithin on lipid exchange, lipid peroxidation processes allows this type of lecithin to be seen as a promising tool for the prevention and comprehensive treatment of a range of diseases in the pathogenesis of which the above processes are being violated.
Keywords: lecithin, phospholipids, chemical composition, physiologically functional properties.

INTRODUCTION

Lecithin is the commercial name of the lipid complex with a preponderance of phospholipids that meets the established requirements [1].

Phospholipids are the substances contained in cells of all living organisms performing vital functions related to the regulation of metabolic processes and protection of cell membranes. As part of the cellular membrane, phospholipids regenerate them, influencing the biological activity of membrane proteins and receptors, play a crucial role in the activation of enzymes, and regulate many metabolic processes, including the transformation of fatty substances, providing lipid exchange [2, 3].

A schematic representation of the structure of the cell membrane is presented in Figure 1.

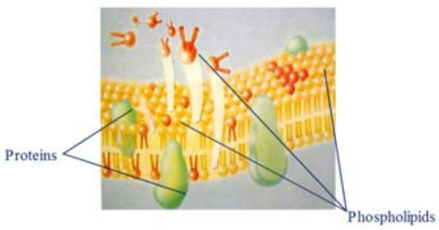

Figure 1 – Cell membrane structure [4]

The phospholipid molecule is shown in Fig. 2.

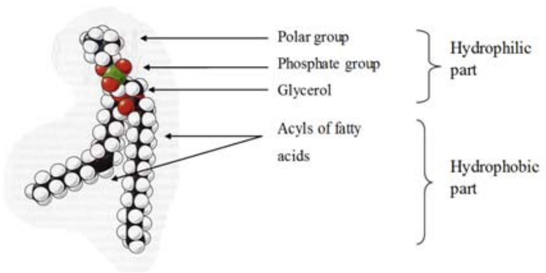

Figure 2 – Structural formula of the phospholipid molecule [1]

The main physiologically functional properties of lecithins are determined by the group composition (type of a polar group) and fatty acid composition (types of acyls of fatty acids), phospholipid molecules. These indicators also identify the major differences of lecithins from different types of raw materials.

The chicken eggs and oilseed plants are the primary sources of lecithin [1].

Currently, the animal-based lecithin is mainly used in pharmaceutical technologies and the plant-based lecithin - in food technologies. In view of the growing interest in the natural lecithin, a comparative research has been carried out on the composition of the components that define the physiological functional properties of animal- and plant-based lecithin.

MATERIALS AND METHODS

The subjects of the study were the samples of powder sunflower lecithin and egg lecithin of Russian origin, as well as a sample of foreign powder soybean lecithin.

The composition of fatty acid acyls of lecithins was determined according to GOST R 51486 using a Cristall-5000 gas chromatograph (ZAO SKB "Khromatek", Russia), a SOLGEL-WAX column 30m × 0.32mm ID SOLGEL-WAX × 0.5µm (GOST 31663, GOST 31665). The group composition of phospholipids was studied by HPLC method using the Agilent 1260 Infinity high-performance liquid chromatograph (Agilent Technology, USA), a LiChrospher 100 250x4 mm column, Diol (5 µm) according to the methods [5, 6].

The content of unsaponifiable substances and their composition were determined by the method [7].

The content and composition of the tocopherols were determined in accordance with GOST EN 12822.

The effect of lecithin on the stability to oxidation of refined deodorized sunflower oil was studied in accordance with

GOST 31758, using the Rancimat 743 apparatus (Metrohm, Switzerland).

The content of metals was determined on an Agilent 240FS atomic adsorption spectrometer with a GTA chamber and the VGA-77 attachment for generation of hydrides.

All experiments were performed at least in triplicate. The results were evaluated using modern methods of static reliability calculation using Statistica 13.0, Microsoft Office Excel 2016, and Mathcad. The level of confidence was 0.95.

The research was carried out on the equipment of the CCU (Centre of collective usage) "Research Center for Food and Chemical Technologies", FSBEI HE (Federal State Budgetary Educational Institution of Higher Education) "Kuban State Technological University".

RESULTS AND DISCUSSION

In the egg, phospholipids are found mainly in the yolk, where they are mainly bound to complexes with proteins (mainly with vitellin), carbohydrates and cholesterol.

In the seeds of oil plants, phospholipids are part of the lipid complex and are extracted together with neutral lipids (oil).

The average data characterizing the group composition of phospholipids found in lecithins obtained from various types of raw materials are presented in Table 1.

It is clear from the data presented that the egg lecithin is characterized by the highest content of phosphatidylcholines - a group of phospholipids with the widest spectrum of physiological action, including those exhibiting pronounced hypocholesterolemic, hypolipidemic and hepatoprotective properties.

Along with the phosphatidylcholines, the content of which is somewhat higher in sunflower lecithin as compared to soybean lecithin, an important indicator of the biological activity of phospholipids is the ratio between phosphatidylcholines and phosphatidylethanolamines, which affects the structural features and interaction of phospholipid molecules. Higher values of this ratio in sunflower lecithin in comparison with the soybean one indicate its greater biological activity.

This conclusion is corroborated by the studies of the Institute of Biomedical Chemistry of the Russian Academy of Medical Sciences, which showed that the phospholipids of sunflower seeds, compared to phospholipids of soybean seeds, have a significantly higher degree of hepatoprotective effect, which consists in a more active regenerative action on biological membranes, in particular, on the membranes of hepatocytes.

It is worth noting the high content of phosphatidylinositols in the sunflower lecithin, a group of phospholipids showing important physiologically functional properties, the specificity of which is the subject of study of modern medicine.

The composition of fatty acid acyls present in lecithins obtained from different types of raw materials is presented in Table 2.

Table 1 - Group composition of lecithins

Name of phospholipid groups	The content of phospholipid groups, % to the amount		
	Egg lecithin	Soybean lecithin	Sunflower lecithin
Phosphatidylcholines (PC)	71	34	36
Phosphatidylethanolamines (PE)	18	26	17
Phosphatidylinositols (PI)	1	19	24
Phosphatidylserines (PS) and Lysophosphatidylethanolamines(LPE)	traces	traces	traces
Phosphatidic acids (PA)	3	4	4
Phosphatidylglycerols (PG) and Diphosphatidylglycerols (DPG)	3	9	14
Polyphosphatidic acids (PPA)	absent	8	5
Sphingomyelins (SM)	4	absent	absent
Ratio of PC/ PE	3.9:1.0	1.4:1.0	2.1:1.0

Table 2 - Fatty acid composition of lecithins

Name of fatty acids	Fatty acids content,% of the amount		
	Egg lecithin	Soybean lecithin	Sunflower lecithin
Myristic $C_{14:0}$	Abs.	0.1	0.1
Palmitine $C_{16:0}$	26.0	22.0	19.0
Stearic $C_{18:0}$	14.0	4.6	3.6
Arachidonic $C_{20:0}$	Abs.	0.2	0.3
Behenic $C_{22:0}$	Abs.	0.4	1.1
Lignoceric $C_{24:0}$	Abs.	0.4	0.4
Σ S	**40.0**	**27.7**	**24.5**
Palmitoleic $C_{16:1}$	Abs.	0.1	0.1
Oleic $C_{18:1}$ (ω_9)	36.0	10.7	14.6
Linoleic $C_{18:2}$ (ω_6)	15.0	55.4	60.4
Linoleic $C_{18:3}$ (ω_3)	1.0	6.0	0.2
Eicosenoic $C_{20:1}$	Abs.	0.1	0.2
Arachidonic acid $C_{20:4}$ (ω_6)	5.0	Abs.	Abs.
Docosahexaenoic acid $C_{22:6}$ (ω_3)	3.0	Abs.	Abs.
Others	-	-	-
Σ US	**60.0**	**72.3**	**75.5**

Table 3 – **Composition of concomitant substances and minor components of lecithins**

Indicator Name	Indicator Value		
	Egg lecithin	Soybean lecithin	Sunflower lecithin
Content of unsaponifiable lipids,%, including:	1.5	1.7	2.0
cholesterol	0.5	absent	absent
phytosterols	absent	0.2	0.6
carotenoids	0.6	$5.0x10^{-2}$	$1.0x10^{-3}$
chlorophylls	absent	$0.12x10^{-3}$	absent
Content of tocopherols, m g%: including:	130	95	50
α-tocopherol	85	14	43
β-tocopherol	9	absent	7
γ-tocopherol	22	67	absent
δ-tocopherol	14	14	absent
Content of metals, mg / kg, including:			
Fe	1.8	0.4	0.6
Cu	0.7	0.3	0.4
Mg	38	170	380
Ca	150	900	940
K	560	560	2040
Na	450	940	910

As can be seen from the data presented, the egg lecithin is different from the sunflower and soybean one by a high content of saturated fatty acids related to atherogenic nutritional factors.

A positive difference between the egg lecithin is the presence in the fatty acid content of physiologically active arachidonic and docosahexaenoic fatty acids, the shortage of which leads to the emergence and development of various pathologies, which is especially important for tender aged children. It should be noted that arachidonic acid is a substitute and is synthesized in the body from irreplaceable linoleic acid, whereas docosahexaenoic acid is indispensable and enters the body only with food. Despite this fact, the main sources of docosahexaenoic acid are not the egg lecithin, but the fats of the marine fish. However, this is one of the factors leading to the predominant use of egg lecithin in the production of drugs for tender aged children.

It should be noted that, in addition to the high cost of egg lecithin, due to the cost of raw materials and to the high cost of its production, the widespread use of egg lecithin is constrained by the risk of potential microbiological pollution. It should be remembered that the low cost of commodity forms of egg lecithin is always associated with a high risk of its microbiological load.

The soybean lecithin is characterized by a large amount of linolenic acid related to the ω_3 class of antiatherogenic fatty acids. This physiologically benign fact at the same time determines the lower stability of soybean lecithin for oxidizing and defines specific requirements for the technology of production and storage conditions.

Sunflower lecithin differs from soybean one by a large amount of oleic and linoleic acids. This characterizes the rather high physiological value of this type of lecithin since mono-ene ω_9 acids contribute to reducing the risk of cardiovascular disease, and linoleic acid is the essential one.

An important aspect of the physiological value of lecithins is the positional distribution of acyls of fatty acids in the molecule of phospholipids.

Thus, the presence of two acyls of linoleic acid in the molecule of phosphatidylcholine is the key factor determining the activity of such phosphatidylcholine in the normalization of membrane disorders and in leveling the associated diseases when introduced into the body. In addition, there are evidences in the scientific literature that phosphatidylcholines with two acyls of linoleic acid show pronounced antioxidant, anti-inflammatory, antifibrogenic and other physiologically functional properties. According to the data of [8], the content of phosphatidylcholines with two acyls of linoleic acid in soybean lecithin averages 40.6%, and in sunflower - 64.2%, which indicates a greater physiological value of the latter.

The results of studying the composition of the concomitant substances and minor components of lecithins are presented in Table 3.

The data presented in table 3 show one of the main differences between plant-based lecithins and egg lecithin, which is included in sterols, which are present therein along with phospholipids: egg lecithin contains cholesterol and plant phytosterols. The presence of cholesterol in combination with a high content of saturated fatty acids reduces hypocholesterolemic and antiatherogenic properties of egg lecithin and may be contraindicated for use by individuals with elevated cholesterol.

However, the favorable ratio of phospholipids and cholesterol from 5:1 to 6:1 ensures a reduction in the atherogenic properties of the cholesterol contained in the egg yolk compared to other animal fats.

Unlike cholesterol, phytosterols have anti-atherogenic properties, so their high (compared to soybean lecithins) presence in the sunflower lecithin explains the hypocholesterolemic and antiatherogenic properties inherent to it.

The presence of soybean lecithin in the composition of unsaponifiable lipids, an increased content of pigments (carotenoids and chlorophylls) often necessitate the bleaching process with the use of hydrogen peroxide in the production of marketable products, which negatively affects its physiological value. In addition, the presence of chlorophylls with prooxidant activity is undesirable in terms of food value and the stability of finished goods during storage.

The data on the composition of the mineral components of plant-based lecithins presented in Table 3 show a significant predominance of bioavailable potassium and magnesium in the composition of sunflower lecithin, which is favorable for persons suffering from cardiovascular diseases [9].

When making a comparative analysis of the physiological values of plant lecithin, one cannot help but assess the risks associated with the use of raw materials that underwent genetic modification.

In the world practice, the soybean is the traditional raw material for the production of plant-based lecithin, which is why the vast majority of the foreign-made lecithins represented on the consumer market of the Russian Federation and customs union countries are derived from the soybean seeds.

Recently, more than 95% of the soybeans have been obtained using genetic engineering techniques. This forces major producers of phospholipid-containing products (lecithins and dietary supplements on their basis) to look for new raw materials, as evidenced by the growing demand from European producers for sunflower lecithin, the main producer of which is Russia.

The results of clinical trials of powder sunflower lecithin, conducted at the Institute of Nutrition of RAMS (Moscow), as well as in medical institutions in Moscow, Tyumen, Krasnodar showed that it had pronounced lipid-lowering, hypocholesterolemic, membrane-protective and antioxidant effects [10].

The mechanism of hypolipemic action of sunflower lecithin is primarily associated with the participation of its constituent phospholipid molecules in the modification of cell membranes, in particular, in processes that increase the degree of their "undersaturation" and, thus, change their physicochemical characteristics and biological properties [11]. This implies another possible mechanism for the hypolipemic action of sunflower lecithin, mediated through the effect of prostaglandins, prostacyclins, leukotrienes, the precursors of the synthesis of which are PUFAs omega-6 as one of the structural components of phospholipid molecules.

Taking into account the data on the ability of sunflower phospholipids to inhibit lipid peroxidation (LPO) processes in platelets, sunflower lecithin can be considered as an effective tool in the complex treatment of diabetes mellitus [12, 13]. Taking into account the fact that the lipid disruption is one of the major complications of diabetes mellitus, expressed hypolipidemic activity of the lecithin makes it a promising tool for use in prevention and treatment of complications associated with various forms of diabetes.

The hepatoprotective properties of the sunflower lecithin are due to the fact that, in the pathology of the liver, its molecules prevent dystrophic changes in hepatocytes and the formation of necrosis, and also enhance the repair processes even more than soybean ones.

A survey of chronic pancreatitis patients performed in the Republican Center for Functional Surgical Gastroenterology (Krasnodar) showed that as a result of the intake of 6 g powder lecithin twice during 16 days, the majority of patients showed a positive trend in the clinical picture of the disease, a decrease in the cholesterol in the blood by 22.1%, triglycerides - by 19.7%, diene conjugates - by 13.8%. However, there had been a decrease in the hexachlorocyclohexane in blood by 52.3%, which was associated with a positive effect on the functional state of the liver and bile ducts and an increase in the elimination of pesticides with bile. In the comparison group, receiving only symptomatic treatment without sunflower lecithin, this effect was significantly less pronounced.

There is experience with the use of powdered sunflower lecithin in the sanatoriums and resorts of Sochi, Gelendzhik, and Anapa. Positive results were noted when using sunflower lecithin in comprehensive treatment for diseases of the gastrointestinal tract ("Metallurg" sanatorium, Sochi), in comprehensive general health programs (F. Dzerzhinsky sanatorium, and "Rus" sanatorium in Sochi).

The quick and beneficial impact of the sunflower lecithin on lipid exchange, lipid peroxidation processes allows this type of lecithin to be seen as a promising tool for the prevention and comprehensive treatment of a range of diseases in the pathogenesis of which the above processes are being violated.

It should be noted that an important advantage of natural exogenous phospholipids is their affinity with endogenous ones. The results of toxicological studies of natural phospholipids cited in the scientific literature indicate a complete absence of toxicity, both at high single doses and for long, up to one year, periods of intake. There is a lack of embryotoxicity, perinatal and postnatal toxicity, as well as the absence of mutagenic and carcinogenic risks [3, 9, 11].

Thus, sunflower lecithin obtained by domestic enterprises can be considered as a promising independent food ingredient, as well as raw material for obtaining comprehensive physiologically functional food ingredients and pharmaceutical preparations.

CONCLUSION

Plant-based lecithins contain significantly fewer phosphatidylcholines - a group of phospholipids with the widest spectrum of physiological action, including those exhibiting pronounced hypocholesterolemic, hypolipidemic and hepatoprotective properties.

The content of phosphatidylcholines in sunflower lecithin slightly exceeds their content in soybean lecithin. The ratio between phosphatidylcholines and phosphatidylethanolamines, which affects the structural features and interaction of phospholipid molecules, is higher in sunflower lecithin, which can be considered as evidence of its greater biological activity.

Sunflower lecithin is distinguished by a high concentration of phosphatidylinositols, a group of phospholipids showing important physiologically functional properties, the specificity of which is the subject of study of modern medicine.

The egg lecithin is different from the sunflower and soybean one by a high content of saturated fatty acids related to atherogenic nutritional factors. However, in the composition of fatty acids, there are physiologically active arachidonic and docosahexaenoic fatty acids, the shortage of which leads to the emergence and development of various pathologies, which is especially important for tender aged children.

A distinctive feature of sunflower lecithin is a greater content of oleic and linoleic acids therein. This characterizes the rather high physiological value of this type of lecithin since mono-ene ω_9 acids contribute to reducing the risk of cardiovascular disease, and linoleic acid is the essential one.

The increased (in comparison with soybean lecithin) presence of phytosterols in sunflower lecithin explains the inherent pronounced hypocholesterolemic and antiatherogenic properties.

The composition of mineral elements of sunflower lecithin is characterized by a high content of bioavailable potassium and magnesium, which is favorable for people suffering from cardiovascular diseases.

The results of clinical trials of powder sunflower lecithin, conducted at the Institute of Nutrition of RAMS (Moscow), as well as in medical institutions in Moscow, Tyumen, Krasnodar showed that it had pronounced lipid-lowering, hypocholesterolemic, membrane-protective and antioxidant effects [10].

Based on the studies conducted, it can be concluded that sunflower lecithin obtained by Russian enterprises can be considered as a promising independent food ingredient, as well as raw material for obtaining comprehensive physiologically functional food ingredients and pharmaceutical preparations.

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