

Представлено науково-технологічне обґрунтування складу структурованих оболонок капсульованих олій, які можуть бути представлені оліями, жирами, сумішами жирівими. Обґрунтування параметрів одержання оболонок таких систем визначає технологічний цикл виробництва продукту та роботи авторського обладнання. Обґрунтування складу та властивостей оболонки капсульованих олій закладає передумови промислового виробництва продукту, що дозволяє розширити асортимент олієжирової сировини, заправок

Ключові слова: ліпіди, капсула, оболонка, альгінат натрію, пакування, сферифікація, капсулювання, напівфабрикат, полісахариди

Представлено научно-технологическое обоснование состава структурированных оболочек капсулированных масел, которые могут быть представлены маслами, жирами, смесями жирными. Обоснование параметров получения оболочек таких систем определяет технологический цикл производства продукта и работы авторского оборудования. Обоснование состава и свойств оболочки капсулированных масел закладывает предпосылки промышленного производства продукта, что позволяет расширить ассортимент масложирового сырья, заправок

Ключевые слова: липиды, капсула, оболочка, альгинат натрия, упаковка, сферификация, капсулирование, полуфабрикат, полисахариды

FOUNDATION OF TECHNOLOGY FOR OBTAINING ENCAPSULATED OILS AND PRESCRIPTION DEVELOPMENT OF SHELLS ON THEIR BASIS

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1. Introduction

In recent years, there has been a strong trend of increasing demand for healthy food and use of convenience food for the production of culinary products with a balanced composition. To a certain extent, this applies to oil and fat raw materials.

Expansion of the range of food containing oil and fat raw materials is due to adjustment of their nutritional value. This opportunity is provided by the developed technology of encapsulated oil and fat raw materials.

Development and implementation of oil encapsulation technology have marketing appeal because of the unique commodity form of oil and fat raw materials in the market, innovative appeal for the fat and oil industry and functionality in terms of technological use in the production of culinary products in the catering and food industry. Besides traditional commodity forms of vegetable oils and fats and gelatin capsules, the shells of which are not sustainable in process streams at high temperatures and prohibited in the Muslim countries for religious reasons, other types of fat products in the market are not found.

Industrial production of hydrophobic systems requires scientific substantiation of process parameters and prescription of shells of encapsulated oils.

Encapsulated oils can be used as a standalone product, convenience food, decorative element in business processes B2C, B2B and in the production process of culinary, bakery

and pastry dishes. First of all, encapsulated oils are used for public catering.

2. Literature review and problem statement

Present public consciousness is characterized by strengthening of the idea of a healthy lifestyle, including balanced nutrition principles [1–5]. The international nutrition policy focuses not only on meeting the population needs in some foodstuff, but also ensuring the balance of the main nutrients.

Today, vegetable oils are mostly presented by refined oils in the liquid state (bulk oils) and in the firm state. Their fatty acid composition is not balanced for important PUFAs, SFAs, phospholipids, sterols, vitamins and so on.

In the food industry, industrial enterprises, technologies are developed that adjust packaging materials to pack food products in an individual edible consumer container by the weight that corresponds to a daily intake and meets consumer needs for catering and services, including airline, office meal, fast food and catering [6, 7].

One of the areas of functioning of innovative food technologies is encapsulation, which would eliminate the narrowed use of fat combinations in technological processes on the basis of physiological properties. The foods produced by this technology can be used as an “immiscible” component or decor of dishes.

A promising direction is processing of oil and fat raw materials into the encapsulated form with a thermostable shell based on ionotropic polysaccharides. This method will expand the range of oil and fat raw materials, ensure their intactness in the food production process, develop a new commodity form, functional and technological properties of which will help to solve numerous technological problems in the industry. The oil encapsulation technology requires the manufacture of the author's equipment, which confirms the innovation of a product. This will allow creating an entirely new food segment and stimulate the development of food technologies. Thus, in view of various functional-physiological and functional-technological properties of oil and fat raw materials that have made them important components of many food products, development of economically feasible oil encapsulation technology, which would meet all modern requirements is a relevant issue. The literature [6, 8] provides little information on the technologies of oil encapsulation in thermostable polysaccharide shells. While the rapidly growing, high-performance food industry dictates the trends, taking leading positions in the formation and increase of the export potential of Ukraine's economy.

There are technologies of vegetable oils, fats in the encapsulated form, differing in the way of production, which are inherent mainly in the pharmaceutical industry [9, 10]. First of all, these are enriched oil and fat fillers in gelatin capsules [9–12]. It is known that gelatins form non-thermostable gels, which at a temperature above the melting point pass into the solution of HMWC (high molecular weight compounds). So, the use of such oil and fat capsules in hot appetizers, warm salads and products that are subjected to heat treatment is impossible.

Modern encapsulation methods enable encapsulation of both hydrophilic and hydrophobic materials, and provide encapsulated products with various dimensional characteristics.

There is a method of producing encapsulated oil and fat raw materials through vertical coaxial extrusion. To date, such encapsulation method is limited due to the complex implementation and parameters of the process [9].

Patent search [11, 13, 14] shows that mainly vegetable oil can be processed into the encapsulated product with a given diameter using gelling agents. This technology cannot be implemented without hardware equipment and has a number of restrictions on the purpose and use of this product or semi-finished product in food technologies. The disadvantages of the specified methods include the use of gelatin solution as a shell, the gel of which is not thermostable, resulting in the non-thermostable capsule shell [11].

The method [11, 13] of obtaining the thermostable capsule with the thermostable shell is given. But the drawbacks include the inability to obtain capsules with fat-based contents, such as oils, molten fat or inverse emulsion because the fat component in these capsules must be in the form of a phase in an aqueous dispersion medium.

Development of technology of encapsulated products using seaweed polysaccharide – sodium alginate (AlgNa) has expanded the range of application of oil and fat capsules in the form of fillers. In addition, encapsulated oils can be used as therapeutic food products, which provide controlled release of the capsule contents in the needed area of the gastrointestinal tract [15].

Scientists have extensive experience [8, 14, 16, 18] in the use of AlgNa in encapsulation technologies. Therefore, it is essential in substantiation of the oil encapsulation technology.

3. Goals and objectives

The goal of the paper is scientific substantiation of the composition of shells in the oil encapsulation technology, which will allow obtaining an industrial product in industrial conditions.

To achieve the goal, it is necessary to solve the following problems:

- scientific substantiation of the parameters of the oil encapsulation technology on the author's device;
- substantiation of the prescription of shells of encapsulated oils.

4. Materials and methods

Determination of scientific and practical prerequisites for the encapsulation process application in the technology of encapsulated hydrophilic food systems, which include the analysis of the production aspects of and properties of the final product is necessary.

The materials and methods of experimental research are presented in detail in [19].

5. Implementation of the oil encapsulation technology in the production cycle

The oil encapsulation technology lies in the balanced coaxial extrusion of AlgNa solution and oil-and-fat raw materials into the two-layer receiving medium, consisting of a layer of refined deodorized sunflower oil and a layer of a water-alcohol solution of Ca^{2+} ions.

The capsule production process involves the transition of capsules from quasi-stable state to a thermodynamically stable state (Fig. 2). This is achieved through the implementation of chemical potentials, performed in the lower aqueous phase of the complex receiving medium, which incorporates an ionotropic gelation mechanism. Due to the chemical interaction of AlgNa, a component of the solution of shells of quasi-stable capsules, with divalent metal ions Ca^{2+} , a mandatory component of the lower aqueous phase of the two-layer receiving medium. Their interaction produces a lyophobic substance – Alg_2Ca , which is presented by the gel grid, and counter-ions – 4Na^+ : (2), (3) [18]:



Despite the objectivity of the course of the chemical reactions (2) and (3), mixing of the two substances may provide different (in strength, elasticity, fragility, permeability) gels, corresponding to different degrees of saturation of the acceptor n (Alg) by Ca^{2+} ions, the donor of which is the receiving medium in properties of gels or systems in the form of porous bodies. The emergence of these structures can be

objectively proved according to basic laws of chemistry and thermodynamics.

6. Research of technological properties of prescription components of shells of encapsulated oils and their effects on the structural and mechanical properties of the final product

Implementation of the oil encapsulation technology in the two-layer receiving medium is defined by the consecutive interaction of “quasi-stable capsule” elements, which exists for some time in the two-layer receiving medium. Formation of the properties of the two-layer receiving medium, as a complex technological system, is subject to implementation of process parameters. Their coordination with process parameters of the quasi-stable capsule, the properties of interacting process blends is aimed at the formation of the desired product.

The main process solution that forms the capsule walls is AlgNa solution, which, in terms of gravitational penetration into the receiving medium, is represented by the total value of the capsule density (ρ_c), which will be determined by the formula (4) and depend on the mass ratio of a hydrophobic phase (e. g. sunflower oil) and AlgNa aqueous solution phase:

$$\rho_c = \frac{\rho_{s.o.} \cdot V_{s.o.} + \rho_w \cdot V_w}{V_c} \tag{4}$$

where $\rho_c, \rho_{s.o}, \rho_w$ – the density of the capsule, sunflower oil, wall; $V_{s.o.}, V_w, V_c$ – the volume of sunflower oil, wall, capsule.

The capsule wall density is a complex value and is calculated as follows:

$$\rho_w = \frac{1}{2}(\rho_w + \rho_{AlgNa}) \tag{5}$$

The analysis of the expressions (4), (5) shows the predicted value of ρ_c , which will meet the following condition:

$$\rho_{s.o.} |V_{s.o.=0} \leq \rho_c \leq \rho_w |V_{w=0} \tag{6}$$

Existence of spherical capsules is possible when extreme values of the inequality $V \neq 0$. It is clear that the value of ρ_c physically will be:

$$926.0 \text{ kg/m}^3 \leq \rho_c \approx 998.23 \text{ kg/m}^3 \tag{7}$$

Under these conditions, the “sunflower oil – Ca^{2+} water-alcohol solution” interface of the two-layer receiving medium is only possible with an effective surfactant as the interfacial tension with equal phase density values of the two-layer medium prevents immersion of the quasi-stable capsule from sunflower oil to the aqueous phase of the receiving medium.

To implement the oil encapsulation technology, it is appropriate to increase ρ_c by involving a third substance with $\rho \gg \rho_c$, which must be introduced into one of the capsule phases. White sugar ($\rho_{\text{white sugar}} = 1580.0 \text{ kg/m}^3$) can be introduced into AlgNa solution, which can form a molecular solution in water, without changing the chemical potential of the AlgNa-based system.

Obviously, the factors influencing the capsule density are also concentrations of AlgNa, white sugar and “capsule wall/sunflower oil” phase ratio.

The gravitational transition of the capsule to the formation zone through the “sunflower oil – Ca^{2+} water-alcohol solution” interfacial layer is possible by increasing the mass of the capsule as a growth regulator of ρ_c . This can be achieved by introducing the third substances, including white sugar, to the shell. According to Table 1, $\rho_{\text{AlgNa solution}} = f(C_{\text{white sugar}})$ this way is promising in terms of gravitational processes, since the density in the $0.01\% < C_{\text{white sugar}} < 40.0\%$ concentration range increases by 1.23 times.

Table 1

Dependence of AlgNa solution density on white sugar concentration at $t=20^\circ\text{C}$

$C_{\text{white sugar}}$ in 1.0 % AlgNa aqueous solution, %	$\rho_{\text{AlgNa solution}}$, kg/m^3	$\Delta\rho = \rho_{\text{AlgNa solution}} - \rho_{s.o.}$, kg/m^3
0.01	997.0	71.0±0.1
5.0	1019.0	93.0±0.2
10.0	1038.0	112.0±0.5
15.0	1054.0	128.0±0.5
20.0	1080.0	154.0±1.0
25.0	1104.0	178.0±1.5
30.0	1126.0	200.0±1.5
35.0	1148.0	222.0±2.0
40.0	1176.0	250.0±2.0

Table 2

Dependence of aqueous solution density on AlgNa concentration at $t=20^\circ\text{C}$

C_{AlgNa} in aqueous solution, %	$\rho_{\text{AlgNa solution}} \times 10^{-3}$, kg/m^3
0.0	998.07
0.1	998.17
0.2	998.27
0.3	998.37
0.4	998.47
0.5	998.57
0.6	998.67
0.7	998.77
0.8	998.87
0.9	998.97
1.0	999.07
1.1	999.17

The capsule density depends on the density of certain raw materials, which are capsule-formation participants, and their weight percentage (wt. %). To substantiate the white sugar introduction into the capsule shell, the capsule density from wt. % at white sugar concentration of 0.01...40.0 % and temperature of $t=20^\circ\text{C}$ are calculated (Table 3).

Table 3 shows that the most effective parameter of the capsule density variation is the white sugar concentration increase, since a significant increase in C_{AlgNa} is impossible due to increased viscosity, and, as a result, extrusion, and adjustment of the properties by the phase ratio (Table 3 – column 1) of encapsulation is limited by organoleptic evaluation indicators. The assumption about the use of white sugar is also confirmed by the possibility of diffusion depletion of walls from white sugar during washing (soaking) of the capsules formed in the water prepared within a reasonable time.

Table 3

Dependence of the capsule density ($t=20\text{ }^{\circ}\text{C}$) on the capsule phase ratio at $C_{\text{white sugar}}=5.0\text{--}40.0\text{ }\%$

Capsule content phase ratio – AlgNa/oil (m^3/m^3)	ρ of quasi-stable capsules, kg/m^3								
	$C_{\text{white sugar}}$ 0.0 %	$C_{\text{white sugar}}$ 5.0 %	$C_{\text{white sugar}}$ 10.0 %	$C_{\text{white sugar}}$ 15.0 %	$C_{\text{white sugar}}$ 20.0 %	$C_{\text{white sugar}}$ 25.0 %	$C_{\text{white sugar}}$ 30.0 %	$C_{\text{white sugar}}$ 35.0 %	$C_{\text{white sugar}}$ 40.0 %
1	2	3	4	5	6	7	8	9	10
5/95	929.6*	930.6	931.6	932.4	933.7	934.9	936.0	937.1	938.5
10/90	933.2	935.3	937.2	938.8	941.4	943.8	946.0	948.2	951.0
15/85	936.8	939.9	942.8	945.2	949.1	952.7	956.0	959.3	963.5
20/80	940.4	944.6	948.4	951.6	956.8	961.6	966.0	970.4	976.0
25/75	944.0	949.2	954.0	958.0	964.5	970.5	976.0	981.5	988.5
30/70	947.6	953.9	959.6	964.4	972.2	979.4	986.0	992.6	1001.0
35/65	951.2	958.5	965.2	970.8	979.9	988.3	996.0	1003.7	1013.5
40/60	954.8	963.2	970.8	977.2	987.6	997.2	1006.0	1014.8	1026
45/55	958.4	967.8	976.4	983.6	995.3	1006.1	1016.0	1025.9	1038.5
50/50	962.0	972.5	982.0	990.0	1003.0	1015.0	1026.0	1037.0	1051.0

Note: * – irrational density values

The oil encapsulation technology is implemented by interaction of chemical potentials of the system. So, introduction of white sugar, which changes the molecular structure when added to the solution, can significantly alter the structural and mechanical properties of the final gel grid of the capsule walls. Under these conditions, the properties of Alg_2Ca gels will be due to the properties of a third substance in the solution. Dilution of the “AlgNa – water” system with white sugar may change the organoleptic characteristics in terms of taste and the gel shell elasticity at equal conditions, as well as intensity and patterns of gelation. Therefore, there is the problem of determining the patterns of formation of elastic properties of shells at constant AlgNa content in the system, but at different white sugar contents. Since the white sugar introduction artificially leads to a relative increase in the AlgNa concentration in the system solvent, model systems without white sugar with high AlgNa content (Table 4) are developed to determine the white sugar effect on the properties of gels. Recalculation of the concentrations allows comparing the rheological values of the structured systems with the equimolecular ratios for AlgNa.

Table 4

Quantitative composition of
“water – AlgNa – white sugar” model systems

Sample No.	C, %		Water, %	Total, %
	AlgNa/white sugar (to water), % – (Fig. 1 (1))	AlgNa/water, % – (Fig. 1 (2))		
1 (control)	1.0*/0.0	1.0/99.0	99.0	100.0
2	1.1*/10.0	1.1/88.9	88.9	100.0
3	1.2*/20.0	1.2/78.8	78.8	100.0
4	1.3*/30.0	1.3/68.7	68.7	100.0
5	1.4*/40.0	1.4/58.6	58.6	100.0

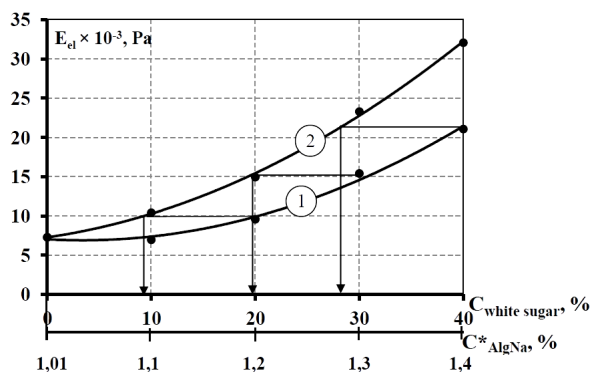


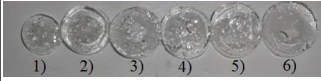
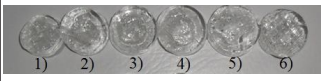
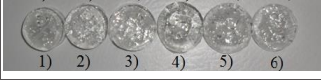

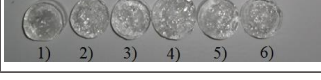
Fig. 1. Dependence of the elastic modulus (E_{el}) of model systems at the Ca^{2+} ion concentration of 0.048 % and AlgNa concentration of 1.0 % in the system at the white sugar content of 10.0...40.0 %: “water – AlgNa – white sugar” (1); “water – AlgNa” (2); C^*_{AlgNa} – specific value

Comparison of instantaneous elasticity moduli of model systems “water – AlgNa – white sugar” – curve 1, “water – AlgNa” – curve 2 (Fig. 1) has confirmed the increase of the elastic properties with an increasing AlgNa concentration with respect to water and formation of a more rigid gel (curve 1, Fig. 1) with an increase in white sugar. Thus, the concentration of solids, namely white sugar, is important in the AlgNa solution prescription. Model Alg_2Sa gels with a concentration of 20.0...40.0 % correspond to the range of instantaneous elasticity modulus ($E_{el}=10.0\text{--}21.5$) $\times 10^3$ Pa.

Comparison of dependencies of two built trend lines 1, 2 suggests that the actual white sugar content of 40.0 % affects the properties of the gel grid and shows typical elastic properties of the gel in a pure solvent at the AlgNa concentration of $1.41\pm 0.05\text{ }\%$. Given the data obtained, it can be argued that with increasing AlgNa and white sugar concentrations, the alginate-calcium capsule shell forms a gel grid with relatively reduced elasticity indexes, and white sugar performs a plasticizing function relative to Alg_2Ca gel.

Table 5

Photomonitoring of the dynamics of dimensional characteristics of Alg_2Ca gel (1.0 % by AlgNa) a in water-alcohol medium

Parameters and conditions	Photomonitoring
$C_{\text{et}}=10$ vol. %; $\tau=1, 2, 3, 4, 5, 6 - (0..6) \cdot 3600$ s respectively	
$C_{\text{et}}=20$ vol. %; $\tau=1, 2, 3, 4, 5, 6 - (0..6) \cdot 3600$ s respectively	
$C_{\text{et}}=30$ vol. %; $\tau=1, 2, 3, 4, 5, 6 - (0..6) \cdot 3600$ s respectively	
$C_{\text{et}}=40$ vol. %; $\tau=1, 2, 3, 4, 5, 6 - (0..6) \cdot 3600$ s respectively	
$C_{\text{et}}=50$ vol. %; $\tau=1, 2, 3, 4, 5, 6 - (0..6) \cdot 3600$ s respectively	

Technological holding of capsules in the zones of influence of two-layer receiving medium is a prerequisite for the process. With a large contact area of two separate systems “capsule”, “medium phase”, there are changes in the properties of the system participants. In the presence of differences of the specific density of the shell gel and sunflower oil of the top phase of two-layer receiving medium, the sunflower oil penetration into the capsule wall will be observed. At the same time, the water-alcohol solution of Ca^{2+} will be characterized, probably, by dehydrating ability, which leads to phase density drop due to moisture release from the capsule walls with simultaneous changes in the properties of the shell. This requires identifying the patterns of these changes and taking them as process parameters. The impact of the medium is estimated by the mass variation of model systems when in the phase environment.

The impact of the receiving technological medium on the properties of walls is investigated in model systems by soaking Alg_2Ca gels ($C_{\text{AlgNa}}=1.0..1.5$ %) in the receiving media at the “gel: environment” ratio of 1:50 (100 g/g).

The mass dynamics of Alg_2Ca gel ($C_{\text{AlgNa}}=1.0..1.5$ %) at the stoichiometric ratio of Alg^- and Ca^{2+} in a water-alcohol solution (10–50 vol. %) for ethanol for understanding the sorption and desorption properties of Alg_2Ca when in different media is studied. The process parameters of encapsulated oil production are substantiated.

Fig. 2 shows the mass dynamics of Alg_2Ca gel ($C_{\text{AlgNa}}=1.0$ %) and ($C_{\text{AlgNa}}=1.5$ %) (Fig. 3) in the stoichiometric value depending on the ethanol concentration. The graph shows that the mass variation of Alg_2Ca gels is multidirectional. This is due to the property of ethanol to dehydrate watered gels at higher concentrations and facilitate solvation of gel-like systems at low concentrations. This effect is probably related to its ability to act as an expressed donor H^+ and acceptor OH^- of residues between ethanol and water molecules during their interaction. Therefore, the increased ethanol concentration in aqueous solution significantly increases the number of hydrogen bonds, and free water present in Alg_2Ca gel is extruded from the gel pores.

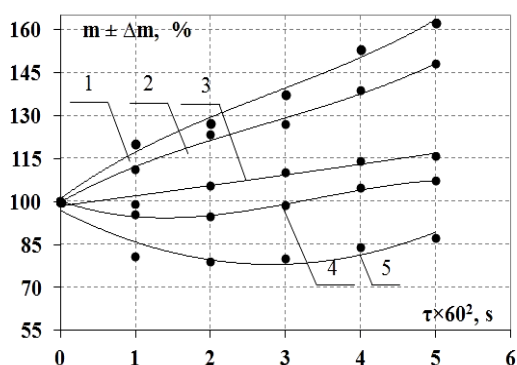


Fig. 2. Mass dynamics ($m \pm \Delta m$, %) of Alg_2Ca gel ($C_{\text{AlgNa}}=1.0$ %) in water-alcohol medium of Ca^{2+} at ethanol concentrations, vol. %: 1, 2, 3, 4, 5 – 10.0; 20.0; 30.0; 40.0; 50.0 respectively

Table 5 shows photomonitoring of the dynamics of dimensional characteristics of the Alg_2Ca gel samples ($C_{\text{AlgNa}}=1.0$ %; ($C_{\text{Ca}^{2+}\text{ions}}=0.048$ %) after holding them in a water-alcohol medium ($C_{\text{et}}=10, 20, 30, 40, 50$ vol. %).

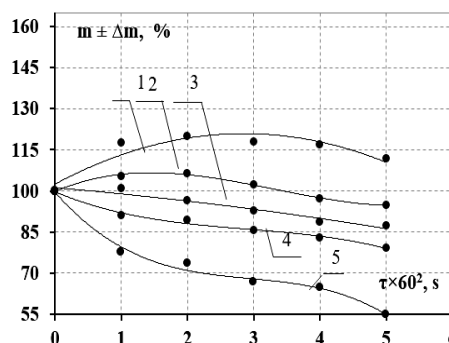


Fig. 3. Mass dynamics ($m \pm \Delta m$, %) of Alg_2Ca gel ($C_{\text{AlgNa}}=1.5$ %) in water-alcohol medium of Ca^{2+} at ethanol concentrations, vol. %: 1, 2, 3, 4, 5 – 10.0; 20.0; 30.0; 40.0; 50.0 respectively

Photomonitoring of dimensional characteristics of the samples proves the property of gels to lose free moisture formed during the chemical reaction. Table 5 shows that the Alg_2Ca gel samples with the same size and concentration of AlgNa , Ca^{2+} ions change their geometric shape under the influence of ethanol, indicating the removal of free moisture from the formed Alg_2Ca grid frame.

The laws of mass variation of the samples (Fig. 2, 3) make it clear that water and water-alcohol solutions do not provide constant dimensional characteristics of capsule-formation of oil raw materials and cannot be used as a storage medium without additional conditions.

Fig. 4 shows the curves that characterize the dynamics ($m \pm \Delta m$) of model Alg_2Ca gels at the AlgNa concentrations of 1.0 % and 1.5 %, which were soaked for $\tau=6 \cdot 3600$ s in sunflower oil at $t=20$ °C. The data show that the mass variation is characterized by low dynamics, due to the structure of the Alg_2Ca gels and their inability to release free moisture into a hydrophobic medium.

The study of the properties of the shell of encapsulated oils allows determining the parameters and conditions for obtaining the final product. It is determined that constant physical and organoleptic parameters of the finished product will be provided when using hydrophobic materials as the

storage medium for encapsulated oils at reasonable storage temperatures.

To substantiate the production operation of the oil encapsulation technology – “soaking for $\tau=6\cdot3600$ s in sunflower oil in Ca^{2+} water-alcohol medium”, it is necessary to determine the process parameters of the operation. It can be concluded that Alg_2Ca gel does not fundamentally change its properties during the technological and technical “path” of holding in Ca^{2+} water-alcohol medium.

Storage conditions of capsulated oils are scientifically substantiated. It is found that the product does not change its properties during storage and implementation with or without a fill, which can be a wide range of hydrophobic substances.

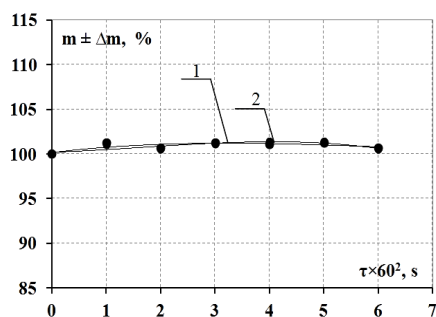


Fig. 4. Mass dynamics ($m \pm \Delta m$) of Alg_2Ca gel in sunflower oil at AlgNa concentrations, % 1 – 1.0; 2 – 1.5 respectively

7. Discussion of the results of science-based development of prescription of shells

The paper describes the system research of the functional properties of the system components, which are subject to encapsulation, “sunflower oil – AlgNa – CaCl_2 ”. The patterns of obtaining thermostable capsules containing sunflower oil raw materials by coaxial vertical extrusion in two-layer receiving medium are determined. Theoretical and experimental research on the development of the oil encapsulation technology, which consists in complex processing of vegetable oils are generalized. Prescription mixtures for

encapsulation and formation of the capsule shell in two-layer receiving medium are developed.

The controlled capsule-formation process by coaxial vertical extrusion on the author’s device provides an industrial product – encapsulated oil – with the desired properties and extended shelf life, characterized by thermal stability of the seamless edible packaging, intactness of the internal dosed oil component.

The use of encapsulated oils as convenience food in business processes B2B, B2C and food technologies of the catering industry allows creating a new segment of this group, which has an innovative approach to catering. Therefore, development of the intact, encapsulated sunflower oil technology and its implementation in modern food technologies can be a new trend.

Implementation of scientific principles within the oil encapsulation technology and science-based industrial encapsulation process (spherification) on the author’s device should also be presented by oil and fat raw materials enriched with polyunsaturated, saturated fatty acids, sterols, phospholipids, fat-soluble vitamins and the like.

8. Conclusions

1. The physical laws of the oil encapsulation technology are grounded. The parameters of the gravitational transition of the quasi-stable capsule to CaCl_2 water-alcohol solution of the two-layer receiving medium on the author’s device are determined. The physical characteristic of the capsule should be greater than the density of the receiving medium, which is expressed in the ratio of the capsule shell and the internal sunflower oil component ($\rho=926.0 \text{ kg/m}^3$).

2. The analytical study of the “capsule – receiving medium” system scientifically proved the conditions of the oil encapsulation technology – the overall capsule density, two-layer receiving medium density, the interface of the two-layer receiving medium. The composition of shells of encapsulated oils is grounded. It is determined that at the white sugar concentration $C_{\text{white sugar}}=23.0\%$, capsules are characterized by elasticity ($E_{el}=11.0 \cdot 10^3 \text{ Pa}$) and constant organoleptic characteristics of the product during storage.

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