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Optimization of Nano encapsulated corn tassel extract by response surface methodology and evaluation of the properties of Nanoencapsules containing extract stabilized by basil seed gum and combination of basil seed gum and sesame protein isolate

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ABSTRACT

In this study, basil seed gum (BSG) alone, and in combination with sesame protein isolate (SPI) were used in ratios 1:0 and 1:1 in order to encapsulate corn tassel extract (CTE) using the response surface method in the central composite design template was used. Also, the quadratic equation was used to optimize and investigate the effect of the concentration of corn tassel extract and homogenization time on the response of particle size and efficiency. At first, total phenolic content (TPC), antioxidant activity and antibacterial activity of corn tassel extract were investigated. In addition, the measured antioxidant activity (DPPH&FRAP) showed a very high potential of these compounds (FRAP=288.11, DPPH=85.05) for encapsulation. The content of total phenol and flavonoids obtained from the test results were 1968.23 and 1346.20, respectively. The analysis results showed that the nanoparticles obtained from coating basil seed gum had the lowest particle size (494.4nm). Also, the highest coating efficiency (76.2%) belongs to the sample coated with basil seed gum. The value of zeta potential increased (+44.57) in the use of composite coating, and reached its highest value. During the storage of encapsulated Nano emulsion in the period of 0,3,7,15 and 21 days, the stability of nanoemulsions decreased with the passage of time, in such a way that, the highest stability related to encapsulated Nano extract in the combined coating (94.85 per day zero and 33.8 for day 21). The result of this study showed that nanoencapsulated of corn tassel extract with basil seed gum is more effective than the combined coating. But by checking other parameters (such as stability), It is suggested to use this gum in combination with other wall materials, including sesame protein isolates, to achieve the desired results.

1. Introduction

Due to the increasing awareness and demand of consumers to get healthy and natural food without artificial additives, in recent years, the food industry has been using more natural additives. Plant extracts and essential oils are a wide range of natural food preservatives that are generally recognized as safe. Plant extracts and essential oils have a specific aroma and taste and show good antioxidant activity as well as antimicrobial properties. Due to their volatile nature and chemical reactivity, plant bioactive compounds cannot be used successfully in most food systems. Poor mixing power and two-phase formation is one of the problems that arise due to the direct addition of extracts and essential oils to food complexes. Thermal, chemical and optical degradation of bioactive compounds are other problems caused by these natural additives[1].

corn(*Zea mays L.*) It is a rich source of nutrients and for this reason, they are widely used for human food[2]. In addition, due to the content of phenolic and carotenoid compounds, corn kernels have a higher antioxidant capacity than wheat, barley and rice kernels.[3]. Epidemiological studies have shown a relationship between dietary intake of carotenoids and prevention of chronic diseases, which in some cases is related to the antioxidant activity of these compounds. Phenolics are a very diverse group of phytochemicals. They are found in free and bound forms in cereal grains .[4] Phenolic compounds are found in flowers, fruits, seeds and other plant parts. The phenolic compounds of plants are known to have beneficial effects on human health due to their anti-inflammatory, anti-cancer and blood sugar lowering effects.[5].

It is interesting to note that both types of compounds (phenolic and carotenoid) have been found in high concentrations throughout the corn plant, especially in its flower, pod, leaf, stem and bark. In general, husks and pods are wastes after harvesting the corn plant. Due to the high content of bioactive compounds in different parts of the plant, there is interest in the potential use of these phytochemical compounds.[6]. In other words, it is possible to produce valuable products such as volatile oils, flavonol glycosides, kaempferol, isorhemantin, and quercetin, and lipids because, as mentioned, this part of corn contains flavonoid, alkaloid, allantoin, pentosan, inositol, polysaccharide, vitaminK AndCThere are several types of organic amino acids and sterols[7]. Also, corn cob extract has antioxidant capacity and has a high ability to inhibit the proliferation of stomach cancer cells. With the increasing awareness of consumers about the harmful effects of chemical preservatives on human health, the tendency to use natural preservatives, especially essential oils and plant extracts, in food products has increased. Using plant extracts with antimicrobial and antioxidant properties in a micro-coated form is a practical solution to achieve safer food products with higher quality and longer shelf life, thus reducing waste. Therefore, corn cob has significant bioactive properties and may be used as a raw material in the production of many valuable products on an industrial scale..[8]

Microencapsulation of plant extracts using biopolymer walls due to increasing the stability of microencapsulated materials by protecting them from environmental, enzymatic and chemical changes, providing a buffer state against changespH، Coping with thermal changes and ionic changes, protection against unpleasant tastes and odors, and controlled release of the microcoated material can be used as a way to increase shelf life.[9]. Today, various coatings are used to micro-coat materials that may have a polysaccharide, protein, or lipid structure and are prepared from plant, marine, animal, and microbial sources. In choosing the wall, attention should be paid to the primary characteristics such as chemical composition and structure, molecular weight, as well as secondary properties such as solubility, rheological behavior, film forming ability, film quality, surface activity, durability and degradability, melting and boiling points. In the microcoating process, various types of carbohydrates (starch,

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chitosan, maltodextrin, dextrin, sucrose, cyclic dextrins), cellulose (carboxymethyl cellulose, methyl cellulose, ethyl cellulose), gums (gum arabic, agar, sodium alginate, carrageenan, etc.) ..) fats (liposome, wax, monoglycerides, oils), proteins (casein, whey, gelatin, albumin, etc.) and food-grade polymers (polypropylene, polyvinyl acetate, etc.) It is used as a wall or carrier material. Coatings may be used individually or in combination[10].

There are various methods for the microcoating of extracts, the most important of which is the use of the emulsion production method. An emulsion consists of an aqueous phase, an oily phase and an emulsifier or surfactant.[11] Nanotechnology is the ability to control matter on an atomic scale and use the emerging properties and characteristics of matter in dimensions of 1-100 nanometers. Encapsulating bioactive substances is a practical and efficient approach to regulate drug release, increase the physical stability of active substances, protect them from reaction with the environment, reduce volatility, increase bioactivity, and reduce toxicity. As mentioned, polyphenols are natural compounds. which have anti-inflammatory and antioxidant properties. Several studies have confirmed that eating foods rich in polyphenols can provide cardiovascular and renal protective effects against various diseases without reducing their anticancer activity. However, the stability, bioavailability and size of polyphenols limit their transport across the cell membrane and thus their biological activity in vivo. To overcome these problems; Researchers have developed nanoparticle carriers. Nanoparticles have been reported to increase polyphenols' stability, bioavailability, transport across cells, and biological activity.[12].

Hydrocolloids are mainly complex carbohydrates that are used to improve consistency and textural properties of liquid and semi-liquid foods. Their activity depends on the type and concentration of hydrocolloids, temperature and process conditions, as well as the content of solids and the chemical composition of food. Many industries have received attention. In addition, with the biological properties and biological decomposition of plant hydrocolloids, they can be successfully used in various fields such as food and pharmaceutical industries. Basil seeds are from the basil plant, which is a member of the basil familyLips is. This plant is originally native to Iran, Turkey, India and other tropical regions of Asia, Africa and Europe. Fresh or dried basil leaves are used as a seasoning all over the world and its essential oils are used in pharmaceuticals and flavorings. Basil seeds produce a gel when soaked in water and are traditionally used in Asian drinks and desserts such as faloude and syrup. Basil seed gum is a hydrocolloid with a high molecular weight (2320 kilodaltons) and intrinsic viscosity (3.917 cubic meters per kilogram).) Is. which is known as anionic heteropolysaccharide containing glucomannan[13].

Polysaccharides in contact with cellular fluids tend to quickly surround[1] and then degraded, thus allowing intracellular releaseprovide In addition, the presence of hydrophilic groups in their structure, such as hydroxyl, carboxyl and amino groups, is a useful strategy to improve the bioavailability of core compounds. Therefore, polysaccharides have a promising future as biopolymer compounds for the preparation of nanoparticles, and finding a new source of biodegradable polymers, especially plant-derived polymers with suitable properties, is an active area of research. basil seed gum[2]BSG) is a high molecular weight hydrocolloid derived from plants. Basil seed gum provides a high viscosity solution and shear thinning behavior and acts as a stabilizer, emulsifier, fat replacer, edible film, and ice crystal growth controller.[14].

sesame (*Sesame indicator* L.) is one of the first crops used that is cultivated for the use of its oil. The main sesame producing countries are India, Sudan, China and Burma, which account for 60% of the total production. There are approximately

1 - Internalized

2-Basil seed gum

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50% oil and 25% protein in sesame seeds. Oil is extracted from sesame seeds by solvent extraction and mechanical pressing. The by-product that remains after oil extraction is called sesame meal and contains approximately 50% protein. Methionine and tryptophan are present in sesame seed in large amount, which makes it stand out among other oil seeds. Each protein is characterized by its unique physicochemical properties that further influence the process. Therefore, sesame flour is used as a source of protein and as an ingredient in the food industry. Sesame protein isolates or concentrates are usually prepared by isoelectric precipitation. Sesame flour and isolated protein rich in methionine(4-2.5 percent) And amino acids contain sulfur (5.5-3.8 percent). Sesame protein consists of 80% α-globulin and 20% beta-globulin. The functional and physicochemical properties of sesame protein concentrate, isolate, as well as its use as a food supplement for drinks and bread have been reported so far.[15].

In general, the aim of this research is: 1- Determining the total phenolic and flavonoid content of corn cob extract 2- Evaluation of antioxidant and antimicrobial activity of corn cob extract 3- Optimizing using the response surface method and choosing the optimal concentration for the microcoating of the extract with wall covering different

2- Materials and methods

1-2- Materials

Single cross 704 grain corn was obtained from the farm in Hashtgerd city, Alborz province. Basil seed gum from Rihan Gam Parsian company, sesame protein isolate after extracting black sesame seed oil, purchased from Khoda Afarin city, according to the alkaline methodOnsaard et al. (2010), It was extracted with some changes, all the chemicals and solvents used were obtained from Sigma Aldrich Company. Double distilled water was used for all samples[16].

2-2- Methods

2-2-1- Preparation of Kakel extract

Corn cob (30 or 45 days after flowering) was used to extract the extract. First, the cockle was dried for 5 days in normal air (room temperature) and then for To remove most of its moisture content, it was dried using a hot air oven at a temperature of 40 degrees Celsius for 48 hours, and then using a grinder, the powder was approximately 1 mm in size and passed through a sieve with a 50 mesh, in order to extract Kakel extract. Food grade ethanol solvent was used. According to the method presented by Younes et al. (2022), with some changes, about 10 grams of dry corn cob powder was added to 20 ml of 60% (w/w) ethanol-water solution and then for 24 hours in a shaking incubator. It was placed at room temperature. And then filter with Whatman No. 1 filter paper and the resulting extract were kept at -18 degrees Celsius until the experiment.[17].

2-2-2- preparation of nanoemulsion

To prepare the nanoemulsion, the extract was added at three levels of 10, 20 and 30% to the oil phase that contains Tween 80 and soybean oil and was stirred for 3 minutes at 50 degrees Celsius. Then it was homogenized at different times for 5, 10, and 15 minutes using an ultrathorax and at a temperature of 10 degrees Celsius. Basil seed gum was prepared individually and in combination with sesame protein isolate at a concentration of 30% and in ratios of 1:0 and 1:1 and stirred for 30 minutes on a magnetic stirrer. 2 samples with the best size were used for coating. The coating solutions were slowly added to the prepared emulsion in the ratio of solution to emulsion of 5:1 and 5:2. In order to further reduce the size of the prepared emulsions, they were subjected to probe type ultrasound for 3 minutes, and in this way the desired nanoemulsion was prepared..[18].

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3-2-2- Determination of flavonoid content and total phenol

The amount of 125 microliters of the extract was mixed with 250 microliters of Folin Ciocalcho reagent, which was diluted 1:10 with distilled water. Then 4 ml of sodium carbonate (1M) was added to it and placed in a water bath at 45°C for 15 minutes to expand the aqueous phase and then absorb it at 760 nm by spectrophotometer.UV-Vis was read The amount of total phenolic compounds in the extract was expressed based on mg equivalent of gallic acid per 100 grams of sample.[6] The flavonoid of the extract was measured based on the aluminum chloride colorimetric method and was expressed in terms of rutin equivalents[19].

4-2-2- Antioxidant activity according toDPPH

To measure the antioxidant activity of the extracts, it was done according to the method of Cappucci et al. (2017). 0.3 ml of extract with different concentrations with 2.7 ml of methanolic solution (6 x 10-5)DPPH The mixture was kept for 60 minutes at room temperature in the dark and the absorbance was read at 517 nm. The control sample contains all the mentioned compounds and conditions without adding the extract. Synthetic antioxidantTBHQ To theppm100 was used as a positive control[5].

Radical scavenging percentage DPPH: (DPPH - sample absorption) / DPPH

2-2-5- Antioxidant activity according toFRAP

To determine the reducing power of iron,In the test tube, add 0.02 ml of the extract (with different concentrations in mg/ml) or the standard aqueous solution of iron sulfate (concentration 0.185-0.37 micromol), 1 ml of the working solution and mix. became. The above mixture was placed at ambient temperature for 5 minutes and then the optical absorption of the samples was read. The reductive activity of the extract was calculated in terms of micromoles of iron per mg. Synthetic antioxidantTBHQ To theppm100 was used as a positive control[20].

6-2-2- Antimicrobial activity of corn cob extract

In order to determine the antimicrobial activity of the extract from the minimum inhibitory concentration(MIC) It was used using the method of dilution series. First, 2 ml of Mueller Hinton Broth culture medium was poured into each of the five test tubes. Then, 2 ml of the extract was added to the first tube and it was completely mixed with the culture medium by the tube shaker. With the help of a sampler, 2 ml of the first tube was added to the second tube and after mixing, half of it was transferred to the next tube. Dilution continued in the same way until the fifth tube, and 2 ml was removed from the fifth tube and discarded. With this method, concentrations of 12.5 to 100 ml were prepared. Then, 100 microliters of microbial suspension (about half McFarland) was added to all the tubes. The opening of all the tubes was closed with cotton and placed in an incubator at 37°C for 24 hours. At the end, the tubes were checked for turbidity and the lowest dilution without turbidity was reported as the minimum inhibitory concentration of the extracts.[21].

7-2-2- Determining the properties of nanoparticles

The characteristics of nanoparticles, including particle size and zeta potential, were determined using the dynamic light scattering method with the help of a zetasizer device. The samples were diluted with deionized water at a ratio of 100:1.

1-7-2-2- Microcoating efficiency

The microencapsulation efficiency was calculated by measuring the ratio of single microencapsulated phenols to total phenols that were used to prepare nanoparticles.[22].

2-7-2-2- Physical stability of nanoemulsion

In order to determine the physical stability of nanoemulsions, 7 ml of different nanoemulsions were added to a cylindrical glass tube with a flat bottom and scanned from bottom to top by a light source. The optical properties of the scattering along the glass tube at different times, the curve

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was considered as a "macroscopic fingerprint". The data from the back dispersion of nanoemulsion were obtained at 0, 3, 7, 15 and 21 days during storage at 4°C.[23].

3- Statistical analysis

In this research of the softwareDesign Expert 11.1.1 In order to design the experiment, data analysis, modeling, parameter optimization and graphs related to the response surface method were used in the form of central composite design. Also to check the parameterssuch as particle size evaluation, microcoating efficiency and analysis of other statistical parameters from the softwareSPSS Version 20 and Test ANOVA AndWith Use From Method like totally by accident Use became.

4- Results and discussion

1-4- Experimental design and data optimization

Treatments At13 The experiment was arranged based on the central compound design. The independent variables used included extract concentration and homogenization time, and the measured responses included Particle size and efficiency They were. The concentrations determined by the software for the desired factors are shown in Tables 1 and 2. eAlso, the effect of each factor on the answers is calculated in the form of the following formula.

Formula (1): Kakel extract coated with composite coating(BSG:SPI):

$Yield= +78.31+2.50A+6.33B-14.09A^2-17.59B^2$

$Particle\ Size= +693.38+24.17A+52.50B-66.33A^2-138.33B^2$

A: Concentration B: Homogenization Time

Formula (2): Kakel extract coated with basil seed gum

$Yield= +94.72+2.50A+6.94B-21.67A^2-18.33B^2$

$Particle\ Size= +624.33-0.8333A+19.92B-131.00A^2-48.75B^2$

A: Concentration B: Homogenization Time

A positive sign in front of the terms indicates a synergistic effect and a negative sign indicates an antagonistic effect.

Table1- Independent variables and Nano emulsion responses of encapsulated corn tassel extract with composite coating by central composite design(CCD) method

		Factor 1	Factor 2	Response 1		Response 2	
Std	Run	A:Concentration	B:Homogenization Time	Yield(%)		Particle Size(nm)	
				Actual	Predicted	Actual	Predicted
		%	Min	%	%	nm	nm
12	1	20	10	80	78.31	700	693.38
6	2	30	10	65	66.72	659	651.22
3	3	10	15	50	50.47	520	517.06
5	4	10	10	60	61.72	612	602.89
4	5	30	15	55	55.47	568	565.39
2	6	30	5	45	42.80	450	460.39
10	7	20	10	80	78.31	700	693.38
1	8	10	5	40	37.80	400	412.06
8	9	20	15	68	67.06	602	607.55
13	10	20	10	80	78.31	700	693.38
7	11	20	5	50	54.39	525	502.55
11	12	20	10	80	78.31	700	693.38
9	13	20	10	75	78.31	650	693.38

Table2- Independent variables and Nano emulsion responses of encapsulated corn tassel extract with basil seed gum coating by central composite design(CCD) method

		Factor 1	Factor 2	Response 1	Response 2

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Std	Run	A:Concentration	B:Homogenization Time	Yield		Particle Size	
				Actual	Predicted	Actual	Predicted
		%	min	%	%	nm	nm
7	1	20	5	70	67.99	555	555.67
2	2	30	5	50	50.28	430	423.83
4	3	30	15	65	64.17	450	463.67
1	4	10	5	45	45.28	420	425.50
10	5	20	10	95	94.72	620	624.33
3	6	10	15	60	59.17	475	465.33
11	7	20	10	95	94.72	620	624.33
8	8	20	15	80	83.33	575	595.50
5	9	10	10	70	70.56	490	494.17
9	10	20	15	85	83.33	620	595.50
12	11	20	10	95	94.72	627	624.33
6	12	30	10	75	75.56	500	492.50
13	13	20	10	95	94.72	627	624.33

2-4- Particle size and zeta potential

The average size of coated nanoparticles is presented in Table 3. As can be seen, both types of coatings used are in the range of nanometers. The combined nanocoating is the largest(SPI:BSG- 533.28nm) and nano coating prepared from basil seed gum(BSG-494.45nm) It had the smallest size that both covers had a statistically significant difference. In other words, the results showed that the change in the wall material has a significant effect on the size of the nanocoating. By examining Table 3, it can be seen that the reduction in the size of particles coated with basil seed gum is more than the combined coating, which is consistent with the findings of Khurrami et al., 2018.[24]. The review of their studies shows that adding a small concentration of basil gum to sodium caseinate emulsion has caused a significant change in particle size and its reduction. The decrease in particle size is due to the adsorption of anionic polysaccharides on the surface of droplets covered with proteins.

Also, particle size is a key parameter that affects the functional properties of proteins such as solubility, emulsification and foaming ability, which according to the findingsDing et al. 2021، Treatment of proteinsmantle Scallop extraction with ultrasound reduced the particle size significantly (average at 300 W, 314.60 nm). [25]. This reduction increased with the increase in ultrasound intensity. The reason for the decrease in particle size due to treatment with ultrasound is probably related to the fact that non-covalent interactions and strong interactions between protein masses are damaged by the turbulent effect, cavitation and strong shear force caused by the intensity of ultrasound. Also, they reported that due to cavitation and shear force caused by ultrasound treatment, the protein structure is reduced and as a result, some exposed free sulfhydryl groups easily form disulfide bonds, so the stability of scallop protein structuremantle improves.Osman Gul et al. 2023 reported that the treatment of sesame proteins with ultrasound led to a significant reduction in particle size (less than 40 micrometers) compared to the control sample (120 micrometers), which is due to the reduction of interactions between particles. [26]. They also stated in their studies that the increase in ultrasound time does not cause noticeable changes, which is probably due to the high mass structure of the insoluble compounds of protein isolate. In 2015, Hosseini et al. investigated the stability of fish oil

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nanoemulsion stabilized with whey protein isolate (prepared by ultrasound) during storage and reported that as a result of treating the solution with ultrasound at different times, the particle size significantly (from 600 nm to below 100 nm) decreased. Increasing the time during the ultrasound process causes the broken oil particles to get more opportunities to be covered by the emulsifier and prevent the increase in the diameter of the particles, and not only the structure is crushed, but the protein itself is also being crushed.[27]. The particle size of nanoemulsions affected by ultrasound depends on factors such as time, temperature, power and intensity of ultrasound, mechanical and physical properties of gum, type of antimicrobial and antioxidant substances, and optical properties.[28]. Porshaigan et al., 2018, in their study, reported the particle size of the nanoemulsion of basil seed gum and Gadumeh Shihari containing kiwi peel extract in the range of 81.53 to 156.17.[29]. Also, in order to investigate the mutual effect of independent variables on the tested traits, a surface response diagram was drawn. In each graph, the effect of two variables was investigated. Figures 1 and 2 show the three-dimensional image of the effect of concentration and homogenization time on the size of nanoemulsion particles of corn cob extract microcoated with basil seed gum individually and in combination with sesame protein isolate.

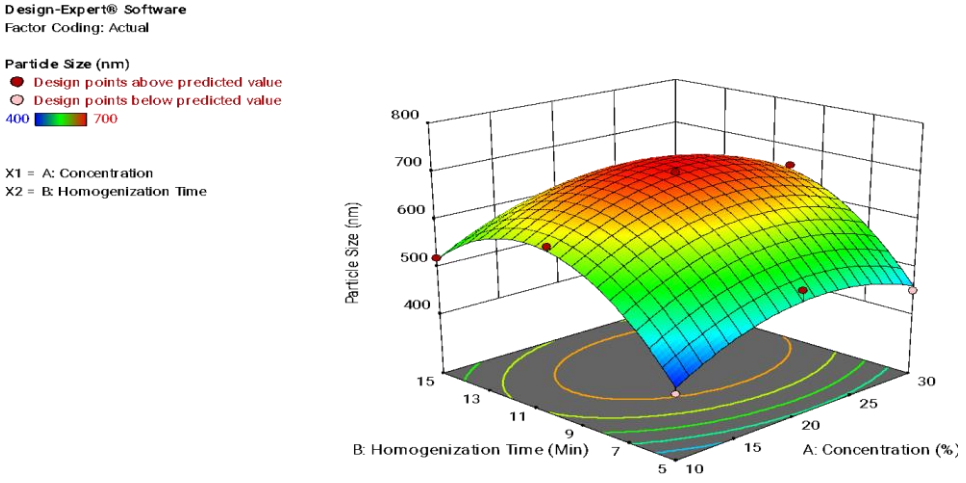

Figure1. Three-dimensional diagram, the simultaneous effect of concentration- homogenization time on Nano emulsion particle size corn tassel extract encapsulated with basil seed gum and sesame protein isolate

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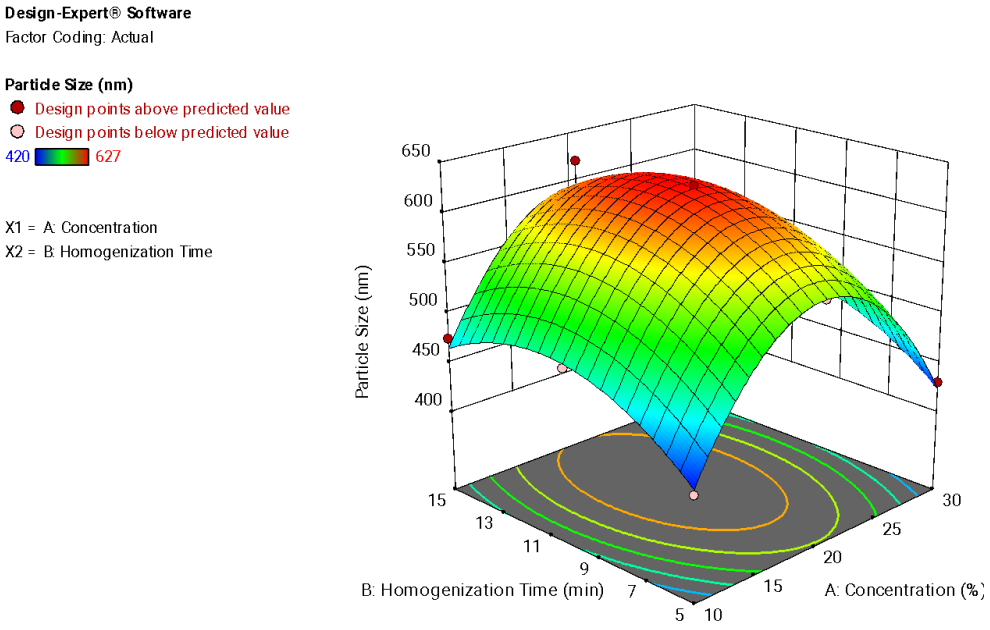

Figure2. Three-dimensional diagram, the simultaneous effect of concentration- homogenization time on Nano emulsion particle size corn tassel extract encapsulated with basil seed gum

As you can see in Figure 1, by increasing the concentration of corn cob extract with a combined coating and during homogenization, the particle size increased. Considering that one of the goals of nanoemulsion is to reach the smallest particle size limit, it can be seen by examining the three-dimensional diagram that the smallest particle size value was obtained at a concentration of 10% and a time of 5 minutes. Also, by examining Figure 2, it can be seen that the lowest value of particle size It has been obtained at a concentration of 10% of corn cob extract coated with basil seed gum and a homogenization time of 5 minutes. According to the studies, the extract has an important effect on the particle size and efficiency of the nanoemulsion due to its viscosity properties, therefore, the encapsulated substance with low viscosity can facilitate the breakdown of the nanoemulsion droplets and lead to a reduction in the particle size. Also, the high roughness of the sample not only increases the viscosity, but also increases the sedimentation of the sample and leads to larger droplet sizes. The results are consistent with the findingsLee et al. 2017 Correspond [30].

Zeta potential is usually used to determine the stability of a solution system. The high zeta potential of the emulsion particles increases the electrostatic repulsion force and as a result increases the physical stability of the system.. [31] As shown in Table 3, the zeta potential of the nanoemulsion solution containing Kakel extract in the coating of basil seed gum and also in the combined coating, Positive Is. which indicates amino acids with more positive charge than negative charge on the surface of the protein. The positive zeta potential of the coatings used (basil seed gum and sesame protein isolate) shows that it is bound to increase the stability of the solution due to good electrostatic repulsion. Its values for the combined coating (45.57) are higher than the coating in basil seed gum (41.85). The results obtained with the findingsOsman gul et al., 2023 Correspond [26]. They reported that the treatment of sesame protein with ultrasound led to an increase in zeta potential (mv8/39)

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and as a result the emulsion becomes stable. The cause of this increase may be due to mechanical forces such as cavitation that occurs during ultrasound. The polar groups in the internal region of the protein move to the surface of the protein molecules due to the cavitation effect, so there is more net charge in the modified protein solution, and the electrostatic interactions form tighter complexes that improve the stability and distribution of the solution. to forgive[32].

4-3- Covering efficiency

The encapsulation efficiency shows the degree of entrapment of corn cob extract inside the capsules. The results in Table 3 showed that the encapsulation efficiency of Kakel extract inside the capsules changes significantly by changing the wall material. The type of wall and particle size are influential factors in encapsulation efficiency. Also, viscosity is one of the influencing factors on encapsulation efficiency. Because with the increase in viscosity, the movement of volatile substances decreases and as a result, the encapsulation efficiency increases .[33]also The homogenization pressure above 500 bar has a positive effect on the encapsulation efficiency and increases it, but above this value, increasing the homogenization pressure decreases the encapsulation efficiency.. [34] By examining Table 3, it can be seen that the efficiency of nano-microcoating of Kakel extract is 76.2% in basil seed gum coating and 58.2% in combined coating. In other words, the highest efficiency is related to the use of basil seed gum alone. In general, the reason for the increased efficiency is the presence of gum in the wall matrix, which makes this situation possible by creating a protective coating on the surface of the cockle extract. Also, the reason for the low efficiency in the combined state is probably due to the increase in the osmotic pressure due to the increase in the amount of protein[35] The results are consistent with the research of Abbasi Ghaznaq et al. 1401. [36] The reason for the difference in the percentage of nanocoating can be attributed to the size of the prepared nanoemulsion particles. Therefore, the smaller the size of the emulsion particles, the higher the microcoating efficiency. The results of this research showed that due to the smaller size of the nanoemulsion particles coated with basil seed gum compared to the combined coating, the efficiency of microcoating with gum coating is higher. The results of our studies are consistent with the findings of Jamshidi et al. 2020[37].

Table 3- Particle size, Zeta potential and encapsulation efficiency of Nano emulsion encapsulated with different wall materials

Type of Nano emulsion	Mean particle size(nm)	Zeta potential (mv)	Encapsulation efficiency (%)
BSG	494.45^{b}	+41.85^{b}	76.2^{a}
BSG:SPI	533.28^{a}	+45.57^{a}	58.27^{b}

Dissimilar letters showed a statistically significant difference at the level of P <0.05
BSG: Basil seed gum, SPI: Sesame protein isolate

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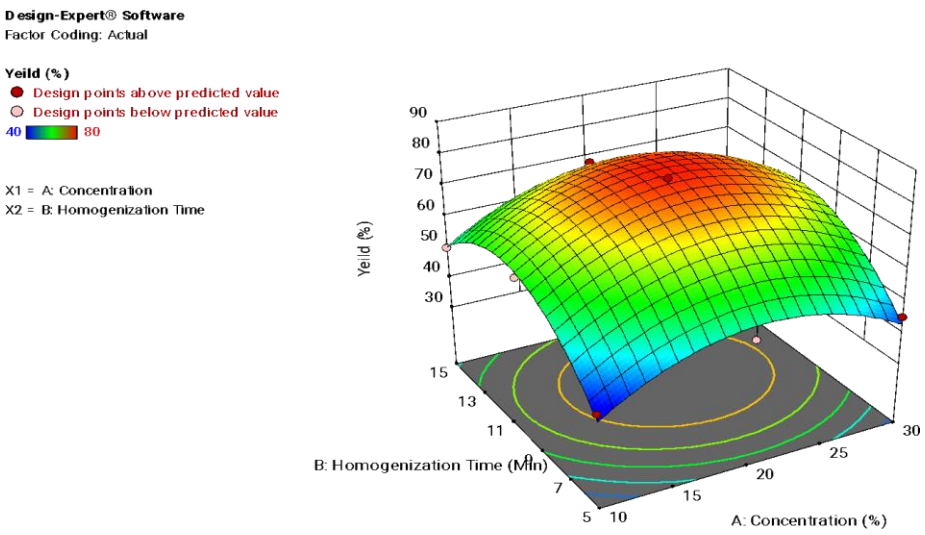

Figure3. Three-dimensional diagram, the simultaneous effect of concentration- homogenization time on Nano emulsion efficiency corn tassel extract encapsulated with basil seed gum and sesame protein isolate

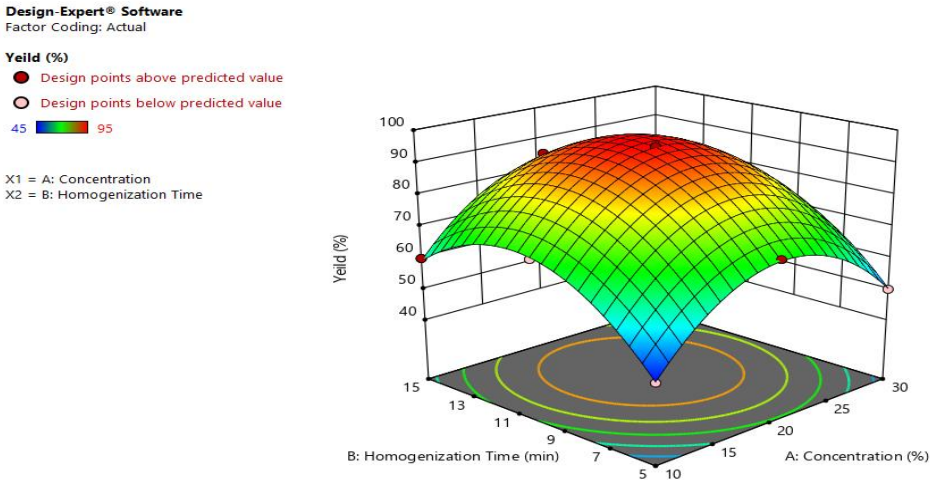

Figure4. Three-dimensional diagram, the simultaneous effect of concentration- homogenization time on Nano emulsion efficiency corn tassel extract encapsulated with basil seed gum

As you can see in Figure 3, by increasing the concentration of corn cob extract with combined coating And the homogenization time, efficiency increased. In examining the effect of concentration-time of homogenization on the efficiency of corn cob extract coated with basil seed gum, the efficiency increased with the increase of extract concentration and homogenization time (Figure 4). As you can see in Figure 4, since the concentration of the extract has an important effect on the particle size and efficiency of the nanoemulsion due to its viscosity properties, therefore, the encapsulated material with low viscosity can facilitate the breakdown of the nanoemulsion droplets. Also, the high roughness of the sample not only increases the viscosity, but also increases the sedimentation of the sample and leads to larger droplet sizes. The results are consistent with the findingsLee et al. 2017 Correspond. [30] Therefore, taking into account that in the nano-coating of plant extracts, the goal is to achieve the maximum efficiency, so the maximum efficiency is related to the concentration of 20% and the time of 10 minutes of homogenization.

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4-4- Stability of nanoemulsions

The stability of the emulsion depends on various factors, the most important of which can be considered the aggregation and mixing of particles. According to Stokes' law, the speed of droplet movement is directly related to the square of its radius. As a result, the stability of the emulsion can be increased by reducing the droplet size. The size of the particles and their distribution have a great impact on many properties of the emulsion, such as phase separation, stability during storage, resistance to the binding process, appearance characteristics, viscosity, sensory and organoleptic characteristics, etc..[38] Usually, plant polysaccharides are known as oil-in-water emulsion stabilizers. These biopolymers contribute to emulsion stability through a non-absorbent mechanism and by reducing the movement of oil droplets.[39]. Stability of nanoemulsion of Kakel extract coated with basil seed gum individually and in combination During storage at 25°C on days zero, 21, 15, 7, 3 are presented in Table 4. As expected, the stability of nanoemulsions decreased with time. The values presented for the samples are significantly different from each other. The highest stability is related to the nanoemulsion of kakel extract microcoated with a combined coating on day 0 and the lowest stability is related to the nanoemulsion of kakel extract microcoated with basil seed gum on day 21. By examining the obtained results, the composite coating is more stable, which shows the effect of the wall type on the stability, and the results obtained from the zeta potential also showed that the nanoemulsion containing the composite extract is more stable. Hosseini et al., 2015, in the study of the stability of fish oil nanoemulsion stabilized with whey protein isolate (prepared by ultrasonic method) during storage, reported that with the passage of time at ambient temperature (25 degrees Celsius), the stability of the nanoemulsion decreased, which was due to faster movement. particles to the surface at a higher temperature which increases gravitational coagulation[29]. The findings of Ghafouri et al. 1400 regarding the physical and chemical stability of omega-3 nanoemulsion show that the stability decreases during the storage period, in other words, the process of creaminess increases with the passage of time, which is probably due to the presence of particles with Heterogeneous sizes and the presence of particles without possible surfactant, the particles are merged with each other due to random movements and the mass phenomenon takes place during the storage period.[40]. The results presented by Shahrampour et al. 1401 also confirmed our studies that the storage time has an effect on the stability of emulsion and nanoemulsion and the particle size increases with the increase of the storage time. [41].

Table4- Investigation of stability in different samples of Nano emulsion prepared from corn tassel extract encapsulated with BSG and BSG: SPI

Extract name	Stability of Nano emulsion in days(%)				
	0	3	7	15	21
Corn tassel extract Nano emulsion encapsulated with basil seed gum	$89/42^{Ab}$	$74/67^{Bb}$	$63/95^{Cb}$	$43/20^{Db}$	$20/89^{Eb}$
Corn tassel extract Nano emulsion encapsulated with basil seed gum and sesame protein isolate	$94/85^{Aa}$	$82/00^{Ba}$	$70/23^{Ca}$	$55/41^{Da}$	$33/80^{Ea}$

Dissimilar letters showed a statistically significant difference at the level of $p < 0.05$

4-5- total phenolic and flavonoid content

Phenolics are a very diverse group of phytochemicals. They are found in free and bound forms in cereal grains [4]. Phenolic compounds are found in flowers, fruits, seeds and other plant parts. The phenolic compounds of plants are known for their anti-

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inflammatory, anti-cancer and blood sugar lowering effects due to their beneficial effects on human health [5]. In general, husks and pods are wastes after harvesting the corn plant. Due to the high content of bioactive compounds in different parts of the plant, there is interest in the potential use of these phytochemical compounds [6]. Valuable products such as volatile oils, flavonol glycosides, kaempferol, isorhemantin and quercetin and lipids can be produced from corn because, as mentioned, this part of corn contains flavonoid, alkaloid, allantoin, pentosan, inositol, polysaccharide, vitamin K and C is several types of organic amino acids and sterols [7].

The amount of total phenol and flavonoid content of Kakel extract are presented in Table 5. As you can see, the amount of total phenol in terms of milligrams of gallic acid per 100 grams of dry matter is equal to 1968.43 and the amount of flavonoids in terms of quercetin is 1346.2. According to the findingsWang et al. 2014 Corn cob contains a variety of bioactive compounds including alkaloids, flavonoids, saponins, polysaccharides, pentosans, allantoin, inositol, vitaminK&C and sterols [19]. The amount of flavonoid compounds, saponins and polysaccharides in corn is 1.67-2.41 and 4.76%, respectively, and these polysaccharide compounds have physiological properties, including antibacterial properties. [42]. The results of our research are consistent with the findings of Garcia et al., 2021 [43] and Khamphasan et al. 2018[44] that the total phenolic content of corn cob extract is 70/33 respectively$\frac{mgGAE}{g}Dw$ And$\frac{mgGAE}{g}Dw$ 7/2024 to 2945 reported, matches.

Table5-Total phenol and Flavonoid content of corn tassel extract

Extract name	Flavonoid(quercetin equivalent/g	Total phenol content(mg GA/100gDW)
Corn tassel	1346.20±86.65	124.47±1968.23

6-4- antioxidant activity of the extract

Corn cob extract has antioxidant capacity and has a high ability to inhibit the proliferation of gastric cancer cells[8]. In Table 6, the antioxidant activity values of corn cob extract in terms ofDPPH AndFRAP Provided. This value is calculatedDPPH, 85.05 percent and according toFRAP, 288.11 micromol of iron per liter.Wang et al., 2014In their study, they reported that flavonoids, saponins and polysaccharides are the most dominant compounds in corn cob extract and their antioxidant activity is based onDPPH77.18, 90.39 and 60.24 percent, respectively, and also based onFRAP It is 691.04, 271.65 and 462.52 micromol/liter, respectively, so it has a prominent antioxidant activity and also the antioxidant activity of corn cob extract is attributed to these compounds. [19]. The results of this research with the findingsGarcia et al., 2021[43] AndKhamphasan et al. 2018[44] that the amount of antioxidant activity of corn cob extract is 2029/61 respectively$\frac{\mu many}{g}DW$ And$\frac{\mu many}{g}DW$ 14,293 to 2,0085 (76.8 to 81.3 percent) reported that it matches.

Table6- Antioxidant activity of corn tassel extract

Extract name	DPPH radical scavenging activity	FRAP (µmol Fe+2/L)
Corn tassel	85.05±2.61	288.11±24.22

4-7- Antimicrobial activity of the extract

Studies have shown that corn polysaccharides are non-toxic and have a wide range of physiological properties, including antibacterial, anti-tumor, immunological and hypoglycemic properties.[19]. The results presented in Table 7 show the antimicrobial activity of corn cob extract for 5 types of food-borne pathogenic bacteria, including Gram-positive bacteria (S.auerus و L. monocytogenes) and gram-negative bacteria(E. coli, S. enteritidis, P. aeruginosa) is

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showing. Bacterial inoculation of 10 microliters at a concentration of 12.5, 25, 50 and 100 mg/ml of corn cob extract to determine the results of the minimum inhibitory concentration used. As can be seen, the minimum inhibitory concentration for Gram-negative bacteria is higher than Gram-positive bacteria. The reason for this is probably the high sensitivity of these bacteria to phenolic and flavonoid compounds in plant extracts.Gram-negative bacteria have an impermeable outer membrane, which is physicochemically more complex than the cell wall membrane. Therefore, Gram-negative bacteria with the mentioned wall are less sensitive to antimicrobial compounds.[26].

The antimicrobial activity of corn cob extract can be attributed to the presence of high phenolic compounds such as gallic acid, chlorogenic acid and caffeic acid, and the antimicrobial effect of these compounds is through destroying the cell wall, blocking ion transport pathways and preventing the synthesis of adenosine triphosphate.(ATP) Is.[21] In fact, gram-negative bacteria show less sensitivity to antimicrobial agents due to the type of walls they have, which can be caused by the presence of lipopolysaccharides in the cell wall of gram-negative bacteria, which prevents large and hydrophobic molecules from entering the cell. Since the effective compounds in plant extracts are hydrophobic, it can be concluded that the type of wall present in Gram-negative bacteria prevents the penetration of these compounds into the cell, and as a result, the resistance of Gram-negative bacteria to plant extracts.[45] According to the findingsElsayed et al., 2022، Corn cob extract extracted with ethanol has relatively lower inhibition zone (1.8-4.9 mg/ml) for pathogenic bacteria.(E. coli, P. aeruginosa, S. typhi, B. cereus and S. aureus) has it.[21]

Table7- Minimum inhibitory concentration (MIC) of Corn tassel extract against pathogenic bacteria

	Gram-positive bacteria		Gram-negative bacteria		
Extract name	S. aureus	L. monocytogenes	S. enteritidis	E.coli	P. aeruginosa
Corn tassel	25	25	50	25	50

5. Conclusion

The aim of this research was to optimize the extract of the microcapsule by the response surface method and evaluate their properties with different extracts (basil seed gum and sesame protein isolate). In this research, the efficiency of different wall materials and their composition in the coating of corn cob extract was evaluated. Basil seed gum showed the lowest particle size and the highest efficiency. The highest value of zeta potential and emulsion stability also belonged to the composite coating. Also, the results of the minimum inhibitory concentration showed that corn cob extract has antimicrobial properties and its effect on gram positive bacteria is more than gram negative bacteria. The results of optimization using the response surface method showed that with increasing extract concentration and homogenization time in each use of both walls, efficiency and particle size increased. By comparing the wall materials, it can be concluded that basil seed gum in combination with sesame protein isolate is a better coating for lining. So In order to check the performance of these microcapsules and their use in food formulations, the need to study them in laboratory conditions(In-vitro) Is.

6- Resources

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چکیده

در این مطالعه از صمغ دانه ریحان(BSG) بصورت منفرد و در ترکیب با ایزوله پروتئین کنجد (SPI) به نسبت های ۱:۰ و ۱:۱ به منظور انکپسوله کردن عصاره کاکل ذرت(CTE) با استفاده از روش سطح پاسخ در قالب طرح مرکب مرکزی استفاده شد. همچنین به منظور بهینه سازی و بررسی اثر متغییرهای غلظت عصاره کاکل و زمان هموژنیزاسیون بر پاسخ اندازه ذرات و راندمان از معادله درجه دوم استفاده شد. در ابتدا محتوای فنلی کل(TPC)، محتوای فلاونوئید کل(TFC)، فعالیت آنتی اکسیدانی و فعالیت ضد میکروبی عصاره کاکل ذرت بررسی شد. علاوه بر این، فعالیت آنتی اکسیدانی (DPPH & FRAP) اندازه گیری شده، پتانسیل بسیار بالایی از این ترکیبات(FRAP=۲۸۸/۱۱ ، DPPH=۸۵/۰۵) را برای انکپسوله کردن نشان داد. محتوای فنل کل و فلاونویید حاصل از نتایج آزمون به ترتیب ۱۹۶۸/۲۳ و ۱۳۴۶/۲۰ بود. نتایج حاصل از آنالیز نشان داد نانو ذرات حاصل از ریزپوشانی توسط صمغ دانه ریحان کمترین اندازه ذرات (۴۹۴/۴nm) را داشتند. همچنین بیشترین کارایی درون پوشانی(۷۶/۲ درصد) نیز متعلق به نمونه ریزپوشانی شده با صمغ دانه ریحان بود. مقدار پتانسیل زتا در استفاده از پوشش ترکیبی افزایش(۴۴/۵۷) یافت و به بالاترین مقدار خود رسید. در طی نگهداری نانوامولسیون های ریزپوشانی در بازه زمانی صفر، ۲۱،۱۵،۷،۳ روز، با گذشت زمان پایداری نانوامولسیون ها کاهش یافت به نحوی که بالاترین پایداری مربوط به عصاره نانو ریزپوشانی شده در پوشش ترکیبی(۹۴/۸۵ برای روز صفر و۳۳/۸ برای روز ۲۱) را به خود اختصاص داد. نتایج این مطالعه نشان داد که نانو ریزپوشانی عصاره کاکل ذرت با صمغ دانه ریحان کارایی بیشتری از پوشش ترکیبی دارد اما با بررسی سایر پارامترها مانند پایداری، پیشنهاد می گردد این صمغ در ترکیب با سایر مواد دیواره از جمله ایزوله پروتئین کنجد مورد استفاده قرار گیرد تا نتایج مطلوب حاصل شود.

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