Studies on formulation of whey protein enriched concentrated tomato juice beverage

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Abstract Whey protein components derived from cheese whey and heat and acid coagulated Indian products (*paneer*, *chhana*, *chakka*) possess valuable functional and nutritional properties. Tomato products rich in lycopene are reported to be anticarcinogenic and antioxidative. The main objective of this study was to formulate a whey protein enriched tomato juice concentrate for use as beverage by employing Response Surface Methodology (RSM) engaging the Central Composite Rotatable Design (CCRD). The ingredients range used for this formulation comprised of Whey Protein Concentrate (WPC) 4–8 g, Cane sugar 10–20 g and Guar gum (stabilizer) 0.75–1.25 g in 100 g of concentrated tomato juice. The most preferred reconstituted beverage was obtained from the formulation developed with WPC 4.98 g, sugar 15.71 g and Guar gum 0.93 g added to 100 g tomato juice concentrate.

Keywords WPC · Tomato juice · Whey protein · Response surface methodology · Beverage

Introduction

Utilization of whey proteins in the production of various protein rich fruit juice beverages, vegetable soups and other food

preparations is receiving great attention world over for promoting the use of whey solids (Puranik 2001; Kosikowski 1979; Mann 1987; Kravchenko 1988; Driessen and Van Den Berg 1990; Jelen 1992; Singh et al. 1994). A number of therapeutic and medicinal properties have been identified in whey proteins components as a source of essential amino acids; growth regulators; modulators and protectors against microbial infections (Regester et al. 1996; Renner and Abu-El-Salam 1991). Whey components promote the multiplication of *Bifidobacteria* and other desirable microflora in the intestines. Whey proteins promote immune system and antitoxin activity (Giovannucci 1999). The abundance of research attention currently being focused on multiple health benefits of whey proteins testifies the power and potential of this incredible and physiologically active food in human health. Tomato and its products are rich source of lycopene, minerals, sugars, vitamins and organic acids with therapeutic attributes (Gould 1992).

The high anti oxidative property of lycopene is reported to prevent the occurrence of various kinds of cancers in human body (Rajoria et al. 2010). Tomato production in India is picking up with the cultivation of high yielding and disease resistant varieties. Enhanced tomato production is opening up new avenues for its utilization in value added products. In a study on this subject (Rajoria et al. 2011), it has been reported that tomato juice beverage enriched with whey was highly acceptable to sensory team. A new product in concentrated form is expected to cut the packaging and transportation costs considerably.

The present work shows some novelty associated to the establishment of the optimum level of WPC added to concentrated tomato juice without impairing the sensory properties of whey protein enriched beverage. The present study was, therefore, planned to optimize a product mix for tomato juice concentrate admixed with WPC for use as a beverage.

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Formulation of a new product by combining whey proteins and tomato juice concentrate would hold great promise for product diversification by promoting profitable utilization of whey solids and tomato juice.

Materials and methods

The source of various raw materials used in the preparation of WPC enriched concentrated tomato juice are described hereunder:

WPC The export grade WPC (WPC -70) containing 69.5 % protein was procured from M/s Mahaan Proteins Ltd., Kosikalan, U.P.

Tomato juice concentrate The tomato juice concentrate was produced in a multiple effect vacuum evaporator (150 kg/hour water evaporation rate) by first standardizing the inlet and outlet temperature. Tomato juice obtained from hot break process (heating at 85 °C for 15 min), after removal of pulp, was concentrated to total soluble solids of 18° Brix. The separated pulp was subsequently returned to vacuum evaporated tomato juice to achieve a final total solid content of 25.4 %. Tomato concentrate was stored in cans at 5 °C and analysed for its physico-chemical properties.

Guar gum Food grade Guar gum (Hindustan gums, Bhiwani) was purchased from Delhi market.

Packaging materials Metalized polyester containers having thickness of 100 gauge and coated with 50 µm aluminum (18×25 cm size) were used for storage of whey protein enriched concentrated tomato juice. Glass bottles of 200 ml capacity with crown corks were used for packing reconstituted WPC enriched concentrated tomato beverage.

Production of concentrated tomato juice Fresh and ripe tomatoes were procured and chopped after washing. The crushed tomatoes were pre heated to 85 °C and passed through a pulper to remove seed and residues. Filtration was carried out and residual pulp was stored separately. The clear tomato juice was vacuum concentrated (50–55 °C) and residual pulp was admixed with concentrated juice. The concentrated tomato juice was pasteurized by heating at 80 °C for 15 min Gould (1992) and packed in pre-sterilized cans and after cooling stored at 5 °C for further use.

Response Surface Methodology (RSM) Design Expert software of Version 7.1.5 (Statease Inc., USA) was used for RSM study using Central Composite Rotatable Design (CCRD). The independent variables comprised of WPC (4–8 g), sugar (10–20 g) and guar gum (0.75–1.25 g). The sensory responses

Table 1 The Central Composite Rotatable Design for Whey Protein Concentrate, Sugar and Guar gum with sensory scores

Trial no.	Composition			Sensory scores				
	WPC (g)	Sugar (g)	Guar gum (g)	Flavour	Colour and appearance	Sweetness	Consistency	Overall acceptability
1	4.0	10.0	0.75	7.2	7.4	7.5	7.5	7.4
2	8.0	10.0	0.75	4.6	4.8	5.1	5.1	5.0
3	4.0	20.0	0.75	7.0	7.2	7.3	7.0	7.1
4	8.0	20.0	0.75	6.2	6.3	6.4	6.7	6.5
5	4.0	10.0	1.25	7.1	6.7	6.8	7.5	7.2
6	8.0	10.0	1.25	5.6	5.4	5.2	5.8	5.6
7	4.0	20.0	1.25	6.3	6.8	6.5	6.7	6.6
8	8.0	20.0	1.25	5.8	6.2	6.4	6.0	6.1
9	2.64	15.0	1.0	7.5	7.6	7.5	7.4	7.5
10	9.36	15.0	1.0	4.8	4.5	5.3	4.6	4.8
11	6.0	6.59	1.0	5.6	5.8	5.1	6.4	5.8
12	6.0	23.41	1.0	6.6	7.0	6.0	6.4	6.6
13	6.0	15.0	0.58	7.8	7.8	8.0	7.3	7.6
14	6.0	15.0	1.42	7.4	7.6	7.3	7.4	7.6
15	6.0	15.0	1.0	8.0	8.1	8.0	8.2	8.0
16	6.0	15.0	1.0	8.5	8.3	8.1	8.0	8.3
17	6.0	15.0	1.0	8.0	8.2	8.0	8.1	8.1
18	6.0	15.0	1.0	8.2	8.5	8.0	7.8	8.0
19	6.0	15.0	1.0	7.8	7.8	8.0	7.9	8.0
20	6.0	15.0	1.0	8.1	7.9	8.0	8.2	8.0

Table 2 Regression coefficients and ANOVA of fitted quadratic model of reconstituted Whey Protein Concentrate Concentrated Tomato Juice

Partial coefficients	Sensory characteristics				
	Flavour	Colour and appearance	Sweetness	Consistency	Overall acceptability
Intercept	8.11	8.14	8.02	8.03	8.07
A-WPC (g)	83.85 ^a	88.26 ^a	2543.29 ^a	158.64 ^a	211.03 ^a
B-Sugar (g)	5.23	13.94 ^a	414.83 ^a	0.41	13.58 ^a
C-Guar gum (g)	0.65	0.69	223.19 ^a	0.029	0.57
A^2	94.71 ^a	97.66 ^a	2230.28 ^a	163.58 ^a	221.69 ^a
B^2	99.21 ^a	69.65 ^a	5135.84 ^a	104.91 ^a	210.70 ^a
C^2	9.65 ^a	6.96 ^a	127.38 ^a	17.57 ^a	16.42 ^a
AB	11.36 ^a	7.70 ^a	516.26 ^a	27.05 ^a	32.60 ^a
AC	2.84	3.42	146.85 ^a	0.25	3.14
BC	5.79 ^a	0.21	2.29	8.13 ^a	6.55 ^a
Lack of fit	NS	NS	NS	NS	NS
Model F value	31.99 ^a	29.74 ^a	1178.63 ^a	49.33 ^a	73.64 ^a
R^2	0.966	0.964	0.999	0.978	0.985
Press	4.94	5.23	0.11	2.79	2.09
Adeq. Press	16.296	16.459	88.620	21.583	25.038

NS non significant

^a Significant at 1 %

selected were flavour, colour and appearance, sweetness, consistency and overall acceptability as per CCRD (Table 1).

Goal set in RSM for optimizing Whey Protein Concentrate Concentrated Tomato Juice The constituents of concentrated beverage as WPC, Sugar and Guar gum were set in range 4–8 g, 10–20 g and 0.75–1.25 g, respectively. The responses of sensory attributes like flavour, colour and appearance, sweetness, consistency and overall acceptability were set to maximize level in RSM software.

Optimization studies for production of WPC enriched Concentrated Tomato Juice (WPC CTJ) The RSM based on CCRD delineated in Table 1 was used for selecting an optimum combination of WPC (69.5 % protein), Sugar and Guar gum. The experiment comprised of 20 trials. The ingredients mentioned in each trial were blended with 100 g of tomato juice concentrate. The formulated samples were reconstituted with previously boiled and chilled potable water to achieve 16°Brix (total soluble solids). The final pH of product mixes was adjusted to 4.25 using 50 % citric acid solution in accordance with the reported studies conducted for tomato juice enriched whey beverage (Rajoria et al. 2011a). The reconstituted beverages were served to sensory panelists at a temperature of 10 °C.

The quadratic models for various sensory parameters were derived from successive regression analysis. The partial coefficient of regression of these responses with respect to the levels of three factors in the form of correlation is presented in Table 2.

Physico-chemical analysis Total solids (%) in the whey protein enriched concentrated tomato juice beverage were determined

using gravimetric method. Total soluble solids in tomato juice and concentrates were measured using hand held calibrated Refractometer (0–32° Brix). The pH of the formulated beverage was determined using a microprocessor controlled pH meter (LABINDIA) at 20 °C. Acidity as percent citric acid was determined by titration against 0.1 N NaOH solution duly standardized with 0.1 N Oxalic acid solution using phenolphthalein as an indicator. Total protein content in the samples was determined by Micro-Kjeldahl method (AOAC 1984). Fat content was measured using Rose-Gottlieb's method described in IS: SP-Part-XI (1980). Reducing and total sugars were estimated by adopting the method of Lane and Eynon (1923). Ash content was determined by the method of AOAC (1997). Lycopene and ascorbic acid estimation were carried out with the help of the methods described by Ranganna (1985). The Polysaccharides content were mathematically calculated by difference.

Sensory evaluation A panel of seven judges was selected on the basis of triangle test for sensory evaluation (Amerine et al. 1965) and acquainted with the attributes of the tomato whey beverage, WPC enriched tomato beverage and reconstituted WPC enriched concentrated tomato juice. A nine point hedonic scale was employed for sensory rating.

Statistical analysis ANOVA obtained from RSM software was used for optimization studies using various combinations of WPC, sugar and Guar gum. *T* test was performed with the predicted and observed values (three replicates) of optimized formulation for calculating the statistical significance.

Results and discussion

The results of sensory evaluation are mentioned in Table 1. The sensory responses elicited from the panelists on hedonic scale were subjected to diagnostic check in the quadratic model. The model F-values for all attributes were more than the table F value ($P < 0.01$). The coefficient of determination (R^2) was more than 0.964 for all responses, indicating that the fitted quadratic model accounted for more than 96 % of variation in experimental data.

The non-significant lack of fit test indicated that model is sufficiently accurate for determining the organoleptic characteristics of whey protein enriched tomato beverage prepared from any combination of the variables within the range evaluated. The adequate precision, which measures the signal-to-noise ratio, is more than four for all the responses, which is highly desirable (Table 2).

Sensory characteristics of different formulations

Effect on flavour

The flavour scores in the formulations out of a maximum of 9.0 ranged from 8.5 to 4.6. The reconstituted sample in trial No. 16 (Table 1) scored maximum which was composed of 6.0 g WPC, 15.0 g sugar and 1.0 g Guar gum. The flavour scores in Trial No. 2 and 10 were minimum. It may be observed that any increase in the concentration of WPC above 6.0 g will decrease the flavour scores drastically in combination with other ingredients at different levels. The RSM plots for flavour scores are depicted in Fig. 1 by maintaining the constant levels of Guar gum, sugar and WPC, respectively. The following response surface equation got developed to predict the change in flavour due to different levels of sugar and Guar gum.

$$\begin{aligned} \text{Flavour} = & -5.30792 + 1.02033 \times \text{WPC} + 0.95127 \times \text{sugar} \\ & + 8.33847 \times \text{Guar gum} + 0.03500 \times \text{WPC} \\ & \times \text{sugar} + 0.3500 \times \text{WPC} \times \text{Guar gum} - 0.200 \\ & \times \text{sugar} \times \text{Guar gum} - 0.18827 \times \text{WPC}^2 - 0.030831 \\ & \times \text{sugar}^2 - 3.84704 \times \text{Guar gum}^2 \end{aligned}$$

The model F-value for flavour attribute was 31.99. This value was greater than the F table value at 1 % level of confidence making it significant. The R^2 value for flavour was 0.966 which indicates that the fitted quadratic model accounted for more than 96.6 % of the variation in experimental data. The lack of fit test, which measures the fitness of the model obtained, did not result in a significant change in F-value, indicating that the model is sufficiently accurate for predicting the sensory attributes of whey enriched tomato beverage made with any combination of ingredients in the

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Flavour

8.5
4.6
X1 = A: WPC
X2 = B: sugar
Actual Factor
C: Stabilizer = 1.00

Guar Gum level - Constant

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Flavour

8.5
4.6
X1 = A: WPC
X2 = C: Stabilizer
Actual Factor
B: sugar = 15.00

Sugar level - Constant

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Flavour

8.5
4.6
X1 = B: sugar
X2 = C: Stabilizer
Actual Factor
A: WPC = 6.00

Whey Protein Concentrate level - Constant

Fig. 1 Response surface plot for sensory flavour score of reconstituted Whey Protein Concentrate Concentrated Tomato Juice as a function of Whey Protein Concentrate, Guar gum and sugar levels

range evaluated. The value of adequate press as 16.296 was greater than 4 which confirmed an adequate signal and the model can be used to navigate the design space (Table 2).

Effect on colour and appearance

The colour is a significant attribute of fruit juice beverages contributing to first impression about quality. The colour and appearance scores in the formulation ranged from 8.5 to 4.5 (Table 1). The colour and appearance score was maximum in formulation No. 18 having 6.0 g WPC, 15.0 g sugar and 1.0 g Guar gum. The minimum scores were given in trial No. 10 having maximum percentage of WPC as 9.36 g with 15.0 g of sugar and 1.0 g Guar gum, respectively. The sensory panelists during post evaluation session opined that use of WPC above 6.0 g was not advisable because of reduced colour and flavour scores. The response surface plots for colour and appearance as a function of WPC and sugar level, WPC and Guar gum level and sugar and Guar gum level are shown in Fig. 2, respectively. The following response surface equation was developed to predict the change in colour and appearance with different levels of WPC, sugar and Guar gum.

$$\begin{aligned} \text{Color and appearance} = & -2.28853 + 1.14885 \times \text{WPC} \\ & + 0.72825 \times \text{sugar} + 4.72407 \\ & \times \text{Guar gum} + 0.0300 \times \text{WPC} \\ & \times \text{sugar} + 0.400 \times \text{WPC} \\ & \times \text{Guar gum} - 0.0400 \times \text{sugar} \\ & \times \text{Guar gum} - 0.19895 \times \text{WPC}^2 \\ & - 0.026883 \times \text{sugar}^2 - 3.39916 \\ & \times \text{Guar gum}^2 \end{aligned}$$

The model F-value for colour and appearance attribute was found to be 29.74. This value is higher than the F table value at 1 % level of confidence making it significant. The R^2 value for colour and appearance was 0.964 which indicates that the fitted quadratic model accounted for more than 96.4 % of the variation in experimental data. The lack of fit test, which measures the fitness of the model obtained, did not result in a significant F-value, indicating that the model is sufficiently accurate for predicting the sensory attributes of whey enriched tomato beverage formulated with any combination of three factors. The value of adequate press of 16.459 being greater than 4 indicated an adequate signal and the model can be used to navigate the design space (Table 2).

Effect on sweetness

The taste perception in acidic beverages is influenced by sweet and sour ratio. Presence of aroma compounds can influence perception of sweetness and sourness. The pH set for the concentrated juice in combination with sweetness predicts the exact sweetness of reconstituted juice. The sweetness scores in all the formulations ranged from 8.1 to

5.1 (Table 1). The maximum score was observed in Trial No. 16 which was formulated with 6.0 g WPC, 15.0 g sugar and

Design-Expert® Software
color appear

8.5
4.5
X1 = A: WPC
X2 = B: sugar
Actual Factor
C: Stabilizer = 1.00

Guar Gum level - Constant

Design-Expert® Software
color appear

8.5
4.5
X1 = A: WPC
X2 = C: Stabilizer
Actual Factor
B: sugar = 15.00

Sugar level - Constant

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color appear

8.5
4.5
X1 = B: sugar
X2 = C: Stabilizer
Actual Factor
A: WPC = 6.00

Whey Protein Concentrate level - Constant

Fig. 2 Response surface plot for sensory colour and appearance score of reconstituted Whey Protein Concentrate Concentrated Tomato Juice as a function of Whey Protein Concentrate, Guar gum and sugar levels

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Sweetness

8.1
5.1

X1 = A: WPC
X2 = C: Stabilizer

Actual Factor
B: sugar = 15.00

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Sweetness

8.1
5.1

X1 = A: WPC
X2 = B: sugar

Actual Factor
C: Stabilizer = 1.00

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Sweetness

8.1
5.1

X1 = B: sugar
X2 = C: Stabilizer

Actual Factor
A: WPC = 6.00

Fig. 3 Response surface plot for sensory sweetness score of reconstituted Whey Protein Concentrate Concentrated Tomato Juice as a function of Whey Protein Concentrate, Guar gum and sugar levels

1.0 g Guar gum. The minimum sweetness scores were observed in Trial No. 2 having lowest amount of sugar (6.59 g) and higher amount of WPC.

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Consistency

8.2
4.6

X1 = A: WPC
X2 = B: sugar

Actual Factor
C: Stabilizer = 1.00

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Consistency

8.2
4.6

X1 = A: WPC
X2 = C: Stabilizer

Actual Factor
B: sugar = 15.00

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Consistency

8.2
4.6

X1 = B: sugar
X2 = C: Stabilizer

Actual Factor
A: WPC = 6.00

Fig. 4 Response surface plot for sensory consistency score of reconstituted Whey Protein Concentrate Concentrated Tomato Juice as a function of Whey Protein Concentrate, Guar gum and sugar levels

The RSM plots for sweetness as influenced by WPC, sugar and Guar gum are depicted in Fig. 3. The following response

surface equation got developed to predict the change in sweetness with different levels of WPC, sugar and Guar gum.

$$\begin{aligned}\text{Sweetness} = & +8.88322\text{E} - 003 + 0.46116 \times \text{WPC} \\ & + 0.90395 \times \text{sugar} + 1.58626 \times \text{Guar gum} \\ & + 0.037500 \times \text{WPC} \times \text{sugar} + 0.400 \times \text{WPC} \\ & \times \text{Guar gum} - 0.0200 \times \text{sugar} \times \text{Guar gum} \\ & - 0.14518 \times \text{WPC}^2 - 0.035250 \times \text{sugar}^2 \\ & - 2.22056 \times \text{Guar gum}^2\end{aligned}$$

The model F-value for sweetness attribute was 1,178.63, higher than the F table value at 1 % level of confidence making it significant. The R^2 value was 0.999 for sweetness which indicates that the fitted quadratic model accounted for more than 99.9 % of the variation in experimental data. The lack of fit test, which measures the fitness of the model obtained, did not result in a significant F-value, indicating that the model is sufficiently accurate for predicting the sweetness of reconstituted whey protein enriched tomato juice made with any combination of three factors within the range evaluated. The value of adequate press as 88.620 being greater than 4 indicated an adequate signal and the model can be used to navigate the design space (Table 2).

The major sugars in tomato juice are glucose and fructose in almost equal amounts, with little or no sucrose in ripe fruits. Plant breeders are getting interested in increasing the levels of sucrose in order to make a sweeter tomato. It is generally recognized that fructose is sweeter than sucrose and both the sugars are sweeter than glucose. The sweetness of tomato juice may be increased by fructose, but this may render the beverage much more expensive.

Effect on consistency

The consistency of a liquid food is determined by its viscosity, flowability, smoothness and density. The consistency scores in the total formulations ranged between 8.2 and 4.6 (Table 1). The maximum consistency score was obtained in Trial No. 15 and 20 having 6.0 g WPC, 15.0 g sugar and 1.0 g Guar gum. The minimum score for consistency was found in Trial No. 10 formulated with 9.36 g WPC, 15.0 g sugar and 1.0 g Guar gum. It can be seen from the formulations that the consistency scores got reduced even at highest levels of WPC and sugar in combination with Guar gum.

The RSM plots for consistency as influenced by WPC, sugar and Guar gum are exhibited in Fig. 4. The following response surface equation was developed to predict the change in consistency with different levels of three constituents.

The following response surface equation was developed to predict the change in consistency with different levels of WPC, sugar and Guar gum.

$$\begin{aligned}\text{Consistency} = & -3.72755 + 1.11463 \times \text{WPC} + 0.62712 \times \text{sugar} \\ & + 9.50797 \times \text{Guar gum} + 0.038750 \times \text{WPC} \\ & \times \text{sugar} + 0.07500 \times \text{WPC} \times \text{Guar gum} \\ & - 0.1700 \times \text{sugar} \times \text{Guar gum} - 0.17750 \\ & \times \text{WPC}^2 - 0.022743 \times \text{sugar}^2 - 3.72329 \\ & \times \text{Guar gum}^2\end{aligned}$$

The model F-value for consistency attribute was 49.33. This value was higher than the F table value at 1 % level of confidence making it significant. The R^2 value for consistency was 0.978 which indicates that the fitted quadratic model accounted for more than 97.8 % of the variation in experimental data. The lack of fit test, which measures the fitness of the model, did not result in a significant F-value, indicating that the model is sufficiently accurate for predicting the consistency of the beverage made with any combination of three constituents within the evaluated range. The value of adequate press as 21.583 being greater than 4 indicated an adequate signal and the model can be used to navigate the design space (Table 2).

Effect on overall acceptability

The overall acceptability is the manifestation of all the sensory attributes compounded together during sensory evaluation. The overall acceptability scores ranged between 8.3 and 4.8. The maximum overall acceptability score was assigned to Trial No. 16 as was also the case for other sensory attributes. The minimum overall acceptability score was obtained in Trial No. 10 (Table 1).

The RSM plots for overall acceptability as influenced by WPC, sugar and Guar gum are illustrated in Fig. 5. The following response surface equation was developed to predict the change in overall acceptability with different combinations of the ingredients used in the formulations.

$$\begin{aligned}\text{Overall acceptability} = & -3.12612 + 0.99134 \times \text{WPC} \\ & + 0.77232 \times \text{sugar} + 6.58795 \\ & \times \text{Guar gum} + 0.036250 \times \text{WPC} \\ & \times \text{sugar} + 0.22500 \times \text{WPC} \\ & \times \text{Guar gum} - 0.1300 \times \text{sugar} \\ & \times \text{Guar gum} - 0.17609 \times \text{WPC}^2 \\ & - 0.027467 \times \text{sugar}^2 - 3.06720 \\ & \times \text{Guar gum}^2\end{aligned}$$

The model F-value for overall acceptability was found to be 73.64. This value was higher than the F table value at 1 % level of confidence making it significant. The R^2 value for overall acceptability was 0.985 which indicates that the fitted

quadratic model accounted for more than 98.5 % of the variation in experimental data. The lack of fit test, which measures the fitness of the model obtained, did not result in a

Table 3 Verification of the predicted and observed sensory scores of Whey Protein Concentrate Concentrated Tomato Juice

Sensory attributes	WPC enriched concentrated tomato juice		
	Predicted value	Observed value ^a	t _{0.01} value
Flavour	8.37	8.30±0.09	1.12 ^{ns}
Colour and appearance	8.31	8.20±0.08	0.91 ^{ns}
Sweetness	8.26	8.17±0.09	2.12 ^{ns}
Consistency	8.20	8.15±0.08	1.0 ^{ns}
Overall appearance	8.26	8.22±0.06	1.3 ^{ns}

^{ns} not significant ($P < 0.01$)

^a Figures are the Mean ± S.D. of three replications

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OA

X1 = A: WPC
X2 = B: sugar

Actual Factor
C: Stabilizer = 1.00

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OA

X1 = A: WPC
X2 = C: Stabilizer

Actual Factor
B: sugar = 15.00

Design-Expert® Software

OA

X1 = B: sugar
X2 = C: Stabilizer

Actual Factor
A: WPC = 6.00

Fig. 5 Response surface plot for sensory overall acceptability (OA) score of reconstituted Whey Protein Concentrate Concentrated Tomato Juice as a function of Whey Protein Concentrate, Guar gum and sugar levels

significant F-value, indicating that the model is sufficiently accurate for predicting the overall acceptability of the beverage formulated with any combination of factors within the evaluated range. The value of adequate press as 25.038 being greater than 4 indicates an adequate signal and the model can be used to navigate the design space (Table 2).

Optimized solution for the formulation and its validation

The criteria for optimizing the formulations were based on the sensory evaluation. The three factors viz. WPC, sugar and Guar gum were kept within the range and responses as sensory scores were aimed at maximum during the course of optimization. The RSM studies concluded that most acceptable product mix with maximum desirability (0.981) could be formulated with 4.98 g WPC, 15.7 g sugar and 0.93 g of Guar gum to be mixed with 100 g of concentrated tomato juice. The verification was conducted by reconstituting the formulated product into beverage and comparing the predicted and observed values using *t*-test which were not found significant, thus validating the suggested solution from RSM to be the most preferred formulation (Table 3).

Composition of WPC enriched concentrated tomato juice

The concentrated product tested 61.48 % moisture, 5.42 % proteins, 0.5 % fat, 23.15 % sugar, 2.86 % ash, 6.59 % polysaccharides, 21.85 mg/100 g ascorbic acid and 128.0 mg/100 g of lycopene. Fresh tomato juice (Total solids 7.0 to 8.5 %) contains about 0.7 % of polysaccharides comprising of pectin and arabinogalactose (about 50 %) xylans, arabinoxylans (about 25 %) and cellulose (about 25 %). The degree of concentration of fresh tomato juice may result in 15 to 24 % soluble solids (USDA Standards). According to Gould (1983) the concentrated tomato juice may contain: moisture around 75 %, protein 3.4 %, fat 0.4 %, total carbohydrates 17.1 %,

fibre 0.9 % and ash 4.1 %. In the present study, the concentrated product carried higher amounts of total solids because of added WPC, sugar and Guar gum. The ascorbic acid content was reported as 49 mg/100 g which is nearly two times higher than in the present investigation. Ascorbic acid is prone to oxidation and processing of tomato juice and presence of other ingredients.

Conclusion

The most preferred formulation was achieved by admixing WPC 4.98 g, sugar 15.7 g and Guar gum 0.93 g with 100 g of concentrated tomato juice using Central Composite Rotatable Design with Response Surface Methodology.

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