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Production and Characterization of Bioactive Components enriched Soft Drinks

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Abstract: Functional foods, which aim to use the existing opportunities effectively to meet the food need due to the increasing population in the world, are still lacking in producing new products to support human health. In this study, functional food components were brought together to produce a non-alcoholic beverage that can be offered to individuals and has a resistance-increasing and immune system-strengthening effect. In the study, extracts containing flavonoids obtained from different plant sources and extraction method were added to the proteins found in liquid form in whey, and the mixture was enriched with casein obtained from milk. Pomegranate, cinnamon and chamomile plants have been selected considering their high flavonoid content and different colors and odours. In the extraction process, it was optimized with the Box-Behnken experimental design by using the classical extraction method in water solvent. Three different beverage samples with different effects were produced by adding casein and whey produced by precipitating the protein of milk with acetic acid and evaporating the acid to the prepared extracts, depending on the amount of antioxidants to be taken daily. It is recommended to prefer chamomile-based drinks for a positive and calming effect on cancer cells, pomegranate flower to neutralize harmful components accumulated in the body, cinnamon-based drinks for a soothing effect in neurodegenerative diseases, and to consume all beverage samples to observe all these anti-inflammatory effects is expected to lead.

Keywords: Functional food, soft drink, antioxidants, casein, sodium caseinate

I. Indroduction

Animal foods with high protein content such as meat, milk and eggs, which are recommended to be consumed for all age groups, are important for human health because they contain essential amino acids and organic nitrogen. Milk, which is a high source of calcium, is also very rich in bioactive components [(1)]. The composition of milk, which also has a high protein content, consists of casein (80%) and whey (20%), which is a mixture of globulin and albumin. Casein is the main protein of milk, precipitating at pH 4.6. Sodium caseinate, the most efficient form of casein, is formed by the reaction of casein in milk with alkaline solutions [(2)]. By coagulating the milk with rennet or organic acid, the greenish yellow part, namely "whey" is obtained [(3)]. With the intense work pace and changing nutritional habits brought about by the developing technology, products with high protein and vitamin content tend to be replaced by functional foods and supplementary foods [(4-8)]. The term functional food, which was first used in Japan in 1984, has not yet found a place for itself in our country and has not reached a position that has a significant share in the world market. Unconscious diets cause weakening of the immune system, and fast foods consumed for "fast" nutrition cause many diseases such as diabetes, obesity, cardiovascular occlusion [(9)].

Along with the animal-derived building blocks of the healthy body, the need for plant-derived bioactive components is undeniable. Antioxidants, a subgroup of functional foods that prevent, delay or eliminate the oxidative damage of the target molecule, have been proven by scientific studies to have a reducing effect on cancer, diabetes, rheumatoid arthritis and death rates by binding free radicals in the body [(10-15)]. Flavonoids, which are found in many vegetables and fruits with antioxidant effects, were discovered a long time ago, but nowadays they gain more importance and their effects and activities are better understood [(16)]. Especially rosmarinic acid is one of the powerful antioxidants found in many plants, its antioxidant activity is stronger than that of vitamin E, and it reduces the risk of cancer and vascular occlusion .Gallic acid, benzoic acid, protocatechic acid, chlorogenic acid, which are also used in cancer and many treatments, are also known for their high antioxidant activities [(17)]. In order to see the positive effects of flavonoids on the human body, daily regular use is required. As a result of studies, the amounts of daily consumption are determined as 1.0-1.1 g in the United States [(18)], 23 mg in the Netherlands [(19)], 28 mg in Denmark [(20)], 36.6 mg in Finland [(21)].

In the world functional food market, beverages with whey are in competition (Table I). Unlike developed countries such as Switzerland, Germany and Norway, there is no functional soft drink production in Turkey. In order to fill this deficiency, the production of whey-based soft drink enriched with sodium caseinate components, which is a source of bioactive peptides, and some properties were studied by choosing the extract of three different herbal materials (pomegranate flower, cinnamon, chamomile) with a high flavanoid capacity that has not been tried before. The Design Expert program, which offers statistical methods and approaches to optimize variable parameters, and the Box-Benhken design were used. With the solutions offered by the program, three beverage samples with different polyphenol source and concentration were obtained. It is predicted that functional foods, including these beverages, will be an alternative solution in order to protect the immune system in the fight against the disease, especially the Coronavirus, which mainly affects the world in these days.

TABLE I. Some whey-based beverages on the European market [(3)].

Commercial Product	Country	Properties/Components
Big M	Germany	Flavored and vitamin E enriched whey
Kur - Molke	Germany	Whey with added apple or orange/maracuja extract
Multivitamin - Molke	Germany	Whey +10 different fruit extracts +10 vitamins
Rivella	Switzerland	Whey, carbonic acid, sugar, natural flavors, acidifying agent (L- Lactic acid)
Fit	Switzerland	Rivella-like beverage, but with 15% fruit pulp or mango extract added to carbonated whey
Latella	Austria	Whey + mango + maracuja and fruit pulp/citrus extract
Djoez	Norway	80% whey + 12.8% fruit concentrate + flavor
Taksi	Norway	85.3% whey + 6.3% fruit concentrate + coloring agent

II. Experimental Arrangement

In this study, casein, sodium caseinate and whey were obtained from milk, respectively. For this purpose, semi-skimmed and pasteurized milk was heated up to 40°C in a water bath (Memmert). Then, 20ml of 10% acetic acid solution (d=1,03 g/mL) was added slowly into it and the mixture was mixed in a magnetic stirrer (VELP AREX) at 400 rpm until casein reaches its isoelectric point. The resulting large amount of gummy casein mass was separated from the whey with the aid of a cotton filter. To obtain sodium caseinate, 1M NaOH was added to 500 ml of distilled water and dripped onto the filtered casein sample until the pH reached the range of 6.7 to 7 [(2)]. After the filtration of the resulting sodium caseinate solution, it was dried in a circulating air dryer (NUVE FN500).

In order to meet the required daily amount of antioxidants (272 mg) [(22)], classical extraction method (Memmert) with the water as a solvent were used for preparation of antioxidant mixtures of the pomegranate flower, cinnamon and chamomile materials selected considering the antioxidant/polyphenol amount [(23)]. Herbal materials were obtained from regional herbalists and stored at room conditions before usage. As a result of the extraction, the mixtures were filtered through Whatman (No: 1) filter paper and the plant material was removed at ambient pH. In the classical extraction process, solid/liquid ratio (0.3-1.5 gr/40 mL), temperature (25-60°C), time (10-60 min) and mixing speed (50-250 rpm) were selected as single optimization parameters in accordance with our previous studies [(24,25)]. In multiple optimization, these parameters were studied with a threeparameter, three-level Box-Behnken experimental design with the aid of the Design Expert program (Table II). Statistical analysis of multiple optimization results was performed using the ANOVA table. Soft drink samples were produced by mixing 150 ml of whey, 500 mg of casein and 3 grams of sucrose for each 50 ml of extracts from different herbal materials prepared under optimum conditions, taking into account of daily intakes. In order to increase the consumability of these drinks, which have different colors and aromas, coloring agent (not exceeding the specified amount in the Food Regulations) has been added.

Table II. Experimental design used in multi-parameter optimization

Herbal Material	**Box-Behnken Design**			
	Parameters	**-1**	**0**	**1**
Pomegranate flower	**A:** Temperature (^{0}C)	40	50	60
	B: Extraction time (min)	10	30	50
	C: Solid/liquid ratio (g/ml)	0.9/40	1/40	1.2/40
Cinnamon	**A** Temperature	20	30	50
	B: Extraction time	30	45	60
	C: Solid/liquid ratio	0.3	0.9	1.5
Chamomile	**A:** Temperature	25	40	65
	B: Extraction time	20	40	60
	C:Mixing rate (rpm)	100	120	150

In order to determine the properties of the final beverage samples and to compare them with other beverages available in the market, some chemical, physical and HPLC analyzes were carried out. The chemicals used in the aforementioned analyzes were obtained from technical companies at analytical purity. AOAC method was used for dry matter analysis of whey and final beverage samples (AOAC-930.15). The viscosities of them were determined by Ostwald Viscometer in which water was used as a reference (μwater= 8.9x10-4 kg/m·s; ρwater= 1 g/cm3).

Chemical analyzes were made and compared for both the whey and the final beverage samples. The pH value of the samples was determined with a pH meter (MILWAUKEE M1150) at room conditions (TS 1728, FCC 740), and the total acidity value was calculated with the volume of 0.1 N NaOH solution, which makes the pH value of the samples 8.1 (TS 1125 ISO 750). Lactic acid was used as a reference. Density measurements and chemical analyzes were repeated every 24 hours.

The Folin-Ciocalteu method was applied to determine the antioxidant amounts of the extracts. Absorbance values were measured at 765 nm wavelength in UV-VIS spectrophotometer (Agilent Tech Carry 60), and mg gallic acid equivalent of soft drinks was calculated using Equation (1). The method was used both to select the effective parameters, to determine the optimum values of these parameters and to determine the antioxidant content of the final beverage samples [(26)].

$$\textbf{Absorbance @765 nm} = \mathbf{0.01532} \textbf{ x Concentration of total polyphenols } \left(\mu g \frac{GAE}{mL}\right) \quad (1)$$

The total amount of reducing sugar in the final beverage samples was determined by the Nelson-Somogyi method [(27)]. The absorbance value was measured at 520 nm wavelength in UV-VIS spectrophotometer, and it was calculated as mg glucose/ml sample with Equation (27).

$$\textbf{Aborbance @520 nm} = \mathbf{0,143} \textbf{ x Glucose concentratio } \left(\frac{mg}{ml}\right); \boldsymbol{R_2} = \mathbf{0,9999} \quad (2)$$

In the analysis in which the sensory properties (color, smell and taste) of the produced beverages were evaluated by volunteers, the subjects were asked to score between 1 (least liked) and 5 (most liked) (TS 3707 ISO 5492). The three samples with the highest social acceptance in terms of taste, color and odor were subjected to HPLC analyzes by Süleyman Demirel University Innovative Technologies Application and Research Center.

III. Results

Single parameter optimization results and flavonoid amounts obtained by extraction of selected plants under these conditions are given in table 3. It was observed that the temperature parameter of the pomegranate plant significantly affected the total phenolic content of the extract, while the temperature and solid-liquid ratio were the determining factors in cinnamon. In the daisy plant, it was determined that the mixing speed was more effective on the yield than the time and temperature. The fact that the plant is lighter than water causes it to stay on the surface. The centrifugal force due to the mixing speed used provides an increase in the mass that is in contact with the water, which increases the extraction efficiency. In solid-liquid extractions, the parameters affecting the yield vary depending on the structure of the plant [(28)]. While choosing the optimum value of each parameter, high efficiency and low cost were taken into consideration.

As a result of multiple optimization, statistical models proposed by the program were evaluated for each plant. It is desired that the adjusted R2 values estimated by the model should be close to each other and close to 1, and the proposed model should be signifcant and the Lack of fit value should be low. Lack of fit measures the success of the model to show the data in the experimental set at points not included in the optimization, and the lack of fit not significant indicates that it is not due to error. Statistical analysis of the model defining the reduced cubic model response surface was evaluated by analysis of variance (ANOVA) (not given) [(29)]. Since it satisfies all these conditions and has low standard deviations, the best model has been determined as the reduced cubic model (table IV.). The fact that the F value is high in the model and the value expressed as "Prob>F" is less than 0.05 indicates that the model is significant. In this study, and for the extraction models of cinnamon, chamomile and pomegranate flower, the F-values were high (3761.02, 33186.06, 206.48); probality values were found to be low (0.0003, 0.0001, 0.0048). The reduced cubic model and test results are found to be compatible, and it is clearly seen that this compatibility model is on the 45^{o} line of the data in the predicted and actual graphs of chamomile, cinnamon and pomegranate flower, respectively (Fig. 1).

Table III. Results of single-parameter optimization procedure

Herbal Material	Parameter	Total phenolics (mg/ml)	Optimum value
Pomegranate flower	Temperature	59.91	50
	Extraction time	52.37	30
	Solid/liquid ratio	52.37	1/40
Cinnamon	Temperature	63.29	40
	Extraction time	60.89	30
	Solid/liquid ratio	63.29	0.9
Chamomile	Temperature	10.45	25
	Extraction time	20.79	40
	Solid/liquid ratio	59.76	120

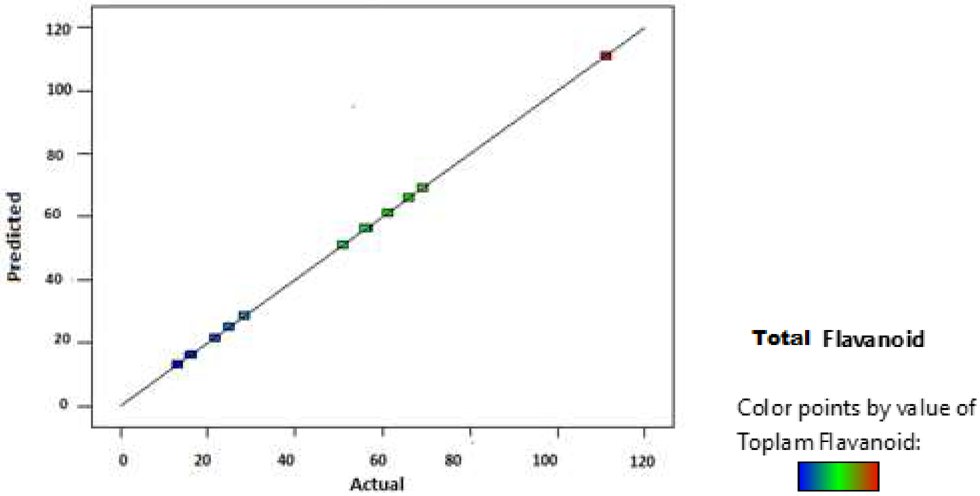
The optimum values determined by numerical analysis of the Design Expert program are given in table IV. It was determined that the chamomile plant produced the highest total phenolic content among the selected plant materials, even when low temperature was used under optimum conditions. Although it is worked at high temperature and can give color easily, less amount of phenolic substance has been detected in the pomegranate plant compared to chamomile. This result is thought to be due to the low gallic acid content of the plant in question, since total phenolics are measured by gallic acid equivalent. The total phenolic content of the cinnamon plant was found to be low compared to the other plants. Of course, the maximum total phenolic production from a certain mass of a plant is valuable in industrial terms, but it should not be forgotten that each plant has its own phenolic components and each component has different positive effects on human health. Therefore, the value of each plant is unique. Quadratic equations expressed with coded values for their total phenolic content are also summarized in the same table. These obtained equations can be used directly in determining the conditions required for the production of beverage samples industrially.

Table IV. Results of multi-parameter optimization procedure

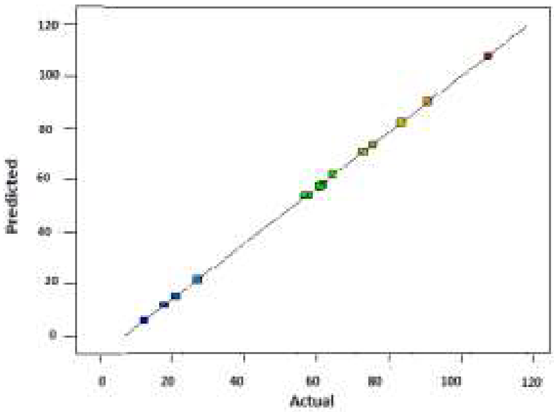
Herbal material	Optimum conditions	Total phenolic content (µg/ml 10^{-3})	Equation of the model	Model R^2 Adjusted R^2 Predicted R^2	Selected Model
Pomegranate flower	A:50 B: 30 C: 1/40	253.91	$R1 = 56{,}3033 + 2{,}19125xA + 3{,}46xB - 1{,}25125xC - 10{,}195xAB + 17{,}2325xAC - 3{,}53xBC - 5{,}56542xA^2 - 21{,}5229xB^2 + 6{,}22542xC^2$	0,9944 NA 0,992	Reduced Cubic
Cinnamon	A: 30 B: 60 C: 1.5/40	147.06	$R1 = 62{,}1667 + 0{,}35xA - 10{,}1888xB - 2{,}24875xC + 3{,}6425xAB + 18{,}0375xAC - 0{,}295xBC - 12{,}7033xA^2 - 17{,}1558xB^2 - 18{,}9258xC^2$	0,9997 NA 1	Reduced Cubic
Chamomile	A:25 B:40 C:150	384	$R1 = 56{,}08 - 92{,}25xA + 11{,}16xB - 7{,}78xC - 131{,}42xAB$	1 NA 1	Reduced Cubic

			$-69,17xAC$ $-3,53xBC$ $+98,36xA^2$ $-3,99xB^2$ $-23,53xC^2$		

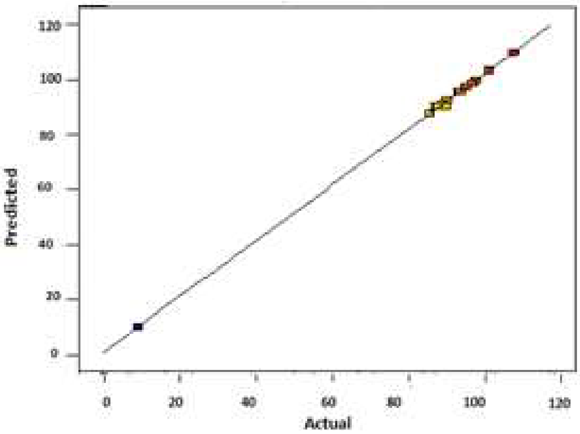
NA: Not available



a) Cinnamon



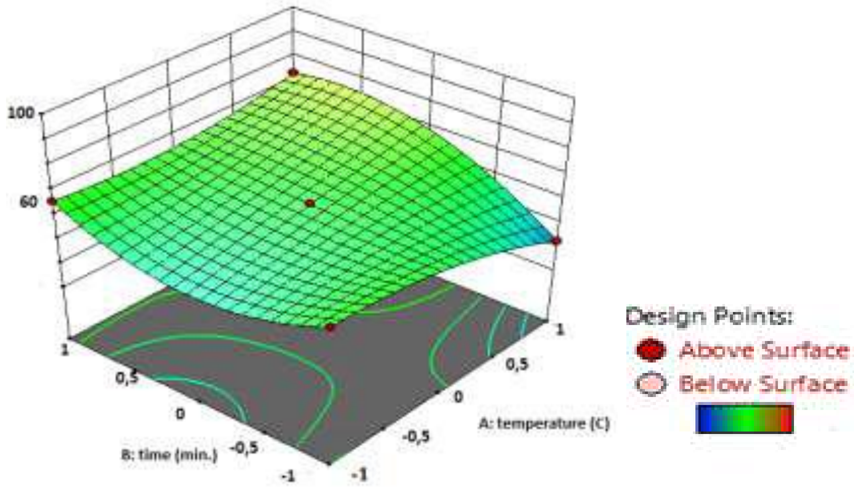
b) Pomegranate flower



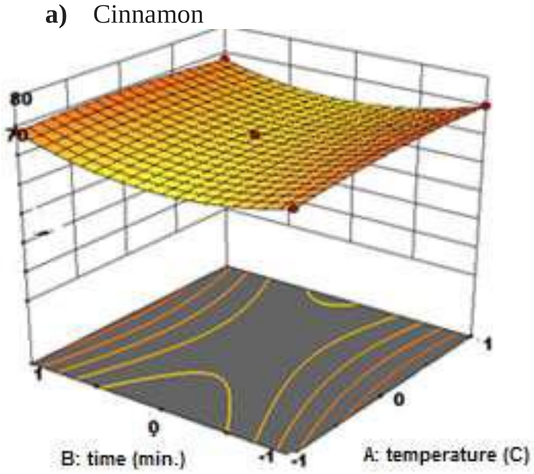
c) Chamomile

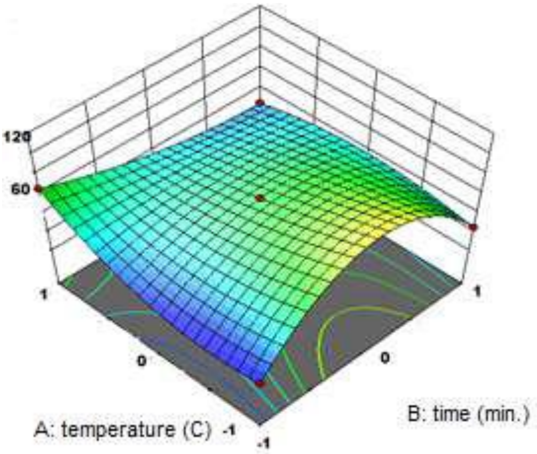
Figure 1. Predicted versus actual graphs of selected models

3D graphs were drawn to detail the relationship of the parameters with each other. These graphs show the increase in extraction efficiency going from blue to red. The density of blue and green areas in cinnamon (a) and chamomile (c) plants shows that the temperature and duration are less related to each other (Fıg 2.) In the condition that the temperature and time are maximum in cinnamon (a) and pomegrante folwer (b), the plant 65-70% of its phenolic content has been extracted. High efficiency was observed, since the longer contact of the material with the solvent caused an increase in the required diffusion time and an increase in temperature caused the addition of thermal diffusion as well as molecular dissolution. For the pomegranate plant (b), 40% of extraction yeild was reached when the temperature is 1 and the time is -1. Observation of a flat surface in the pomegranate (b) plant, where high yield was obtained at every temperature and time studied, indicates that these parameters are independent of each other. In the chamomile (c) material, the maximum concentration is 20% when the temperature and time are the highest. It was studied in the temperature range of 25 to 65ºC in chamomile, 40 to 60ºC in pomegranate flower, and 20 to 60ºC in cinnamon. However, while temperature was more effective than duration in pomegrante flower and cinnamon plants, duration was found to be more dominant than temperature in chamomile. This can be explained by the fact that the diffusion constants of the flavonoid components of pomegranate flower and cinnamon are temperature dependent, while the components of chamomile are independent of temperature. The variation in the yield of pomegranate extract, which took place in a very narrow range, shows that the extraction process is highly sensitive to the temperature of extraction.



a) Cinnamon

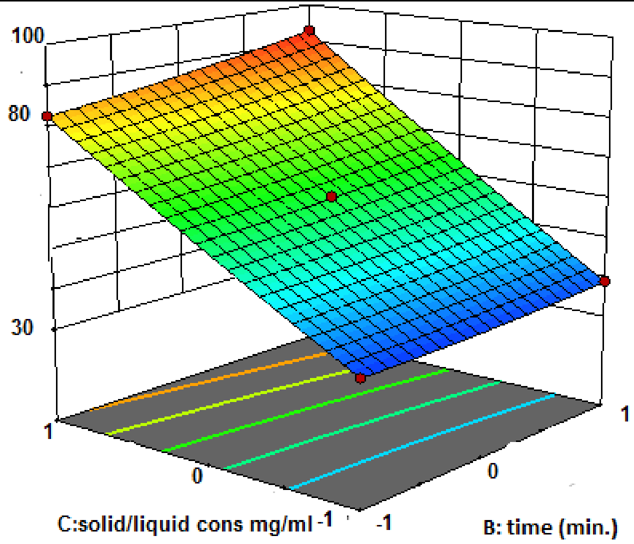




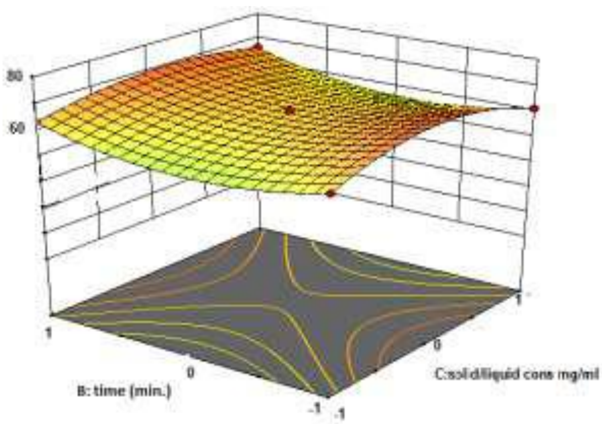
b) Pomegranate flower **c)** Chamomile

Fig 2. Three-dimensional surfaces of temperature-time

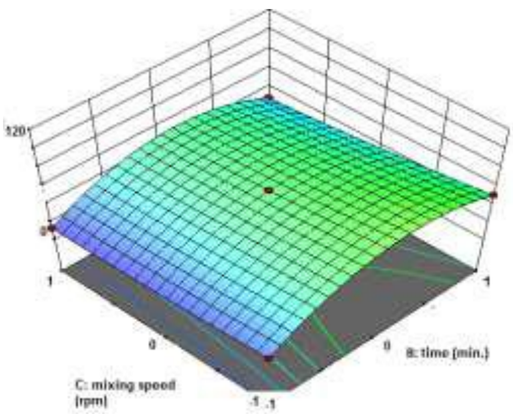
In Figure 3, where the time-solid/liquid relationship was given, the amount of phenolic substance reached 95% under the condition that the parameters took the maximum values in the extraction of the cinnamon plant. When the time was kept constant, it was determined that the concentration was 15% at the lowest solid/liquid ratio, while it caused an increase up to 80% in the highest ratio. While the interaction of binary parameters was quite high in cinnamon, it was negligible effect in the narcissus plant. On the other hand, in the graph of the mixing speed against time of the chamomile material (c), 62% concentration was reached at the conditions where the time was the highest and the mixing speed was the lowest.



a) Cinnamon



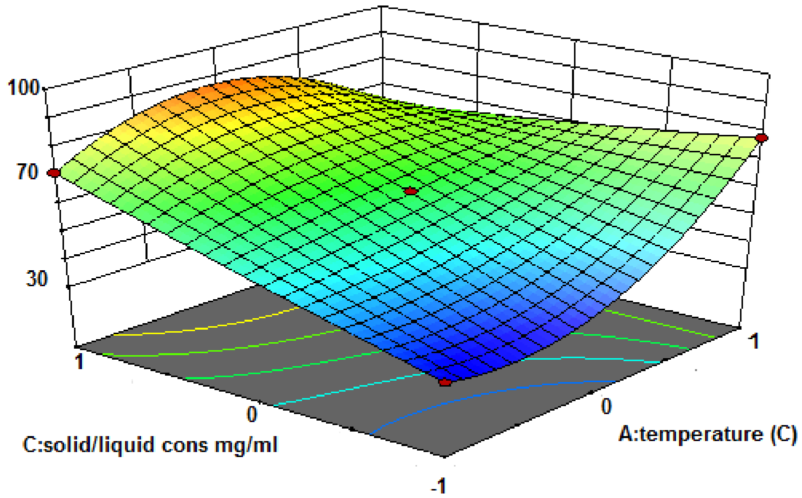
b) Pomegranate flower



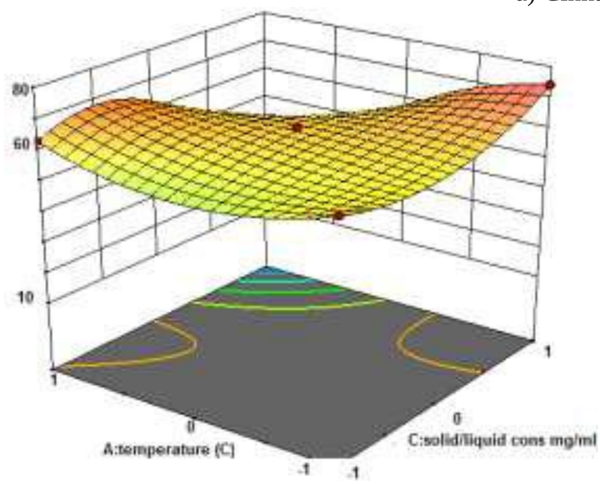
c) Chamomile

Fig 3. Three-dimensional surfaces of time-solid/liquid and time-mixing rate

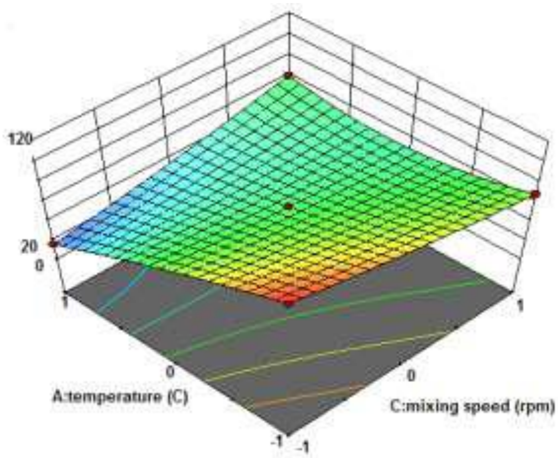
The following findings were obtained from the three-dimensional surface graphics given in Fig. 4: The highest concentration (85%) was reached in cinnamon (a) when the solid/liquid ratio was 1 and the temperature was 0. Solid/liquid ratio was more dominant than time in affecting the amount of phenolic substance in extraction. In the pomegranate (b) plant, on the other hand, it could be seen from the abundance of red regions that high concentrations were reached in all conditions. Although the effect of the double interaction of temperature and solid/liquid ratio parameters on yield was very low in cinnamon and pomegranate flower, it was determined that this change tripled the yield in chamomile. This situation supports that choosing the mixing speed as a parameter for the plant in question is a correct approach.



a) Cinnamon



b) Pomegranate flower



c) Chamomile

Fig 4. Three-dimensional surfaces of temperature-solid/liquid and temperature-mixing

The optimum extraction conditions obtained with the numerical solutions of the program are given in Table V. Under these conditions, extraction was carried out and final beverage samples were prepared.

Table V. Optimum parameters obtained by numerical optimization

	Chamomile	**Cinnamon**	**Pomegranate flower**
Temperature (°C)	25.04	27.00	42.00
Time (min)	41.00	59.7	50.00
Solid/liquid (g/ml) or mixing rate (rpm)	90.00	1.5/40	1.19/40

The chemical and physical analysis results of these beverages were presented in Table VI. Despite the addition of the same amount of sodium caseinate, sucrose and herbal extract, the differences in the amounts and types of phenolic substances contained in the extracts caused the final sample viscosity to be lower than the viscosity of the whey. Both the pH analysis and the total acidity value of the beverage prepared from the pomegranate plant, which is also known for its mild unpleasant taste, were found to be more acidic than whey and other beverages, and the amount of sugar of it was higher. The fact that the dry matter content of the final beverage samples was higher than the whey was an expected result due to the added materials. The total phenolic content of the drinks was found to be quite close to each other.

Table VI. Physical and chemical analysis results of beverages

	Analysis before Beverage production	Analysis of beverages		
	Whey	Pomegranate flower	Cinnamon	Chamomile
Viscosity (10^{-4})	9.840	9.62	9.13	8.84
pH	4.6	3.15	4.70	5.07
Acidic value (%)	3.96	4.23	1.04	1.18
Amount of reduced sugar (mg/ml)	NA	11.20	9.80	4.32
Total dry matter (gr/ml)	0.03	0.057	0.056	0.051
Total phenolics	NA	106.21	90.72	80.48

NA: Not available

Sensory analysis of beverage samples was performed with 10 volunteer groups. In terms of both fragrance and color, the ranking obtained was as pomegranate flower > daisy > cinnamon; and in terms of taste, it was in the form of narcissus > cinnamon > chamomile. Volunteers found the vivid and red color of the pomegranate flower and its cherry-like taste attractive, and stated that the slightly yellow color of the chamomile reminded of the protein and the smell of the natural antioxidant. Cinnamon, on the other hand, took the last place because it is very sharp in terms of color and smell. The sugary structure of cinnamon caught the liking of many people, but the amount of sugar was too much for some people.

Table VII. Results of sugar type analysis by HPLC

Samples	Sucrose	Glucose	Fructose
Cinnamon (ppm)	24278.9	369.4	207.6
Chimomile (ppm)	34409.9	1364.8	656.1
Pomegranate flower (ppm)	38857.9	1205.0	NA

NA: Not available

Since three grams of sucrose is added to each sample while the beverage samples are being prepared, it is an expected result that the sucrose ratio is high in the final samples. The presence of some amount of sucrose in their chemical contents of chamomile and narcissus made them have higher ratios than cinnamon. The most glucose was detected in the beverage obtained from the chamomile plant, then in the pomegranate flower and then in cinnamon. It has been observed that there is no fructose in the beverage obtained from the pomegranate flower. The phenolic component amounts of the final beverage samples are given in table VII. According to the results, while the drink containing pomegranate flower was found to be the richest in terms of chlorogenic acid, the drink found the richest in terms of rosmarinic acid was cinnamon.

Table VII. Analysis of phenolic type by HPLC

	Cinnamon	Chamomile	Pomegranate flower
Gallic acid (ppm)	0.1	NA	1.0
Protocatechic acid (ppm)	2.3	1.2	4.3
P-hydroxy benzoic acid (ppm)	1.5	0.2	NA
Chlorogenic acid (ppm)	NA	3.1	37.7
Caffeic acid (ppm)	0.2	1.8	NA
Benzoic acid (ppm)	2.8	2.4	0.5
Rutin (ppm)	NA	0.8	1.8
Rosmarinic acid (ppm)	1032.6	NA	6.7
Cinnamic acid (ppm)	14.0	0.1	0.4

NA: Not available

IV. Conclusion

In this study, the producibility of non-alcoholic beverages based on cinnamon, pomegranate flower and chamomile plant extracts, rich in whey components and sodium caseinate content, was proven. As a result of the study findings, it is predicted that cinnamon-based beverages may have an effect that can be used as a support in cancer treatment due to their richness in rosmarinic acid and as a sedative in neurodegenerative diseases due to their richness in cinnamic acid. Chamomile, which is known for having many positive effects on cancer cells and for its calming effect, gets this feature from the protocatechic acid it contains. The chlorogenic acid found in the pomegranate-based drink is used to relieve edema and neutralize harmful components that accumulate in the body. The fact that each of the produced beverages contains many different phenolic components reveals beverage samples suitable for continuous consumption that can support many different treatments. Eight cinnamon-based, 2.5 chamomile-based or 10 pomegranate flower-based beverage samples (330 ml) would be sufficient to complete the daily average intake of phenolic substances.

V. Acknowledgements

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