

**PROCESS STANDARDIZATION FOR WHEY PROTEIN
CONCENTRATE ENRICHED *SHRIKHANDWADI***

By

Mr. TORADMAL ROHAN KANTILAL

(Reg. No. K-15/151)

A Thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH,

RAHURI, DIST. AHMEDNAGAR,

(M.S.), INDIA

In partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

In

DAIRY SCIENCE

DIVISION OF ANIMAL HUSBANDRY AND DAIRY SCIENCE

COLLEGE OF AGRICULTURE, KOLHAPUR

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2017

CANDIDATE'S DECLARATION

*I hereby declare that this thesis or part
there of has not been submitted by
me or other person to any other
University or Institute
for a Degree or
Diploma.*

Place: Kolhapur

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Date : / /2017

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CERTIFICATE

This is to certify that the thesis entitled, “**PROCESS STANDARDIZATION FOR WHEY PROTEIN CONCENTRATE ENRICHED *SHRIKHANDWADI***”, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra State in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE) in DAIRY SCIENCE**, embodies the result of the piece of bonafide research work carried out by **Mr. ROHAN KANTILAL TORADMAL**, under my guidance and supervision and that no part of the thesis has been submitted for any other degree, diploma or publication in other form.

Place: Kolhapur.

Date: / / 2017

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CERTIFICATE

This is to certify that the thesis entitled, “**PROCESS STANDARDIZATION FOR WHEY PROTEIN CONCENTRATE ENRICHED *SHRIKHANDWADI***”, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra State in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **DAIRY SCIENCE**, embodies the result of the piece of bonafide research work carried out by **Mr. ROHAN KANTILAL TORADMAL**, under the guidance and supervision of **Dr. D. D. PATANGE**, Assistant Professor, Division of Animal Husbandry and Dairy Science, College of Agriculture, Kolhapur and that no part of the thesis has been submitted for any other university for degree, diploma or publication in other form.

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(Toradmal R. K.)

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LIST OF ABBREVIATIONS

<i>et al.</i>	Any other
@	At the rate of
CD	Critical difference
°C	Degree Celsius
etc.	Et cetera
Fig.	Figure
g.	Gram
IS	Indian standards
L.P.G.	Liquefied Petroleum Gas
ml.	Milli litre
min.	Minute
viz.,	Namely
N.D.R.I.	National Dairy Research Institute
NS	Non-significant
%	Per cent
% LA	Per cent lactic acid
SNF	Solid not fat
SE	Standard error
i.e.	That is
w/w	Weight per weight
Wt.	Weight
>	More than
<	Less than
lit.	Litre
RSM	Response surface methodology
kg/cm ²	kilo gram per centimeter square
TSS	Total soluble solid
SMP	Skim Milk Powder
WPC	Whey Protein Concentrate

NCDC	National Collection of Dairy Culture
A.O.A.C	Association Of Official Analytical Chemist

ABSTRACT

PROCESS STANDARDIZATION FOR WHEY PROTEIN CONCENTRATE ENRICHED *SHRIKHANDWADI*

by

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A candidate for the degree

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Research Guide : **Dr. D. D. Patange**
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Shrikhand is consumed as a dessert after meals. It is prepared by fermentation of milk using known strains of lactic acid bacteria followed by draining of whey and addition of sugar and flavours to the drained curd. The partial evaporation of moisture by converting into solid confection (*Shrikhandwadi*) can be an excellent means to extend the shelf-life of *Shrikhand*. Whey in the form of whey protein concentrate (WPC) has gained importance as a nutritional and functional ingredient. WPC is rich in essential amino acids and have a high Protein Efficiency Ratio, Biological Value and Net Protein Utilization.

In the present investigation, *shrikhandwadi* was prepared from buffalo milk standardized at 4 per cent fat. To know the effect of level and stage of addition of WPC and SMP, the WPC was added in six levels i.e. 1, 3, 5, 7, 9 per cent and control sample of chakka and SMP was added in three levels i.e. 5, 10 and 15 per cent. In the study of addition of two stages i.e. at before heating stage of chakka and at after heating stage of chakka. On the basis of sensory evaluation, the level of WPC and SMP was kept at 5 per cent and 10 per cent, respectively and addition of WPC and SMP at after heating stage of chakka was selected as best.

To optimize the level of WPC and sugar the experiment was conducted as per Response Surface Methodology (RSM) by using Design Expert 10.0.0 software. The prepared *shrikhandwadi* was analysed for their sensory and physico-chemical qualities. RSM experiment was conducted including two factor viz., WPC (2.17-7.84 per cent) and sugar (100-129 per cent). The results of the study revealed that the colour and appearance, body and texture, flavour and overall acceptability score of *shrikhandwadi* was recorded maximum for formulation, which had 5 per cent WPC and 115 per cent sugar and run at 1st. The statistical analysis of data revealed that the calculated adequate precision value for all the sensory score was found to be more than 4 which was high enough for satisfactory model. Further, the model 'F' value also indicate all the model was significant. The maximum per cent of moisture, protein, ash and acidity content was observed in formulation which had 9 per cent WPC and 115 per cent sugar. The protein content of *shrikhandwadi* was ranged from 9.10 to 14.10 per cent. At linear term WPC shows significant positive effect on moisture, protein, lactose, total sugar and ash content of *shrikhandwadi*.

During optimization the best solution exerted through the software contained WPC and sugar at 4.12 and 125.96 per cent, respectively. The verification of the prediction was done by actual observations recorded for sensory score. The optimized formulation had 8.22, 8.16, 8.20, and 8.19 score for colour and appearance, body and texture, flavour and overall acceptability, respectively. The optimized product formulation contained the moisture, protein, fat, lactose, total sugar, ash and acidity as 9.55, 12.10, 6.4, 22.15, 71.15, 1.12 and 1.2 per cent, respectively. Developed *shrikhandwadi* was drying in cabinet air dryer. The optimized time-temperature required for drying at 40°C for 30 min. in cabinet air dryer for preparation of *shrikhandwadi*.

1. INTRODUCTION

Indian milk sweet has played a significant role in the economic, social, religious and nutritional well being of our people. The importance of milk and milk products in India is realized since Vedic period. It supplied vitamin A and lactose. It contains milk fat which generates nearly 2.5 times more energy than other food products. It supplies milk sugar, minerals and carotene whose deficiency may lead to night blindness. Milk has been describing as most ideal food, which referred as “Bank of Nutrient”. (Ghanbahadur *et al.*, 2016). It estimated that about 50-55 per cent of milk produce is converted by the traditional sector into variety of milk product using processes such as heat and acid coagulation, heat desiccation and fermentation.

Fermented dairy products are those, which are prepared by inoculating the milk with starter culture/ organism mainly Lactic Acid Bacteria (LAB). These bacteria hydrolyze the lactose of milk into lactic acid and thus raise the acidity and decreases pH of milk. The fermentation is accompanied by jelling of solids, particularly the proteins. In some fermentation, alcohol is produced along with acids due to yeast or fungi. Fermented milk and milk products have occupied a place of satisfaction in satisfying the pallate and nutritional requirements of human being since the ancient time. Fermented milk are palatable and digestible than milk and are easily assimilated than milk by the human system and contains beneficial antibodies it also improving bowel movement. Fermented milk products improve immunity and mineral absorption (Kanawajia, 2006). Of the total milk produced in India, 7 per cent is used for the preparation of fermented milk products which mainly includes *dahi*, *lassi* and *shrikhand* (sweetened concentrated curd).

Shrikhand is fermented and sweetened milk product of Indian origin which is derived from Sanskrit word 'shrikarini' meaning a curd prepared with the addition of sugar, flavouring material, dried fruits, etc. It is regularly consumed in Gujarat, Maharashtra and certain parts of Karnataka, Madhya Pradesh and Rajasthan. In addition to these places, because of its typical sweet-sour taste, it is becoming popular in other parts of the country. *Shrikhand* has a typical semi-solid consistency with a characteristic smoothness, firmness and pliability that make it suitable for consumption directly after meal or with 'puree' or bread (Nigam *et al.*, 2009). As per FSSAI (2011) *Shrikhand* means the product obtained from chakka or skimmed milk chakka to which milk fat is added along with sugar. It may contain fruits, nuts, sugar, cardamom, saffron and other spices and blended to smooth and homogenous consistency. It shall not contain any added colouring and artificial flavouring substances. *Shrikhand* should contain minimum 58 per cent total solid (TS), milk fat minimum 8 per cent (on DM basis), milk protein min. 9 per cent (on DM basis). Consumers in Gujarat prefer its sweet type while those in Maharashtra prefer the tangy/slightly sour type (Aneja, *et al.*, 2002).

The shelf life of fermented dairy products is limited due higher moisture content, presence of microflora and to lack of efficient cold storage facilities (Gupta *et al.*, 2015). The shelf life of *Shrikhand* is 1 to 2 days at ambient temperature and its freshness is lost beyond 1 week storage under refrigerated conditions due to it contain high percentage of moisture and microbial activity. People in other country like Indian fermented dairy products but it is difficult to export due to its short storage stability. The future for commodities like powder and ghee does not appear sustainable and hence a major shift in product mix for organized dairy industry seems inevitable. Empirical

evidences also suggest that the composition of an average Indian's food basket is gradually shifting towards value added products. It is therefore essential that research priorities in the country should focus on greater value addition for imparting competitive edge to the Indian dairy industry for meeting the emerging challenges of the domestic and global market (Singh, 2006).

Preservation technologies generally employed for food products are either sterilization or dehydration. Drying or dehydration of *dahi* offers great advantage to obtain *dahi* powder which can be regarded as a convenience based ingredient in ready to use foods (e.g., kadhi mix and raita) and formulations. The formulation of health drink mix based on fermented dairy products (*dahi*) powder offers great potential for the Indian dairy industry due to the well established health benefits of *dahi* and its sensory character (Shiby and Mishra, 2007). Few attempts have also been made to prepare *Shrikhand* in ready dry mix. The powdered form of premix would be anticipated to have advantages of higher shelf life, minimal requirement of storage conditions and lower cost of packaging in addition to being consumer eco-friendly. The powder premix should be formulated in way that it can be easily reconstituted in water to prepare a *Shrikhand* as and when required. The partial evaporation of moisture by fortification into solid confection (*Shrikhandwadi*) can be excellent mean extend shelf life of *Shrikhand*. In the course of manufacture of *Shrikhand* and *Shrikhandwadi* the whey lost during the preparation of chakka as a result the protein quality of such product is hampered (Bramhapurkar *et al.*, 2007).

Today's health conscious consumers are increasingly making food choices based on a food's ability to provide health benefits, such as enhancing body functions or reducing the risk for certain disease.

Many traditional dairy ingredients provide unprecedented opportunities for the food industry to improve existing and/or develop new products with unique health benefits. New technologies to isolate dairy ingredients and emerging research identifying biological roles for dairy ingredients, such as whey proteins, are leading to growing interest in their potential use in functional foods (Smithers *et al.*, 1996).

Whey is a byproduct obtained during the production of cheese, casein, paneer, chhana, shrikhand etc. Disposal of whey has always been environmental problem due to its high Biological oxygen demand (BOD).Whey which contains nearly 50 per cent of milk solids, and thus it is great significance to utilize whey solids in human food chain. Whey represents a heterogeneous pool of proteins with wide ranging physico-chemical and functional properties. Whey in the form of whey protein concentrate (WPC) has gained importance as a nutritional and functional ingredient. WPC is rich in essential amino acids and have a high Protein Efficiency Ratio (3.6), Biological Value (104) and Net Protein Utilization (95) and are next to egg. The nutritional and functional properties of WPC are well documented. Owing to their excellent nutritional and functional properties, WPC finds numerous applications in food industry. (Sodini *et al.*, 2005) Whey and whey products have been used successfully in conventional foods, fortified, enriched or enhanced foods and dietary supplements. Whey products contribute to creaminess, texture, water binding, opacity and adhesion in a variety of food systems. Whey protein concentrates, which can now be abstracted in an extremely pure form from whey, are therefore particularly suited for the protein enrichment of several articles of food.

Considering limited shelf life of *shrikhand* and important nutritional properties of WPC, attempts have been made to standardize the value added and protein enriched *Shrikhandwadi* by addition of WPC with the following objectives

- 1) To optimize the level and stage of addition of whey protein concentrate in *Shrikhandwadi*
- 2) To optimize the time-temperature combination for preparation of *Shrikhandwadi*
- 3) To study the sensory and physico-chemical properties of *Shrikhandwadi*.

2. REVIEW OF LITERATURE

The research work was carried out on various aspects of related to *Shrikhandwadi* have been reviewed here under.

2.1 *Shrikhand* preparation:

Biyabani *et. al*, (1998) had made an attempt to develop directly acidified *shrikhand* by suitably modifying the earlier reported procedure to over come the problem of hard grainy texture. It involved standardization of buffalo milk to 6 per cent fat and bringing to boil followed by addition of disodium hydrogen phosphate at a level of 0.1 per cent. then cooled to room temperature followed by chilling to 5°C. Using 50 per cent lactic acid solution, the pH of the chilled milk was adjusted to 4.8. The acidified milk was then allowed to set in an incubator at 37°C for 3 hr. Then the *chakka* was obtained from the well set curd in the similar manner to that of conventional *chakka*. The directly acidified *chakka* was then added with 40 per cent ground sugar and 2 per cent cardamom powder and mixed thoroughly. The mixture was then passed through muslin cloth to obtain Shrikhand. However, it was reported that the overall acceptability of directly acidified Shrikhand was significantly less than that of conventional shrikhand.

Singh and Jha (2005) had developed a technology for the production of *Shrikhand* by partial replacement of sugar using Raftilose[®], a commercial sugar replacer and dietary fiber. It involved separation of milk followed by pasteurization at 90°C for 16 seconds and cooling to 37±1°C. After that the milk was inoculated with 2 per cent yoghurt culture and incubated at 42 ± 1°C. Once the desired pH of 4.3 was attained the curd was transferred into a muslin cloth and *chakka* was obtained by draining the whey. They also reported that the sensory attributes were most acceptable when sugar and Raftilose[®] were added @ 12.5 per cent and 4 per cent, respectively to the product. These workers also reported that the calorific value of conventional and developed

Shrikhand were 232.05 and 127.86 kcal/100g, respectively thereby enabling about 45 per cent reduction in total calorific value.

Ansari *et al.*, (2006) also developed the technology for the manufacture of *shrikhand* using UF pre-concentrated skim milk. It involved pasteurization of skim milk (9% TS) at 92°C for 5 min followed by cooling to 30°C. The suspended solids were removed by cloth filtration and the milk subjected to concentration using UF membrane. The UF-concentrated skim milk with 11 to 12 per cent TS was used to make *chakka*. This *chakka* after removal of whey had 18 per cent TS. It was reported that this UF-concentrated skim milk *chakka* when subsequently used for making *shrikhand* resembled conventional *shrikhand*. However, the Milk concentrate with 19 to 20 per cent TS, when directly was used for *shrikhand* making without whey drainage had a curdling time of 9 to 10 hr for reaching 2 per cent acidity. *Shrikhand* made from this *chakka* was reported to be poor in quality and showed formation of hard particles during pasteurization. Hence, these recommended further studies to improve the quality of *shrikhand* using UF-concentrated skim milk.

Kulkarni *et al.* (2006) reported method of manufacture of *Shrikhand* depends on its scale of production. The traditional method is still predominantly used for small-scale production. In this method boiled milk after cooling is fermented by using a culture to make yogurt, which is then filtered through muslin cloth to remove whey. The thickened mass known as *chakka* was pressed over a strainer to get a smooth product which when mixed with sugar gives *Shrikhand*. On an industrial scale *Shrikhand* is prepared by using different mechanical devices. In this process, pasteurized milk or skim milk is inoculated with the culture. The yogurt thus prepared is centrifuged in a continuous quarg separator to produce *chakka*, which is then mixed with cream, ground sugar and flavours in a scraped surface heat exchanger for manufacture and pasteurization of the product. Post-processing heat treatment (70°C for 5 min) for the *Shrikhand* was found to yield a product with superior overall quality and increased shelf life.

Pal and Raju (2006) also described the traditional method of making *Shrikhand* which involves the preparation of curd or dahi by culturing cow or buffalo milk with natural starter (curd of the previous batch). After a firm curd is formed, it is transferred in a muslin cloth and spell for 12-18 hr to remove free whey. The semi-solid mass obtained is called as '*chakka*'. The *chakka* is mixed with required amount of sugar, color, flavoring materials and spices and blended to smooth and homogenous consistency. *Shrikhand* is stored and served in chilled form. The batch to batch large variation in the quality and poor shelf-life of *Shrikhand* was the serious drawbacks of the traditional method. Generally the recovery of solids in *chakka* was also low.

Shukla *et al.* (2007) studied the manufacture of *shrikhand* with the application of ultra filtration technology in terms and recovery of solids and characterizing chemical and sensory attributes. An attempt was also made to standardize the formulation and process of *shrikhand* manufacture with respect to sugar levels type of lactic culture, final acidity of milk coagulation and type of flavour.

De (2009) also explained the procedure for preparation of *shrikhand*. He stated that for preparation of good quality *shrikhand*, fresh, sweet from buffalo milk, which has been standardized to 6 per cent fat, is needs pasteurized at 71°C for 8-10 minutes and cooled 28 to 30°C. Which is then inoculated @ 1 per cent lactic culture followed by incubation at 28 to 30°C for 15-16 hr. The obtained curd is then broken and placed in muslin cloth bag to drain out the whey for 8 to 10 hr. The product thus obtained is called *chakka*, in which sugar is added and kneaded for uniform mixing to get *shrikhand*.

Mehta (2013) stated that *shrikhand* is a semi soft sweetish sour milk product prepared from lactic acid fermented curd. The curd is partially strained through cloth to remove the whey, which produces a solid mass called *chakka*. It is the basic ingredient for *shrikhand*. Further, *chakka* is mixed with the appropriate quantity of sugar and found different aroma and varieties can be

prepared by adding different fruit pulps, dry fruits, saffron, cardamom and other spices.

Singh and Singh, (2014) stated that *Shrikhand* is an indigenous semi-soft, sweetish-sour, whole milk delicious and delightful dairy dessert, particularly in western part of India. It is made with chakka (strained curd/ yoghurt) which is finely mixed with sugar and flavoring agents. *Shrikhand* has very high nutritive, characteristics flavor, taste, palatable nature and possible therapeutic value. It improves the digestive system by strengthening immune system. The present article has reviewed for the use of *shrikhand* as health food in our diet.

2.2 Technologies for production of fermented milk products in dried form.

Date *et al.*, (1955) reported that the apart from improving the palatability of milk sweets is an elegant method of conserving the food value of several of the valuable constituents of milk. A large section of people have acquired a taste for lactic fermented milk in the form of *dahi* and products prepared from sour milk are therefore, quite popular. Of the milk products, Burfi prepared from whole milk and *Shrikhandwadi* prepared from dahi are made in many Indian households. Because of the low keeping quality of these products, they are not normally kept for more than a few days.

Kumar and Mishra (2004) developed yoghurt powders with primary objective to preserve yoghurt in a shelf-stable powdered form without refrigeration. Such powder can be prepared by various methods, viz. freeze-drying, spray-drying, microwave-drying and vacuum drying. Before drying, it is beneficial to concentrate yoghurt by different methods including cloth bag method, mechanical, centrifugation, ultrafiltration and vacuum concentration. They found *S. thermophilus* shows less sensitivity in comparison to *L. bulgaricus*, during freeze as well as spray-drying of yoghurt and freeze-dried yoghurt can be stored for up to 1–2 years at 4°C. After 1 year of storage, the powder typically contained total bacterial counts of 10⁶ cfu/g. Active cultures

are spell for 1 year under cool, dry conditions for spray-dried yoghurt; it can be used in the bakery and confectionary industries.

Shiby and Mishra (2007) conducted study on air drying of *dahi*, for buffalo milk was standardized to 4.5 per cent fat and 10 per cent solids-not-fat, mixed in a high speed mixer at 19000 rpm and then pasteurized at 85°C for 15 min. The milk was then cooled to 22°C and inoculated with NCDC-167 at the rate of 2.5 per cent and incubated at 29°C for 16 hr. *Dahi* was dried in a laboratory scale re-circulatory convective air dryer to a final moisture content of 0.04 kg water/kg dry solid⁻¹. Drying characteristics of *dahi* were investigated under varying conditions of *dahi*

Bramhapurkar *et al.* (2007) standardized the process for preparation of *Shrikhandwadi* blending of chakka, sugar (100%) and skim milk powder (15 %) in a shallow pan fallowed by heating. The obtained thick mass then cooled and make into rectangular pieces and stored at room temperature.

Gupta *et al.* (2015) prepared *Shrikhand* premix using microencapsulated rice bran oil as fat alternative and hydrocolloids as texture modifier. A premix of *Shrikhand* was prepared using skim milk powder, skim milk curd, sucrose and microencapsulated rice bran oil (RBO) as fat alternative. RBO was microencapsulated using spray drying under the optimized conditions of air inlet temperature (135°C), feed rate (15 ml/hr) and solid content (17%) in emulsion. They found that Hicap-100 (modified starch) was showed best encapsulation (62.83 ± 0.57%) to RBO as compared to that of gum arabic and maltodextrin as wall material. The premix was used to prepare *Shrikhand* and compared with market sample with respect to composition, texture, colour and sensory profile. Addition of blend of xanthan and gellan gum (80:20) improved the texture of prepared *Shrikhand* to the level of market *Shrikhand*.

Shiby and Pandey (2015) development of lassi powder by D-optimal mixture design with 2 factors at 5 levels was used for blend optimization of two fruit lassi (Indian yoghurt drink) powders. The responses studied were overall

acceptability and acidity of the formulations. The lassi: Pine apple juice and lassi: Musk melon pulp ratios selected on the basis of response analysis was 49:51 and 72:28, respectively. In both lassi powders 0.15% carboxy methyl cellulose and 8.5 % sugar were found to be acceptable. The level of juice/ pulp in the blend had significant effect on the quality of lassi powders. Freeze dried fruit lassi powders were analysed for proximate composition, physico-chemical and flow properties. pH, acidity of the reconstituted drinks were estimated. The freeze dried mixes had good colour, light weight and were instantly soluble in water. These products offer a healthful combination of dairy and fruit components with the added advantage of culture organisms and low lactose.

2.3 Technologies for ready to reconstitute traditional milk desserts.

Ranganadham (1988) developed technologies for small scale and industrial production of khoa powder. Three different options were tried. In the first option, Khoa, made from standardised buffalo milk by traditional method was grated into flakes and subjected to heat treatment to evaporate moisture before grinding in a small scale laboratory grinder. The ground khoa was uniformly distributed over an aluminium tray and dried in a vacuum and atmospheric hot air oven at 70°C. In the second process, grated khoa was dried in a fluid bed drier with an inlet air temperature of 98°C. It took about 4 hours to dehydrate the product in a hot air oven and 30 min in a fluid bed drier.

Pal *et al.* (1993). Rasogolla mix powder has been successfully developed employing ultrafiltration at this institute cow skim milk was first subjected to ultrafiltration to attain 3 fold concentration. The retentate had milk proteins, part of the minerals and lactose as obtained in chhana. However excess of the mineral and lactose were removed through diafiltration to make the composition of the retentate identical to chhana. The pasteurized cream was added to diafiltered retentate and subsequently spray dried under standard drying conditions. The dried retentate was blended with selected additives to produce desired flavour and texture.

Mishra *et al.* (2004) studied comprised of preparation of syrup mix powder and dehydrated patties to be mixed into an instant rasmalai mix. The syrup mix powder was prepared by dry blending of sweetened milk solids (SMP) powder, whole milk powder (WMP) and sugar powder. To the dry mix, saffron was also added and packed in co-extruded multilayer plastic pouches. The sweetened milk solids powder was prepared from standardized buffalo milk (fat: SNF ratio of 0.35) by heat desiccation. Standardized milk was boiled in a steam-jacketed stainless steel scraped surface heat exchanger to obtain sweetened khoa with a smooth body. The mixture was transferred into a stainless steel tray and allowed to set for 12 h at room temperature. The resulting pat was cut into cubes and dehydrated using a novel technology employed for the first time for manufacturing a dairy product to a moisture content of less than 10 percent

Sharma *et al.* (2004) developed ready-to-use *Basundi* mix using the concept of osmo-air drying and spray drying. The product mix was formulated by dry blending of ingredients like whole milk powder (WMP), sweetened milk solids (SMS), particulated whey proteins (PWP) and sugar.

2.4 Physico-Chemical composition of fermented milk products in dried form.

Date *et al.*, (1955) reported the chemical composition of *shrikhandwadi* made with chakka and sugar. The final moisture content was 6.5 per cent, fat 7.4 per cent, protein 7.7 per cent, ash 0.8 per cent, total sugar 62.9 per cent and lactose 15.9.

De (1980) *Shrikhandwadi* referred the composed and parameter of Vol.2. moisture content 6.5 per cent, fat 7.5 per cent, protein 7.7 per cent, lactose 15.9 per cent, titrable acidity 1.0 per cent and total sugar 62.9 per cent,

Kumar and Mishra (2004) reported the chemical composition of various dried yoghurt powder. The final moisture content of the dried product varied from 5.1 to 6.3 per cent, protein 35-37 per cent, fat 1.5, lactose 45-50 and titratable acidity 5-8 per cent.

Bramhapurkar *et al.* (2007) reported the chemical composition of *Shrikhandwadi* made from chakka mixed with sugar and SMP. The moisture content of *Shrikhandwadi* (control at 125 per cent sugar) was 9.4 per cent which reduced to 8.3 per cent on fortification with 10 per cent SMP. The total solid, protein and total carbohydrate content were increased from 90.6, 7.7. and 69.1 to 91.7, 8.4 and 69.7 per cent, respectively.

Shiby and Pandey (2015) reported the following chemical composition as of *lassi* powder made from pineapple and muskmelon fruit juice

Table 2.1 chemical composition of lassi powder

Quality Parameter	Fruit Lassi Powder		Plane lassi powder
	Pineapple Lassi	Muskmelon Lassi	
Moisture content (%)	2.5±0.01	2.0±0.01	2.8±0.02
Ash (%)	8.4±0.03	8.21±0.02	7.6±0.01
Protein (%)	8.3±0.02	9.93±0.01	13.4±0.01
Fat (%)	5.8±0.01	8.26±0.03	11.6±0.01
Carbohydrate (%)	76±0.1	72±0.1	65.6±0.02
Colour changes (ΔE)	14.5±0.03	12±0.02	11±0.01
Bulk density(g/cc)	0.55 ±0.002	0.6± 0.02	0.5±0.01
Rehydration time(min)	1.5±0.01	2.0±0.03	1.5 ±0.1
Water activity	0.287±0.02	0.272±0.01	0.306±0.03
Energy Value (Kcal/100g)	389± 1	402 ± 1	420±1

2.5 Organoleptic quality of fermented milk products in dried form.

Bramhapurkar *et al.* (2007) reported the organoleptic quality of *Shrikhandwadi* made with addition of 75 per cent sugar gave lowest scores for all the sensory attributes, which increased considerably by increase in sugar level

from 75 to 125 per cent. The sensory scores of the product though improved by addition of 100 per cent sugar, did not differ significantly. Addition of 125 per cent sugar improved the body and texture, flavor and overall acceptability score significantly as compared to other two sugar levels. The colour and appearance scores, however, declined marginally. The lowest score at 75 per cent sugar level in the product might be due to more acidic after taste and increased brittleness in the product indicating that this sugar level was insufficient to provide a desired sweet acidic aroma and more cohesive and compact body in the product. Addition of 125 per cent sugar, however, improved the scores considerably due to increased sweetness combined with acidic and aromatic perceptions and cohesive body.

Shiby and Pandey (2015) reported the organoleptic quality of fruit lassi powder the samples were subjected to sensory evaluation on 9 pt hedonic scale by a semi-trained panel of 11 judges. Fruit lassi samples were prepared in 100 ml cups and stored overnight at 2-5 °C before subjecting them to organoleptic evaluation. The samples were served at 10°C. A panel of 11 judges, from among the faculty and research scholars of Defence Food Research Laboratory, Mysore was formed on the basis of their knowledge of the product and their willingness to participate on a regular basis after obtaining agreement among the judges on the characteristics of good quality fruit lassi and what they meant by the terminology for sensory evaluation. Appearance and colour, consistency, flavour and overall acceptability were rated on a 9 point hedonic scale.

2.6 Utilization of whey protein concentrate in dairy food products

Patel *et al.* (1993) prepared good quality khoa from cow milk with the incorporation of whey protein concentrate (5%). Khoa from cow milk has been reported to be salty in taste, sticky/pasty in body and texture and slight yellowish in colour. WPC addition has shown to improve the flavour, body and texture, colour and appearance and thereby overall sensory attributes of cow milk khoa. Addition of 5 per cent WPC solids to cow milk improved the flavour, body and texture and colour of khoa prepared. WPC incorporated cow

milk khoa compared well with the traditional buffalo milk khoa.

Thapa and Gupta. (1996) reported with the increase of moisture content over a wide range, the firmness of processed cheese food decreased in a highly significant manner it was also observed that increased amount of WPC in processed cheese foods impart milder flavor in the final product.

Dewani and Jayaprakasha (2002) studied the effect of addition of whey protein concentrate (WPC) on sensory characteristics of peda. They reported that increasing the level of WPC upto 40 per cent showed increasing color and appearance, body and texture and overall acceptability scores of peda whereas, flavor score increased even upto 50 per cent level of addition.

Sudhir (2002) reported that though the flavour score for 12 per cent WPC added khoa were higher than other WPC added khoa samples, the improvement was not statistically significant between 8%, 10% and 12% WPC added khoa. Increased level of WPC increased the grain size of khoa and decreased stickiness/pastiness, however, it also resulted in reduced cohesiveness and increased dryness in the product. Hence, the selection of level of WPC is subject to the requirement of type of khoa intended for further use e.g. Khoa prepared by addition of higher level can be suitable for the product like kalakand.

Reddy (2005) made efforts to improve the viability of *Lactobacillus acidophilus* in set and stirred the probiotic yoghurts by incorporating whey protein concentrated @ 0.5 to 1.0% in yoghurt milk and changes in pH and overall acceptability of product during storage at 4° C over a period of 5 weeks.

Pinto *et al.* (2007) prepared of cheddar cheese comprising of 66 per cent of 2-3 months old and 34 per cent of 4-5 months old cheddar cheese for preparation of processed cheese spread. Cheese solids were partially replaced by whey protein concentrate (WPC) (38.00 per cent protein) solids at different levels, viz. 1.5, 3.0 and 4.5 per cent. Incorporation of WPC resulted in a significant improvement in body and texture score of spread particularly at 3.0

and 4.5% level. However, addition of WPC at higher levels imparted a milder flavour to the product. Processed cheese spread with good ability to melt, desired characteristics with improved spread ability can be prepared by using dried WPC at levels up to 4.5% of cheese solids

Pandiyan *et al.*(2010) prepare Ice cream by replacing skimmed milk powder with whey protein concentrate (WPC) with the objective of improving the biological value of ice cream protein. Physico-chemical, microbiological and sensory qualities of WPC incorporated ice cream was assessed. Ice cream was prepared by replacing skim milk powder at 0 (control), 10 (T1), 20 (T2), 30 (T3) and 40 (T4) per cent levels. A significant ($P < 0.05$) difference in the acidity of the ice cream was observed between the control and treatments. The acidity was significantly higher at 40 per cent replacement. The fat and total solids contents were not statistically significant between treatments. The mean (\pm SE) protein content (in per cent) showed a significant difference ($P < 0.01$) among treatments. The protein content of control, T1, T2, T3 and T4 were 4.63 ± 0.05 , 5.99 ± 0.05 , 6.75 ± 0.06 , 7.55 ± 0.07 and 8.36 ± 0.04 respectively. The mean melting time (in minutes) of the control, T1, T2, T3 and T4 were 6.20 ± 0.07 , 6.15 ± 0.06 , 5.44 ± 0.08 , and 4.68 ± 0.11 and 4.63 ± 0.13 respectively and showed a significant difference ($P < 0.01$). As the percentage of WPC increased the melting time of ice cream decreased. The mean standard plate count and coliform count in the control and treatments were within the limits prescribed by Bureau of Indian Standards. The total sensory scores (25 points) had no significant difference between control and treatments. In conclusion, replacement of skim milk powder up to 40 per cent level with whey protein concentrate, did not affect the sensory qualities of the ice cream.

Shrinivasa *et al.* (2012) conducted on experiment with spray dried whey protein concentrate (WPC) used in the preparation of probiotic enriched shrikhand. The control and the experimental samples of shrikhand were subjected to physico-chemical, microbiological and sensory attribute studies in order to find out the suitability of WPC in the shrikhand preparation. The study

revealed that, with the increase in the level of WPC, there was progressive improvement in the quality attributes of shrikhand upto a level of 5 per cent by weight of chakka.

2.7 Utilization of WPC in confectionary food products

Munaza *et al.* (2012) carried out study with the objective to prepare whey protein enriched biscuits by supplementing wheat flour with whey protein concentrate at different levels of substitution, to assess the nutritional quality and storage stability of the product. The product was further analysed for cost. Control and three experimental treatments were prepared with varying proportions of whey protein concentrate – 4 per cent, 7 per cent and 10 per cent. Each treatment was replicated three times. Sensory evaluation of the biscuits was carried out using 9 point hedonic scale. The data obtained during the study was analysed statistically using analysis of variance and critical difference techniques. On the basis of results it was concluded that 10 per cent WPC was best regarding sensory characteristics – colour and appearance, taste and flavour, body and texture and overall acceptability of the product. All the experimental treatments and control were also analysed chemically using AOAC procedures. Chemical analysis showed that the moisture content of the biscuits varied from 1.24 – 2.13 and the highest moisture content was found in biscuits contained highest amount of WPC, the moisture content also increased with the storage time. Estimation of protein content of sample showed high improvement in nutritional value of whey protein enriched biscuits with a maximum value of 21.86 per cent. There was linear increase in ash content of the product from 0.30 – 1.11 per cent.

Wani *et al.* (2015) Incorporated WPC into cookies at different levels (0, 2, 4, and 6%). Cookies were analyzed for physicochemical, color, textural, microbial, and sensory attributes. Physicochemical analysis and revealed that 6% WPC supplemented cookies shows maximum protein content (13.22%), moisture content (11.33%), fat content (23.08%), and ash content (2.02%) as compared to control. However, control sample shows significantly different (*p*

≤ 0.05) value for crude fiber and carbohydrate content. Maximum thickness (9.63 mm), diameter (44.06 mm), and weight (9.10 g) were found for control and these decreased significantly ($p \leq 0.05$) with increase in WPC supplementation level in cookies. Cookie supplemented with 4% WPC showed maximum overall acceptability (4.76). Texture analysis revealed that 6% WPC supplemented cookie shows maximum cutting force (55.3 N). Lightness (L^*) value of cookies decreased from 67.32 to 57.94. Where as a^* and b^* value increased from 0.37 to 3.57 and 25.35 to 27.54, respectively. The total plate count of cookie samples was under acceptable limits.

Sarabhai *et al.* (2015) studied the effect of 5, 7.5 and 10 % protein concentrates namely soya protein isolate (SPI), (WPC) and addition of 0.5 % emulsifiers such as glycerol monostearate (GMS), sodium stearoyl- 2- lactylate (SSL) and lecithin (LEC) on the rheological, sensory and textural characteristics of cookies with rice flour and its immunochemical validation. The results showed that the use of 7.5 % SPI/WPC along with GMS significantly improved the quality characteristics of cookies with rice flour. Dot-Blot and Western-blot studies of cookies with 7.5 % of SPI or WPC confirmed that the anti-gliadin did not recognize these proteins. Carry- through process using ELISA kit confirmed that gluten was within the permissible limit in all the stages of processing and hence these cookies can be consumed by people suffering from celiac disease.

2.8 Utilization of skim milk powder in dairy foods

Rajorhia (1989) pointed out that use of spray dried skim milk powder (SMP) in preparation of gulabjamun mix powder leads to case hardening of balls during deep fat frying and prevents absorption of sugar syrup. The texture of resulting sweet becomes hard. A number of approaches were tried to overcome these problems which included i) variations in the proportions of raw ingredients, ii) partial replacement of skim milk powder (SMP) with butter milk powder, iii) exposure of mix powder to high temperature of heating, iv) addition of texture

improvers and v) modifications in the method of making gulabjamun. The increase in the proportions of fat and baking powder and decrease in the contents of semolina gave soft product with increased absorption of sugar syrup. Partial replacement of SMP with butter milk powder improved the dough quality and texture of sweet, although it adversely affected the colour. Heating of SMP and mixture of SMP and starch separately at 800 C for 15 min. improved the texture but there was a problem of slight cake formation in the mixture. Use of texture improvers helped to a great extent in overcoming the problems. Among the additive, such as sodium alginate, sodium citrate, disodium hydrogen 47 orthophosphate, citric acid, carragenan and carboxyl methylcellulose when tried alone and in combination at different rates, the most effective was the mixture of SMP and sodium citrate. From this formulation, gulabjamun samples of comparative quality and softness were obtained.

Shinde (1995) worked on utilization of skim milk powder for preparation of shrikhand and found that it contains total solids 53.53 per cent, moisture 46.46 per cent, fat 8.76 per cent, protein 6.27 per cent, sucrose 38.66 per cent, acidity 1.005 per cent and ash 0.896 per cent.

3. MATERIAL AND METHODS

The study entitled, 'Process standardization for protein enriched *Shrikhandwadi*' was undertaken in the laboratory of Animal Husbandry and Dairy Science, College of Agriculture, Kolhapur. The material used and methodology adopted to achieve the objectives of present investigation are discussed in this chapter under following headings.

3.1 Materials:

For the preparation and evaluation of *Shrikhandwadi* following materials were used

3.1.1 Milk : Fresh buffalo milk was obtained from Dairy Farm, College of Agriculture, Kolhapur

3.1.2 Starter culture: Starter culture LF-40 procured from National Collection on Dairy Culture, NDRI, Karnal (Haryana).

3.1.3 Skim Milk Powder: Spray-dried skim milk powder (SMP) was obtained from Kolhapur District Milk Product Union (Gokul), Kolhapur.

3.1.4 Whey Protein Concentrate: Whey Protein Concentrate (WPC) was obtained from Modern Dairy, Karnal.

3.1.5 Sugar: Sugar was procured from local market of Kolhapur city

3.1.6 Utensils / equipments

3.1.6.1 Karahi: An Futura Non-sticky karahi was used for preparation of *Shrikhandwadi*.

3.1.6.2 Stirrer: Long handled stirrer with flattened end made up of wood was used for stirring - cum scraping the chakka during preparation of *Shrikhandwadi*.

3.1.6.3 Hot water bath: Electrical water bath was used throughout study period to determine chemical parameters of *shrikhandwadi*

3.1.6.4 Incubator: Metalab Ltd. make incubator was used for incubation of milk inoculated with LF-40 starter culture.

3.1.6.5 Cabinet Air Dryer: Metalab Ltd. makes Cabinet Air dryer was used for drying.

3.1.6.6 Food grinder cum Mixer: To grind the sugar and mix with chakka.

3.1.7 Chemicals :

All the chemicals required for the analytical work was used of Analytical Reagent (AR) or Guaranteed Reagent (GR) grade manufactured by Merk, India Ltd/Glaxo India Ltd.

3.2 Methodology:

3.2.1 Preparation of *Shrikhandwadi*:

Shrikhandwadi was prepared as per the procedure reported by Date *et al.* (1955) and Brhampurkar *et al.*(2007) with certain modification (Fig.3.1). Initially buffalo milk was standardized at 4.0 per cent fat, which was then heated (90°C for 5 min) and cooled to 22 to 24°C. The milk was then inoculated with LF-40 starter culture @1.5gm per kg of milk and then incubated at same temperature for 12 to 14 hr. The obtained *dahi* then transfers on muslin cloth and hang for 6-8 hr to remove free whey. The semi-solid mass obtained is called as “chakka”. The chakka was blended with sugar powder in blender for 30 sec. at medium speed to get uniform blend of chakka and sugar. The homogeneous mass was then transfered in non-sticky pan and content was allow for further heating for 10 min for 80-90°C followed by addition of SMP and WPC and continue heating for another 2.5 min. At last the mixture was allowed to cool by spread of 5mm thickness in tray. When the product was cooled it was formed into circular shape of 20mm diameter.

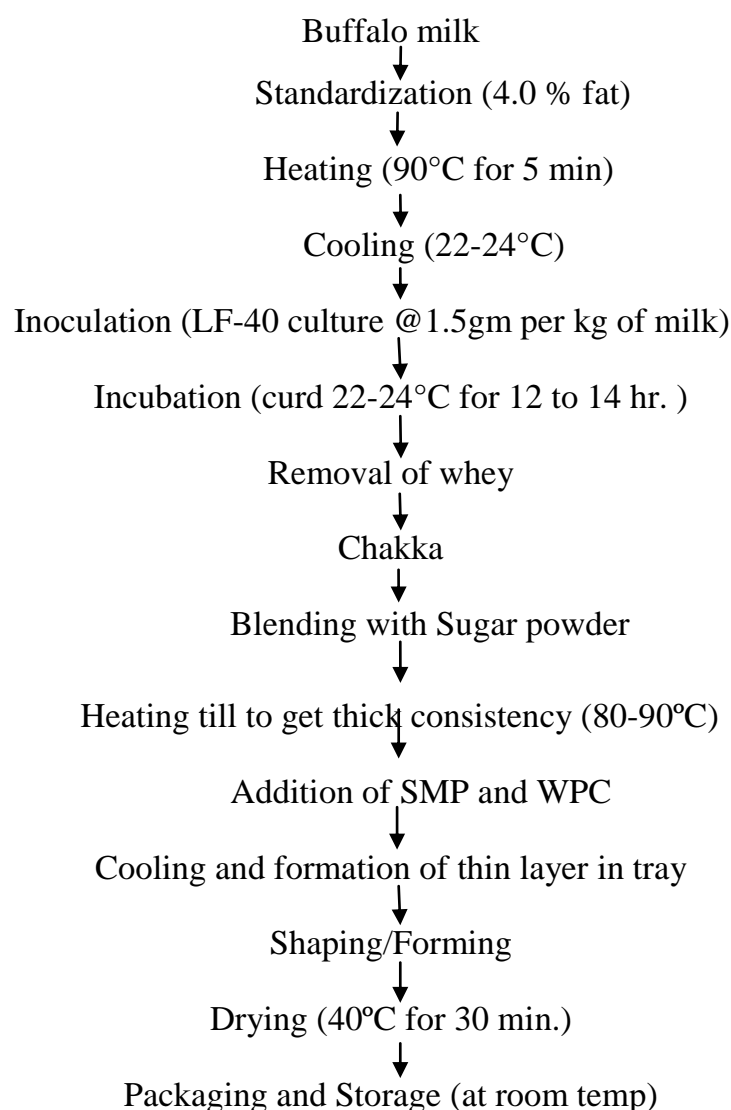


Fig 3.1: Flow diagram for preparation *Shrikhandwadi* enriched with whey protein

3.2.2 Optimization of the level of WPC in *Shrikhandwadi*:

The level of WPC was optimized by addition of WPC at five different levels viz. 1, 3, 5, 7 and 9 per cent of chakka and compared with the control (0% WPC). The quantity of sugar and SMP was kept constant at 125 and 10 per cent of chakka, respectively, during this part of study the treatment as follows were:

W_0 : *Shrikhandwadi* added with 0 % WPC

W_1 : *Shrikhandwadi* added with 1 % WPC

W_2 : *Shrikhandwadi* added with 3 % WPC

W₃: *Shrikhandwadi* added with 5 % WPC

W₄: *Shrikhandwadi* added with 7 % WPC

W₅: *Shrikhandwadi* added with 9 % WPC

The product was examined for sensory qualities and the best level of WPC in chakka was optimized on the basis of sensory qualities of *Shrikhandwadi*. The effect was also assessed for physico-chemical parameters.

3.2.3 Optimization of the level of SMP on sensory qualities of *Shrikhandwadi*:

The level of SMP was optimized by addition of SMP at three different levels viz. 5, 10 and 15 per cent of chakka. The quantity of WPC and Sugar was kept constant at 5 and 125 per cent of chakka, respectively, during this part of study were:

SMP₁: *Shrikhandwadi* added with 5 % SMP

SMP₂: *Shrikhandwadi* added with 10 % SMP

SMP₃: *Shrikhandwadi* added with 15 % SMP

The product was examined for sensory qualities and the best level of SMP in preparation of *Shrikhandwadi* was optimized on the basis of sensory quality of *Shrikhandwadi*. The effect was also assessed for physico-chemical parameters.

3.2.4 Optimization of the stage of addition of WPC in *Shrikhandwadi*:

To optimize the stage of addition of WPC, the product was prepared by blending of sugar (125%), SMP (10%) and WPC in chakka at following stages.

SW₁: *Shrikhandwadi* prepared by addition of WPC at before heating stage of chakka.

SW₂: *Shrikhandwadi* prepared by addition of WPC at last stage of heating of chakka.

The product was examined for sensory qualities and the best stage of addition of WPC in chakka was optimized on the basis of sensory qualities of *Shrikhandwadi*.

3.2.5 Optimization of the stage of addition of SMP in *Shrikhandwadi*:

To optimize the stage of addition of SMP, the product was prepared by blending of sugar (125%), WPC (5%) and SMP in chakka at following stages.

SM₁: *Shrikhandwadi* prepared by addition of SMP at before heating stage of chakka.

SM₂: *Shrikhandwadi* prepared by addition of SMP at last stage of heating of chakka.

The product was examined for sensory qualities and the best stage of SMP in chakka was optimized on the basis of sensory qualities of *Shrikhandwadi*.

3.2.6 Optimization of WPC and Sugar level

During the preliminary study of optimization (vide section 3.4.2 to 3.4.5) it was found that addition of WPC at 5 per cent and sugar at 125 per cent was generated better quality product. To know the interaction effect and intermingling level of WPC and sugar, it was decided to optimize the best combination by Response Surface Methodology (RSM) for two factors as independent variables. The optimized levels were based on dependent responses of sensory characteristics of *Shrikhandwadi*. The level of ingredients of the design matrix for the experiment is presented in Table 3.2. The data generated were analyzed using Design-Expert Software and generalized polynomial equations were obtained for each response. Adequacy of model were evaluated using F ratio and coefficient of determination (R^2). The lack of fit was calculated. Model was considered adequate when F-calculated was found more than table F-value and R^2 found more than 80 per cent. The effects of the variables at linear, quadratic and

interactive levels on individual responses were described using 1 and 9 per cent levels of confidence. The Design of matrix was as fallow

Table 3.1 Experimental range and levels of independent variables used in RSM in terms of actual and coded factors.

Variables	Range of levels					
	Actual	Coded	Actual	Coded	Actual	Coded
WPC(A)	2.17%	-1	5%	0	7.82%	+1
Sugar(B)	100.85%	-1	115%	0	129.14%	+1

Table 3.2 Design of matrix of Independent variables in RSM

Std	Run	WPC (%)	SUGAR (%)
9	1	5	115
2	2	7.82	100.85
4	3	7.82	129.14
8	4	5	135
5	5	1	115
10	6	5	115
12	7	5	115
7	8	5	95
13	9	5	115
6	10	9	115
1	11	2.17	100.85
3	12	2.17	129.14
11	13	5	115

3.2.7 Goals set in RSM for factors and responses to optimize *shrikhandwadi* for predicted and actual formulation

Table 3 Goals set in RSM for factors and responses to optimize *shrikhandwadi*

Constituents	Goal set for <i>shrikhandwadi</i>	Lower limit	Upper limit
Factor			
WPC	In range	2.17	7.84
Sugar	In range	100.8	129.1
Responses			
Colour and appearance	In range	7.50	8.35
Body and texture	In range	7.50	8.30
Flavour	In range	7.50	8.40
Overall acceptability	In range	7.75	8.45

The goals of sensory quality were chosen to be in the range from minimum to maximum scores with the relevant ranges of a factor. The factors viz. WPC and sugar were kept in a range to achieve the best product. The two formulations like predicted and actual values of sensory attributes was optimized.

3.2.8 Drying study of *Shrikhandwadi*:

The *Shrikhandwadi* prepared by above optimized formulations was keep in Cabinet air dryer for drying of *shrikhandwadi* at to 40, 50 and 60°C for 15 and 30 min. The sensory qualities of product were examined after removal of product from dryer and attending the various temperature. The temperature and minimum time with superior quality of *Shrikhandwadi* was optimized based on the sensory evaluation.

T₁: *Shrikhandwadi* kept at 40°C temperature for 15 min.

T₂: *Shrikhandwadi* kept at 40°C temperature for 30 min.

T₃: *Shrikhandwadi* kept at 50°C temperature for 15 min.

T₄: *Shrikhandwadi* kept at 50°C temperature for 30 min.

T₅: *Shrikhandwadi* kept at 60°C temperature for 15 min.

T₆: *Shrikhandwadi* kept at 60°C temperature for 30 min.

3.3 ANALYTICAL METHODS

3.3.1 Milk

3.3.1.1 Fat: The fat content of milk was determined by Gerber method as described in IS: 1224 (Part-I), 1977.

3.3.1.2 Protein: The protein content of milk was determined by formal titration method as described by Mathur *et al.* (1999).

3.3.1.3 Lactose: The lactose was determined as per Lane-Eynon's method given in IS: 1479 (Part-II), 1961.

3.3.1.4 Ash: Ash will be determine by as per the method describe in A.O.A.C (1995)

3.3.1.5 Total Solids: It was determined by Gravimetric method as per IS: 1479 (Part-II), 1961.

3.3.1.6 Titratable acidity (% LA): The titratable acidity of milk was determined by the procedure recommended in IS: 1479 (Part-I), 1960.

3.3.2 Chakka

3.3.2.1 Fat: The fat content of milk was determined by Gerber method as described in IS: 1224 (Part-I), 1977.

3.3.2.2 Protein: The protein content of milk was determined by formal titration method as described by Mathur *et al.* (1999).

3.3.2.3 Lactose: The lactose was determined as per Lane-Eynon's method given in IS: 1479 (Part-II), 1961.

3.3.2.4 Ash: Ash will be determine by as per the method describe in A.O.A.C (1995).

3.3.2.5 Total Solids: It was determined by Gravimetric method as per IS: 1479 (Part-II), 1961.

3.3.2.6 Titratable acidity (% LA): The titratable acidity of milk was determined by the procedure recommended in IS: 1479 (Part-I), 1960.

3.3.3 Physico-chemical Analysis of *Shrikhandwadi*

3.3.3.1 Moisture

Moisture content of *Shrikhandwadi* was determined as per SP:18 (Part XI), 1981. About 2 g of *Shrikhandwadi* sample was weighed into a dish previously dried and weighed. The dish containing material was heated after uncovering in the electric oven maintained at $102 \pm 1^\circ\text{C}$ for about 2 hours. Cooled in desiccator and weighed with the cover on. Repeated the process of drying, cooling and weighing at 30 minutes interval until the difference between the two consecutive weighings was less than 1 mg and recorded the lowest weight. The per cent moisture in *Shrikhandwadi* was calculated by using following formula :

$$\text{Moisture (\% by weight)} = \frac{100 (W_1 - W_2)}{W_1 - W}$$

Where,

W_1 = Weight in gm of the dish with *Shrikhandwadi* before drying

W_2 = Weight in gm of the dish with *Shrikhandwadi* after drying

W = Weight in gm of the empty dish

3.3.3.2 Protein

For determination of protein the formal titration method described by Mathur *et al.* (1999) was used. About 3 gm of *Shrikhandwadi* samples was kept in paste form out into 100 ml conical flask. 2.5 ml of saturated potassium oxalate solution were added in it and leave aside for about 5 minutes then add 1 ml of phenolphthalein indicator. Titrating against the 0.1 N sodium hydroxide solution till the faint pink colour appeared. About 7 ml of neutral formaldehyde solution were added into it. Again titrating against the 0.1 N sodium hydroxide solution till the same end point appeared as before. Record the volume required for the second titration only and calculated the percentage of total protein by using following formula.

$$\text{Protein (\%)} = V \times 1.7$$

Where, V= vol. of 0.1 N NaOH required for second titration.

1.7= Pyne's constant or formal factor.

3.3.3.3 Fat

Fat of *shrikhandwadi* was determined by Gerber method as described in IS: 1224 Part-I (1977).

3.3.3.4 Lactose

Lactose was determined as per Lane-Eynon's method given in IS: 1479 (Part-II) 1961. For that 10 ml of *Shrikhandwadi* sample was transferred in a 250 ml conical flask and diluted with 80 ml of distilled water. Then 10 per cent acetic acid was added by drop by drop until the clear precipitate appeared and make up the final volume to 100 ml with distilled water. Filter through dry Whatman No. 42 filter paper, discard first few milliliters filtrate and rest was collected in dry conical flask. Then burette was filled with that filtrate. 5 ml of each Fehling's solution A and B were taken into 250 ml conical flask and were kept on boiling and 3-4 drops of methylene blue indicator was added in it. During boiling, Fehling solution titrates against the filtrate till the blue colour change to brick red. Recorded this titration value and calculated the lactose percentage by following formula.

$$\text{Lactose (\%)} = \frac{\text{Factor x vol. made (100 ml)}}{\text{MBR of sample x Wt. of sample}} \times 100$$

3.3.3.5 Total sugar

Total sugar of *Shrikhandwadi* samples was determined as per Lane-Eynon's method given in IS: 1479 (Part-II) 1961. About 40 ml of prepared filtrate under (3.2.2.6) was taken in 250 ml conical flask and diluted with 25 ml distilled water. 10 ml of 6.34 N HCL solution was added in it and heated to 49°C for half hour. After cooling it was neutralized with 1N sodium hydroxide solution using methyl red indicator and final volume was made

up to 250 ml. The sugar was measured as mentioned in the procedure above (3.2.2.6).

$$\text{Total sugar (\%)} = \frac{\text{Factor}}{W} \times \frac{V_1}{V_2} \times \frac{V_3}{\text{MBR}} \times 100.$$

Where,

W= weight of sample

V₁= volume made of sample

V₂= volume taken for inversion.

V₃= volume made after inversion.

MBR= mean burette reading.

3.3.3.6 Ash

The total ash content of *Shrikhandwadi* sample was measured as per method given in IS: 1479 (Part-II) 1961. About 3 ml of *Shrikhandwadi* samples was weighed into silica crucible previously dried and ignited on a laboratory Bunsen burner. The final incineration was done in a muffle furnace at 550±5°C temperature for 2 hrs until the ash was free from carbon, cooled into desiccator and weighed. Constant weight of ash considered to have reached when the difference in two consecutive weighing after repeated ignition was less than 0.5 mg. the ash content was expressed as per cent of the gross product.

$$\text{Total ash (\%)} = \frac{\text{Weight of residue}}{\text{Weight of sample}} \times 100$$

3.3.3.7 Titratable acidity

Acidity of *Shrikhandwadi* samples was measured as per procedure stated in IS: 1479 (Part-I) 1960. The sample was mixed well and measured 4 gm in powder form into 250 ml conical flask in paste form. About 10 ml fresh distilled water was added in it. After adding 1ml of phenolphthalein indicator, 0.1N standard sodium hydroxide solution filled in burette and the content was titrated against drop by drop until the colour of content changes to faint pink. The result was expressed as per cent of lactic acid.

$$\text{Acidity (\%LA)} = \frac{\text{titration value} \times 0.009}{\text{Wt. of sample}} \times 100$$

3.3.3.8 Solubility

A single piece of *shrikhandwadi* (1.8 ± 0.31) was placed in 150ml glass beaker having 100ml distilled water. The beaker was kept in Hot water bath adjusted at 37°C. The time required (min) for complete soluble of *shrikhandwadi* particle was recorded by visual observation.

3.4 Sensory Evaluation

The product was evaluated for sensory quality by using 9 points Hedonic scale given by Amerine *et al.* (1965) for various body and texture, colour and appearance, flavour and overall acceptability attributes described by Panase and Sukhatme, (1985).

3.5 Statistical Analysis:

The data generated from the experiment of stage of addition of WPC and SMP, effect of level of sugar and SMP and effect of drying method on preparation of *Shrikhandwadi* was analyzed by employing RBD technique (Snedecor and Cochran, 1994). While the data generated during selection of major ingredients were analyzed statistically using Stat-Ease Design Expert 10.0.0 procured from stat ease Inc., USA (www.statease.com/dx10.html).

3.6 Facilities required and their availability:

All the facilities required to undertake the research work available at Division of Animal Science and Dairy Science and Division of Horticulture, College of Agriculture, Kolhapur was utilized.

4. RESULTS AND DISCUSSION

Of the total milk produced in India, 7% is used for the preparation of fermented milk products which mainly includes *dahi*, *lassi* and *shrikhand* (sweetened concentrated curd). *Shrikhand* is consumed as a dessert after meals. It is prepared by fermentation of milk using known strains of lactic acid bacteria followed by draining of whey and addition of sugar and flavours to the drained curd (Gupta *et al.* 2015). The partial evaporation of moisture by converting into solid confection (*Shrikhandwadi*) can be an excellent means to extend the shelf-life of *Shrikhand*.

The present investigation aimed at partially evaporating the moisture from chakka and fortification by whey protein concentrate (WPC), skim milk powder (SMP) and sugar to obtain *Shrikhandwadi* with desirable sensory and physico-chemical characteristics. The results of it are tabulated and discussed under following heading.

- 4.1 Chemical analysis of milk used for *shrikhandwadi* preparation
- 4.2 Chemical analysis of Chakka
- 4.3 Process optimization
 - 4.3.1 Effect of level of WPC on sensory qualities of *shrikhandwadi*
 - 4.3.2 Effect of level of SMP on sensory qualities of *Shrikhandwadi*
 - 4.3.3 Selection of stage of addition of WPC
 - 4.3.4 Selection of stage of addition of SMP
 - 4.3.5 Optimization of Level of WPC and Sugar by RSM
- 4.4 Sensory quality of *Shrikhandwadi*
- 4.5 Physico-chemical analysis of *Shrikhandwadi*
- 4.6 Verification of optimized product formulation
- 4.7 Chemical composition of optimized level of WPC enriched *shrikhandwadi*
- 4.8 Drying study of *Shrikhandwadi*.

4.1 Chemical analysis of milk used for *shrikhandwadi* preparation

The buffalo milk was obtained from Dairy farm, College of Agriculture, Kolhapur. The procured milk was standardized according to Pearson's square method described by De (1980) to 4 per cent fat by using skim milk. The milk was analyzed for total solids, fat, protein, lactose and acidity. The data are furnished in Table 4.1.

Table 4.1: chemical composition of milk used for *shrikhandwadi* preparation

Sr. No.	Constituents	Values*
1.	Total solids (%)	13.6 ± 0.39
2.	Fat (%)	4.00 ± 0.19
3.	Protein (%)	3.7 ± 0.07
4.	Lactose (%)	5.1 ± 0.04
5.	Ash (%)	0.8 ± 0.02
6.	Acidity (% LA)	0.15 ± 0.01

* mean±SE of three replications.

The result presented in Table 4.1 indicates that the milk used in the present investigation was of good quality. The total solids, fat, protein, lactose, acidity, and ash was 13.6 ± 0.39, 4.00 ± 0.19, 3.7 ± 0.07, 5.1 ± 0.04, 0.8±0.02 and 0.15 ± 0.01, respectively.

De (1980) also reported an average chemical composition of milk as moisture 84.2 per cent, fat 4.5 per cent, protein 3.9 per cent, lactose 5.2 per cent and ash 0.8 per cent.

4.2 Chemical analysis of Chakka

The chakka was prepared from above said (vide 4.1) buffalo milk, skim milk and was analyzed for total solids, fat, protein, lactose, acidity and ash. The data thereof compiled are in Table 4.2.

The result presented in Table 4.2 indicates that the chakka used in the present investigation was of good quality. The percent total solids, fat, protein, lactose, and ash was 31.7 ± 0.17, 13.2 ± 0.19, 10.8 ± 0.15, 3.1 ± 0.07 and 1±0.20, respectively.

Table 4.2: Average chemical composition of Chakka

Sr. No.	Constituents	Values*
1.	Total solids (%)	31.7 ± 0.17
2.	Fat (%)	13.2 ± 0.19
3.	Protein (%)	10.8 ± 0.15
4.	Lactose (%)	3.1 ± 0.07
5.	Ash (%)	1 ± 0.20
6.	Acidity (% LA)	2.1 ± 0.05

* mean±SE of three replications.

Jogalekar (1973) standardized the milk at 5 per cent fat and from prepared chakka for *shrikhand* preparation and observed that chakka contain fat, moisture, protein, total solid and ash was 19.5, 64.5, 10.5, 35.5 and 1.2, respectively. The present finding are in accordance with the report of Patil (1991) who reported that 13.13, 34.25 and 0.94 per cent for fat, total solids and ash.

4.3 Process optimization

During the preliminary studies of process standardization, the levels of WPC and SMP were optimized individually, simultaneously by the stage of addition of these ingredients were finalized. Latter on study was concentrate on interaction effect of sugar and WPC using Response Surface Methodology (RSM). At last the drying parameters were also studied to produce the best quality *shrikhandwadi*.

During these study product was evaluated for sensory analysis and the data generate were presented as under for the process optimization of WPC enriched *Shrikhandwadi*

4.3.1 Effect of level of WPC on sensory qualities of *shrikhandwadi*

To optimize the level of WPC in *Shrikhandwadi*, chakka was prepared from milk containing 4 per cent fat blended with 10 per cent SMP and 125 per cent sugar. The WPC was added at 0 (W₀), 1 (W₁), 3 (W₂), 5 (W₃), 7 (W₄) and 9 (W₅) per cent by weight of chakka and their effect were compared with W₀ i.e. *shrikhandwadi* without addition of WPC and results are present as under.

The perusal of data from Table 4.3 showed that the score for colour and appearance was increased as the level of addition of WPC was increased up to 3 per cent of level and later on score was decreased. The highest score (8.03 ± 0.07) was obtained by the treatment W_2 i.e. *shrikhandwadi* with addition of 3 per cent WPC and this highest score may be due to its natural appealing slight yellowish with faint greening tings colour which was liked by the judges. Lowest score (6.77 ± 0.05) was observed for treatment W_5 i.e. *shrikhandwadi* blended with 9 per cent WPC.

Table 4.3 Effect of level of WPC on sensory qualities (score) of *Shrikhandwadi*.

Level of WPC	Sensory attributes (score*)			
	Colour and appearance	Body and Texture	Flavour	Overall acceptability
W_0	$7.06^b \pm 0.07$	$7.02^a \pm 0.07$	$7.00^b \pm 0.03$	$7.07^b \pm 0.05$
W_1	$7.4^c \pm 0.03$	$7.27^b \pm 0.04$	$7.31^c \pm 0.04$	$7.44^c \pm 0.03$
W_2	$8.03^e \pm 0.07$	$7.75^c \pm 0.05$	$7.75^d \pm 0.05$	$7.79^d \pm 0.06$
W_3	$7.76^d \pm 0.05$	$8.02^d \pm 0.09$	$8.00^e \pm 0.07$	$7.92^e \pm 0.05$
W_4	$7.00^b \pm 0.07$	$7.25^b \pm 0.07$	$7.00^b \pm 0.07$	$7.17^b \pm 0.05$
W_5	$6.77^a \pm 0.05$	$7.00^a \pm 0.04$	$6.65^a \pm 0.05$	$6.86^a \pm 0.04$
CD ($P < 0.05$)	0.18	0.21	0.13	0.11

* mean \pm SE of five replications (within column followed by same letter are non- significantly different at $p < 0.05$.)

This lowest score might be due to millard browning reaction occurs with WPC at higher level during the the time of heating, resulted in gradually increase the brown colour which was not accepted by the judges. Gallagher *et al.* (2005) also reported that addition of WPC at higher level increased surface brownness of biscuits.

The perusal of data from Table 4.3 reveled that the score for body and texture was ranged from 7.00 to 8.02. The highest score (8.02 ± 0.09) was

obtained to *shrikhandwadi* prepared by addition of 5 per cent WPC, this might be due to increase soft body and smooth texture which was liked by the judges. Pinto *et al.* (2007) incorporated WPC in cheese spread and found a significant improvement in body and texture score particularly at 3.0 and 4.5 per cent level. Lowest score (7.00 ± 0.04) was observed for treatment W_5 i.e. *shrikhandwadi* blended with 9 per cent WPC. This lowest score was associated with more hard and firm body and texture of products, which was not accepted by the judges. Increased level of WPC was responsible for increased the grain size of khoa and decreased stickiness/pastiness, as reported by (Sudhir, 2002). Gallagher *et al.* (2005) observed addition of 5 and 10 per cent dairy protein powders reduced dough hardness.

The perusal of data from Table 4.3 showed that the *shrikhandwadi* prepared under W_3 treatment recorded highest score for flavour (8.0 ± 0.07) followed by W_2 treatment (7.75 ± 0.05). The flavour score was increased up to W_3 level of addition WPC and later on decreased up to 6.65 in treatment W_5 . This lowest score was associated with more cooked and powdery flavour of the products as reported by the panel of judges. Pinto *et al.* (2007) found that addition of WPC at higher levels imparted a milder flavour to the products this report was in accordance with the present findings.

From the average score of overall acceptability in Table 4.3, revealed that *shrikhandwadi* prepared by addition of WPC at 5 per cent level (W_3) scored the highest (score 7.92 ± 0.05), followed by *shrikhandwadi* prepared of 3 per cent WPC (score 7.79). The overall acceptability score for *shrikhandwadi* of W_0 , W_4 and W_5 were 7.07 ± 0.05 , 7.17 ± 0.05 and 6.86 ± 0.04 , respectively. On the basis of results obtained, we can affirmatively state that amongst the levels of WPC used, 5 per cent level (W_3) was found most acceptable by judges. The present finding is supported by the study of Wani *et al.* (2015), who studied the effect of WPC of the sensory qualities of cookies supplemented with 3, 5 and 7 per cent of WPC and observed that the overall acceptability of cookies of (4% WPC supplemented) got the maximum score of 4.76, while (6% WPC supplemented cookies) was at bottom obtained minimum score of 3.38. The

decreased in overall acceptability was due to decrease in quality score in response to texture, taste, and flavor of the 6% WPC supplemented cookies.

4.3.2 Effect of level of SMP on sensory qualities of *Shrikhandwadi*

To optimize the level of SMP in *Shrikhandwadi*, *chakka* was prepared from milk containing 4 per cent fat blended with 5 per cent WPC and 125 per cent sugar. The SMP was tried at 5 (SMP₁), 10 (SMP₂) and 15 (SMP₃) percent by weight of *chakka* and its effect were studied and results are present as under.

The perusal of data from Table 4.4 indicate that the score for colour and appearance was also significantly (P<0.05) affected by addition of SMP.

Table 4.4 Effect of level of SMP on sensory qualities (score) of *Shrikhandwadi*

Level of SMP	Sensory attributes (score*)			
	Colour and appearance	Body and Texture	Flavour	Overall acceptability
SMP ₁ (5)	7.63 ^b ± 0.04	8.0 ^b ± 0.04	7.74 ^b ± 0.04	7.94 ^b ± 0.04
SMP ₂ (10)	8.04 ^c ± 0.05	8.21 ^c ± 0.05	8.07 ^c ± 0.06	8.03 ^b ± 0.06
SMP ₃ (15)	7.75 ^a ± 0.07	7.26 ^a ± 0.05	7.53 ^a ± 0.06	7.29 ^a ± 0.03
CD (P<0.05)	0.18	0.19	0.14	0.14

* mean ± SE of five replications within column followed by same letter are non-significantly different at p< 0.05.

The highest score (8.04 ± 0.05) was obtained by the treatment SMP₂. *Shrikhandwadi* and this highest score may be due to appropriate appealing slight yellowish white colour appears to the product. Lowest score (7.75 ± 0.07) was observed for *shrikhandwadi* blended with 15 per cent SMP. This lowest score might be due to millard browning reaction occurs with SMP at the time of heating, resulted in gradually increase in the brown intensity. Waghmare (1977), reported that the decline in sensory scores was due to increased maillard browning on account of excess use of SMP in the preparation of *Shrikhandgolla*.

The perusal of data from Table 4.4 showed that the score for body and texture was significantly (P<0.05) affected by the rate of addition of SMP. The highest score (8.21 ± 0.05) was obtained by the treatment SMP₂ *shrikhandwadi*. Similar findings was reported by Bramhapurkar *et al.* (2007) who reported that

addition of SMP upto 10 per cent in chakka for *shrikhandwadi* resulted in significant improvement in body and texture score as compared to the 5 and 15 per cent level of SMP. Lowest score (7.26 ± 0.05) was observed for treatment SMP_3 and it was associated with firm and compact body and texture of products, which was not accepted by the judges.

The perusal of data from Table 4.4 showed that the *shrikhandwadi* prepared under treatment SMP_2 recorded highest score for flavour (8.07 ± 0.06) attributes followed by SMP_1 (score 7.74 ± 0.04). Lowest score was noticed for *shrikhandwadi* blended with 15 per cent SMP (score 7.53 ± 0.06). This lowest score was associated more cooked and powdery flavour occurred at 15 per cent SMP level and similarly, Waghmare (1977) also recorded decline in sensory scores was due to increased chalky (powder) flavour on account of excess use of SMP in *shrikhandgolla*.

From the average figures of overall acceptability score (Table 4.4), it is seen that *shrikhandwadi* prepared by addition of SMP at 10 per cent level (SMP_2) had maximum scored (score 8.03 ± 0.06), followed by *shrikhandwadi* prepared by addition of 5 per cent and 15 per cent SMP and the score were 7.94 ± 0.04 and 7.29 ± 0.03 , respectively. On the basis of results obtained, we can affirmatively state that amongst the levels of SMP used, 10 per cent level (SMP_2) was found most acceptable fortification with SMP up to 10 per cent level in significant improvement in all the sensory attributes of the *shrikhandwadi* was reported by (Bramhapurkar *et al.* 2007). Addition of SMP level to resulted in significant improvement in all the sensory attributes hence 10 per cent level of addition of SMP was optimum for getting desirable quality of *shrikhandwadi*.

4.3.3 Selection of stage of addition of WPC

To know the effect of stage of addition of WPC two experiment was conducted viz. addition of WPC before heating of mix (SW_1) and addition of WPC at the last stage of heating of mix (SW_2). The products were evaluated for sensory qualities and results are presented as under. The effect of stage of addition of WPC in preparation of *Shrikhandwadi* on sensory qualities is

presented in Table 4.6. It is revealed from the data that all the sensory qualities were significantly ($p < 0.05$) affected by the stage of addition of WPC.

Table 4.5 Effect of stage of addition of WPC on sensory qualities of *Shrikhandwadi*.

Stages of addition of WPC	Sensory attributes (score*)			
	Colour and appearance	Body and Texture	Flavour	Overall acceptability
SW ₁	7.57 ^a ± 0.05	7.25 ^a ± 0.06	7.06 ^a ± 0.06	7.32 ^a ± 0.04
SW ₂	8.18 ^b ± 0.04	8.11 ^b ± 0.05	8.24 ^b ± 0.04	8.17 ^b ± 0.03
CD (P<0.05)	0.11	0.05	0.14	0.15

* mean ± SE of five replications within column followed by same letter are non-significantly different at $p < 0.05$.

The maximum score (8.18 ± 0.04) for colour and appearance was observed of *Shrikhandwadi* prepared by addition of WPC at last stage of heating followed by addition of WPC at before heating stage and had recorded score 7.57 ± 0.05. The colour and appearance score for *Shrikhandwadi* prepared by of SW₁ stage was lowered due to development of brown colour as of prolong heating and it was also reported by judges that the *Shrikhandwadi* was more brown in colour. Sharma *et al.* (2012), reported that accentuates or brown colour development during more cooking and baking of milk-based powders.

It was observed that the maximum score (8.11 ± 0.05) for body and texture was obtained to the *Shrikhandwadi* prepared by addition of WPC at last stage of heating (SW₂). Whereas addition of WPC was at before heating stage SW₁ stage had recorded 7.25 ± 0.06 score. Judges expressed their views that the texture of the product was soft and firm, when the product was prepared by addition of WPC at last stage of heating. Sharma *et al.* (2012), reported that the improvement in gelling and heat setting properties of milk powder by exposing to less heating time and also giving creamy and smooth texture of food products.

The Flavour score of *Shrikhandwadi* was also affected by stage of addition of WPC. It is cleared that as the last stage of heating, the flavour score was recorded maximum (8.24 ± 0.04). The product at this stage was minimum caramel flavour. The score recorded for flavour for SW_1 and SW_2 treatments were 7.06 ± 0.06 and 8.24 ± 0.04 , respectively. Sharma *et al.* (2012), who reported that the increased baked flavour of milk based powders during over baking and heating.

The overall acceptability score presented in Table 4.5, revealed that the most acceptable stage for addition of WPC was SW_2 which had recorded maximum score 8.17 ± 0.03 for *Shrikhandwadi* followed by addition of WPC at SW_2 stage with chakka, sugar and SMP (7.32 ± 0.04).

From the above sensory observation of colour and appearance, body and texture, flavour and overall acceptability it was concluded that the best quality *Shrikhandwadi* could be prepared by addition of WPC at last stage of heating.

4.3.4 Selection of stage of addition of SMP

The effect of stage of addition of SMP in a preparation of *Shrikhandwadi* on sensory qualities is depicted in Table 4.6. From the table, it was revealed that the sensory parameters like colour and appearance, body and texture, flavour and overall acceptability were significantly ($p < 0.05$) affected by the stage of addition of SMP.

Table 4.6 Effect of stage of addition of SMP on sensory qualities of *Shrikhandwadi*.

Stages of addition of SMP	Sensory attributes (score*)			
	Colour and appearance	Body and Texture	Flavour	Overall acceptability
SM_1	$6.93^a \pm 0.07$	$7.96^a \pm 0.07$	$7.20^a \pm 0.05$	$7.24^a \pm 0.04$
SM_2	$7.93^b \pm 0.08$	$8.27^b \pm 0.04$	$8.16^b \pm 0.06$	$8.31^b \pm 0.05$
CD ($P < 0.05$)	0.35	0.24	0.25	0.24

* mean \pm SE of five replications within column followed by same letter are non-significantly different at $p < 0.05$.

To ascertain the effect of stage of addition of SMP two experiment was conducted viz. SMP was added before heating the mix (SM_1) and SMP added at last stage of heating the mix (SM_2)

The maximum score (7.93 ± 0.08) was observed for colour and appearance of *Shrikhandwadi* when SMP was added in last stage of heating for preparation of *Shrikhandwadi*. The comment of judges on *Shrikhandwadi* prepared by addition of SMP of last stage of heating indicated that, the product was uniform yellowish brown in colour whereas *Shrikhandwadi* prepared by addition of SMP in SM₁ stage was more brown in colour.

It was observed that the maximum score (8.27 ± 0.04) was observed for body and texture of *Shrikhandwadi* prepared by addition of SMP at last ending stage of heating (SM₂), followed by addition at SM₁ stage (7.96 ± 0.07). Judges expressed their views that the texture of the product was slightly soft, when the product was prepared by addition of SMP at last stage of heating. It might be because of excess exposure of time for heating resulted in to more binding and change in compositional behaviors of SMP.

The maximum score (8.16 ± 0.06) was observed for flavour of *Shrikhandwadi* prepared by addition of SMP in last stage of heating. The score for flavour for SM₁ and SM₂ for *Shrikhandwadi* was 7.20 ± 0.05 and 8.16 ± 0.06 . The judges were expressed their views that pronounced cooked flavour was noticed in SM₁ stage product.

From Table 4.6 it was observed that the maximum score (8.31 ± 0.05) for overall acceptability of *Shrikhandwadi* prepared by addition of SMP at last stage of heating.

From foregoing study it was concluded that *Shrikhandwadi* prepared by addition of SMP at last stage of heating was more acceptable. Hence, further trials for studies were conducted by adding SMP at last stage of heating.

4.3.5 Optimization the combine effect of WPC and sugar

Optimization of the processing conditions is a very crucial stage if one wants to develop an efficient and yet economic process (Sanjay *et al.*, 2007). Optimization can be carried out empirically or statistically. The former, which uses one-factor-at-a-time method in which one factor is variable at a time while all other factors are constant, has many drawbacks such as interactions between variables cannot be determined, time consuming, less effective and expensive .

According to Montgomery (2005), response surface methodology (RSM) is a powerful tool that is useful for applications in which a response is influenced by several factors. Unlike the traditional empirical method, RSM also evaluates the interactions between one or more response variables with fewer experimental runs. For this reason, RSM is used extensively for optimization of different food processes (Rakshit *et al.*, 2015).

Response Surface Methodology experiment was conducted by including independent two factor i.e. WPC (2.17-7.84 per cent) and sugar (100-129 per cent) for the production of *shrikhandwadi*. The rate of SMP was fixed for all treatment i.e. 10 per cent of chakka. In total 13 formulations were prepared using different levels of the ingredients as per Design Expert 10.0.0 version software (Table 3.2). The various terms, their definitions, maximum or optimum limits for the best model as recommended by the Design Expert were given in Table 4.7. The response measured in the *shrikhandwadi* was sensory and physico-chemical parameters.

Table 4.7 various terms used in RSM (Design Expert 10.0.0 statistical package)

1)	Prob> F :	This is the probability value that is associated with the F value for this term. Term that has a probability value less than 0.05 would be considered a significant effect. Probability value greater than 0.1 is generally regarded as not significant.
2)	Adequate precision :	It is a measure of the range in the predicted response relative to its associated error, in other words a signal to noise ratio. Its desired value is 4 or more.
3)	Leverage :	It is the potential for a design point to influence the fit of the model coefficients, based on its position in the design space. Leverages near 1 should be avoided.
4)	Linear :	Sequential sum of squares for the linear terms. A small P- value (prob.>F) indicates that adding linear terms has improved the model.
5)	2F1 :	Sequential sum of squares for the two factor interaction (AB) terms. A small P- value (prob.>F) indicates that adding interaction terms has improved the model.
6)	Coefficient estimate :	Regression coefficient representing the expected change in response 'Y' per unit change is 'X' when all remaining factors held constant.

4.4 Sensory qualities of *Shrikhandwadi*

Sensory evaluation of any consumable product is the best method of judging its acceptability by the consumers. The assessment was done by studying the characters like color and appearance, body and texture, flavour, and overall acceptability of product by the sensory panel of judges by using “9-Point Hedonic Scale”. Each sample was bearing a code number so as to avoid its identity and have impartial results. The RSM data on sensory characteristics of the *Shrikhandwadi* were analyzed using a quadratic model and the results of regression analysis were presented in Table 4.9

Table 4.8 Effect of ingredient levels on sensory attributes of *Shrikhandwadi*

Std	Run	Factor 1 A:WPC %	Factor 2 B:SUGAR %	Colour and appearance	Body and texture	Flavour	Overall acceptability
9	1	5	115	8.35	8.45	8.07	8.29
2	2	7.82	100.85	7.5	7	7.25	7.25
4	3	7.82	129.14	7.25	7.75	8.1	7.7
8	4	5	135	8	7.5	8	7.83
5	5	1	115	7.25	8	8.25	7.83
10	6	5	115	8.35	8.2	8.05	8.2
12	7	5	115	8.4	8.25	8.2	8.28
7	8	5	95	7.95	6.5	7.5	7.31
13	9	5	115	8.3	8.2	8.2	8.23
6	10	9	115	6	7.5	7.9	7.13
1	11	2.17	100.85	7.75	7.5	8	7.75
3	12	2.17	129.14	7.5	8.5	8.3	8.1
11	13	5	115	8.25	8.2	8.15	8.2

Table 4.9 Coefficients of quadratic polynomial model for coded sensory attributes

Factor	Color & Appearance	Body & Texture	Flavour	Overall Acceptability
Intercept	8.33	8.26	8.13	8.24
WPC (A)	-0.28*	-0.24*	-0.18*	-0.24*
Sugar (B)	-0.054	0.40*	0.23	0.19*
AB	0.000	-0.063	0.14*	0.025
A ²	-0.80*	-0.18	-0.029	-0.34*
B ²	-0.13	-0.55*	-0.19*	-0.29*
R ²	0.9390	0.9308	0.9356	0.9655
F-value	21.55	18.82	20.34	39.16
Mean	7.76	7.81	8.00	7.85
Adequate Precision	13.504	11.960	14.199	15.886

(*Significant at 5%)

4.4.1 Colour and appearance

The colour and appearance score of *Shrikhandwadi* (Table 4.8) ranged from 6.00 to 8.40. The minimum score (6.00) was obtained for formulation, which had 9 per cent WPC and 115 per cent sugar of 6th run. The maximum score (8.40) was obtained for formulation, which had 5 per cent WPC and 115 per cent sugar of 7th run.

The regression analysis of a data presented in Table 4.9 reveals that the coefficient of determination (R²) was 0.9390. The adequate precision was found to be 13.504, appreciably higher than the minimum desirable (4) for high prediction ability. Further the statistical analysis indicated that the model fitted the data well (model 'F' value 21.55).

The coefficient for colour and appearance score model shows that the level of different variables had significant effect on the score. The '+ve' sign indicates that there was an increased in the score of response with an increased in the level of ingredient, while '-ve' sign indicates the reciprocal effect on the response. The WPC level in linear terms had negative significant effect on the colour and appearance score. It can be seen from Fig. 4.1, the increasing sugar

level slowly increased in the colour and appearance score. Whereas, comparatively the rate of increased in colour and appearance score was more affected by the addition of the WPC

The interaction of WPC and sugar level had negative effect on colour and appearance. However, at quadratic level of WPC and sugar had significant effect on colour and appearance, but in negative terms. At highest of WPC and sugar in *shrikhandwadi* reflected dark brown colour to intense brown colour of *shrikhandwadi* was recorded by the judges it might be because of caramelisation of sugar and browning reaction on WPC due to heating.

The response surface equation derived for predicting colour and appearance score could be given as:

$$\text{Colour and appearance} = -1.67128 + 0.90290 * \text{WPC} + 0.14283 * \text{SUGAR} - 3.54339\text{E-}017 * \text{WPC} * \text{SUGAR} - 0.10031 * \text{WPC}^2 - 6.37500\text{E-}004 * \text{SUGAR}^2.$$

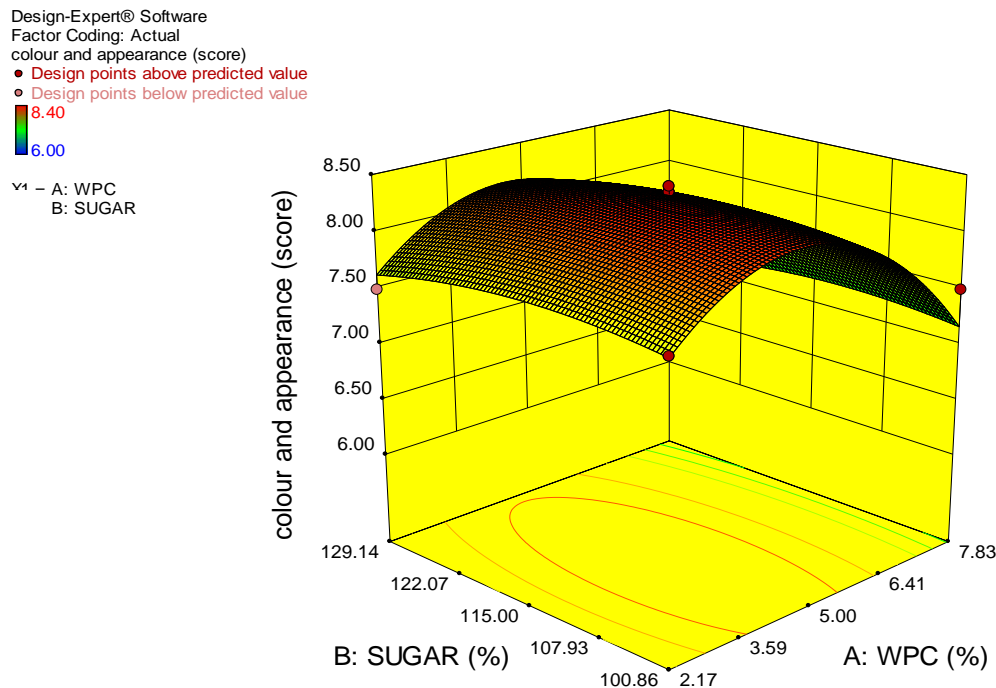


Fig. 4.1 3D graph for effect of WPC and sugar on colour and appearance score of *Shrikhandwadi*

Patel and Upadhyay (2003b), concluded that the sugar level has non-significant

effect on colour and appearance of *khoa burfi*. Gallagher *et al.* (2005), observed that addition of WPC increased surface brownness with increase the level of WPC.

4.4.2. Body and texture

The body and texture score of *shrikhandwadi* were as affected by the level and interaction of WPC and sugar also presented in Table 4.8 and the score was ranged from 6.5 to 8.5. The minimum score was obtained for formulation which had 5 per cent WPC and 95 per cent sugar. The maximum score was obtained for *shrikhandwadi* which had 2.17 per cent WPC and 129.14 per cent sugar of 12th run.

The regression analysis of data for body and texture score presented in Table 4.9 reveals that the coefficient of determination (R^2) was 0.9308. The adequate precision was found to be 11.960 indicates an adequate signal which means model could be used to navigate the design space. Further the statistical analysis indicated that the model fitted the data well (model 'F' value 18.82).

The body and texture score of *Shrikhandwadi* was significantly affected due to sugar level in the linear term it gives positive effect where as at quadratic term at higher level it gives negative effect. It can be seen in Fig. 4.1 as the sugar level increased the body and texture score also increased at a certain point beyond that body and texture score was declined. The increase in body and texture score of product might be due to at higher concentration of sugar, exhibit softening property to the product and thus resulted in soft and compact body of *shrikhandwadi*. Bramhapurkar *et al* (2007), were reported that *shrikhandwadi* made with addition of 125 per cent sugar was resulted in improvement in body and texture score considerably due to soft and cohesive body. The body and texture score slightly affected due to WPC level.

At quadratic terms of WPC and sugar had significant effect on body and texture score of *shrikhandwadi* but in negative terms.

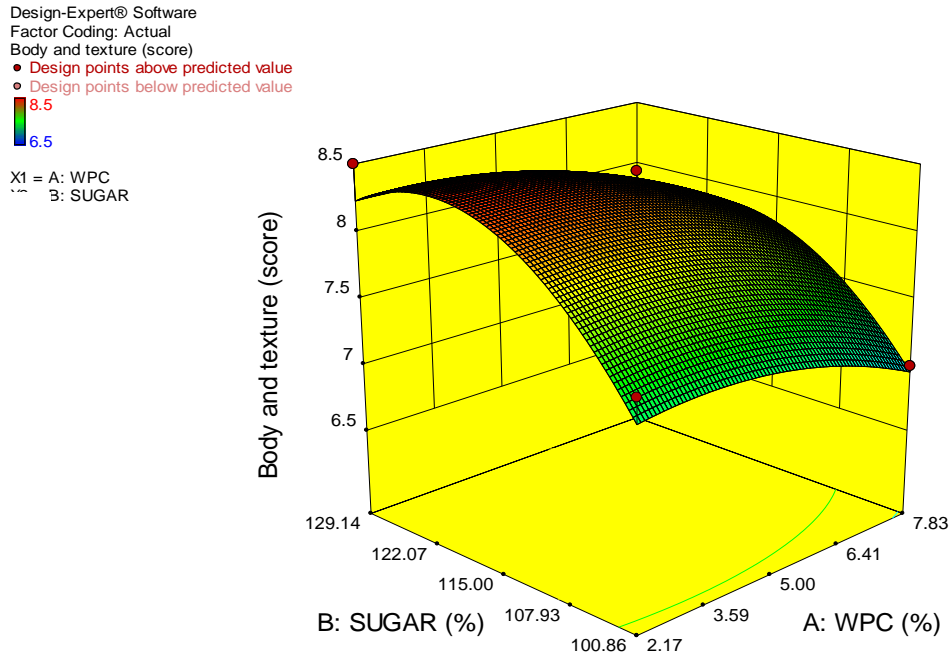


Fig. 4.2 3D graph for effect of WPC and sugar on body and texture score of *Shrikhandwadi*

Pinto *et al.* (2007), were reported that the incorporation of WPC resulted in a slightly improvement in body and texture score of spread particularly at 3.0 and 4.5 per cent level. (Sudhir, 2002), also reported that increased in level of WPC increased the grain size of khoa and decreased stickiness/pastiness, however, it also resulted in reduced cohesiveness and increased dryness in the product.

The response surface equation derived for predicting body and texture score could be given as:

$$\text{Body \& texture} = 8.26 - 0.244638348 \cdot \text{WPC} + 0.395526695 \cdot \text{SUGAR} - 0.0625 \cdot \text{WPC} \cdot \text{SUGAR} - 0.176875 \cdot \text{WPC}^2 - 0.551875 \cdot \text{SUGAR}^2$$

4.4.3 Flavour

The flavour score of *Shrikhandwadi* was also presented in Table 4.8 which ranged from 7.25 to 8.3. As the minimum score was 7.25 indicated that, all the products of different formulations were in between liked very much to The highest score was secured for *Shrikhandwadi* which had 2.17 per cent WPC and 129.14 per cent sugar of 12th run.

The regression analysis of data for flavour score is presented in Table 4.9 and same was graphically represented in Fig.4.3. It reveals that the coefficient of determination (R^2) was 0.9356. The adequate precision was found to be 14.199 indicates an adequate signal which means model could be used to navigate the design space. Further the statistical analysis indicated that the model fitted the data well (model 'F' value 20.34).

The coefficient for flavour score model shows that the level of different variables had significant effect on the score. The flavour score was significantly affected by the addition of sugar at linear terms. The addition of WPC also gave the positive effect in increasing the flavour score of *shrikhandwadi* at linear term. At quadratic terms of WPC and sugar significantly affected on flavour score but in negative manners. Form the Fig. 4.3, it is seen that the flavour score of *shrikhandwadi* was increased with increasing sugar level at certain point but beyond that flavour score declined slowly. The flavour score also negligibly decreased with increase in WPC level. Whereas, the interaction effect of WPC and sugar on flavour score were increased up to a certain point and beyond that it decreased slowly.

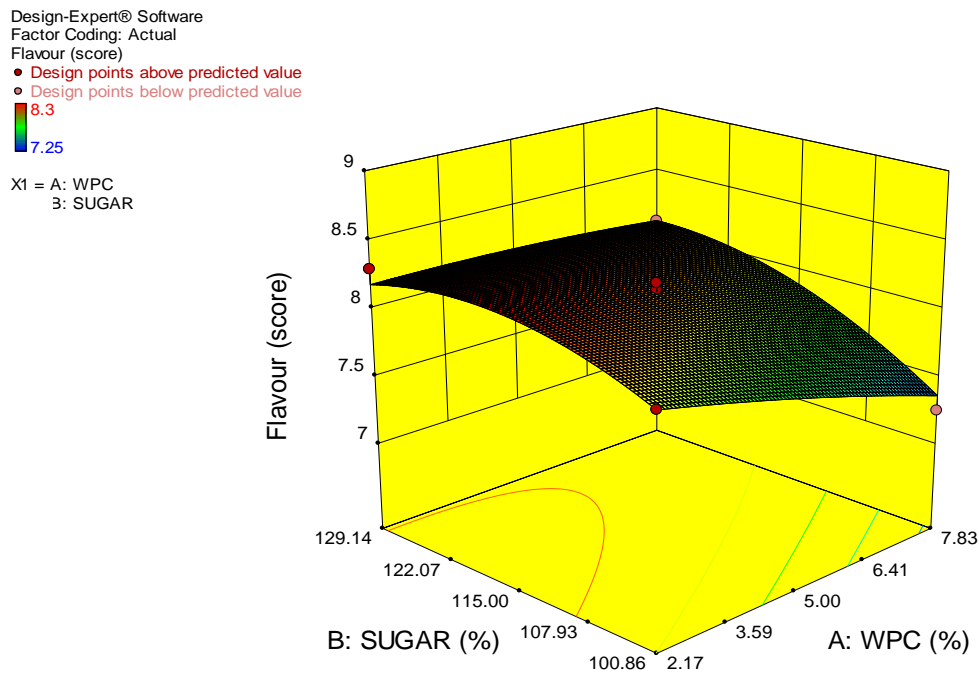


Fig. 4.3 3D graph for effect of WPC and sugar on flavour score of *Shrikhandwadi*

Similar effect of sugar level on flavour score of *shrikhandwadi* was reported by Bramhapurkar *et al.* (2007), addition of increased sugar level to reduced acidic and aromatic flavour. Pinto *et al.* (2007), who found that the present findings are in accordance with the report of addition of WPC at higher levels imparted and milder flavour to the products the results that substitution of cheese solids with WPC decreased the flavour score.

The response surface equation derived for predicting flavour score could be given as:

$$\text{Flavour} = -4.24601 - 0.42230 * \text{WPC} + 0.22003 * \text{SUGAR} + 3.43750 \text{E} - 003 * \text{WPC} * \text{SUGAR} - 3.68750 \text{E} - 003 * \text{WPC}^2 - 9.60000 \text{E} - 004 * \text{SUGAR}^2.$$

4.4.4 Overall acceptability

The effect of WPC at different levels on overall acceptability of *shrikhandwadi* is tabulated in Table 4.8. For overall acceptability, score obtained for colour and appearance, body and texture, flavour were considered.

The overall acceptability score of *shrikhandwadi* was ranged from 7.13 to 8.29. The minimum score was obtained for formulation which had 9 per cent WPC and 115 per cent sugar of 6th run. The maximum score was obtained for *shrikhandwadi* which had 5 per cent WPC and 115 per cent sugar of 7th run. The regression analysis of data for overall acceptability score presented in Table 4.9 reveals that the coefficient of determination (R^2) was 0.9655. The adequate precision was found to be 15.886 indicates an adequate signal which means model could be used to navigate the design space. Further the statistical analysis indicated that the model fitted the data well (model 'F' value 39.16).

The overall acceptability score was significantly affected due to sugar and WPC linear as well as quadratic terms. From the figure 4.4 it was seen that as the sugar level increased the overall acceptability score was also increased, however, it was largely affected due to WPC level. As WPC level increased the overall acceptability score also increased up to certain point beyond that it was start declined.

Design-Expert® Software
 Factor Coding: Actual
 Overall acceptability (score)
 ● Design points above predicted value
 ● Design points below predicted value
 8.29
 7.13
 X1 = A: WPC
 3: SUGAR

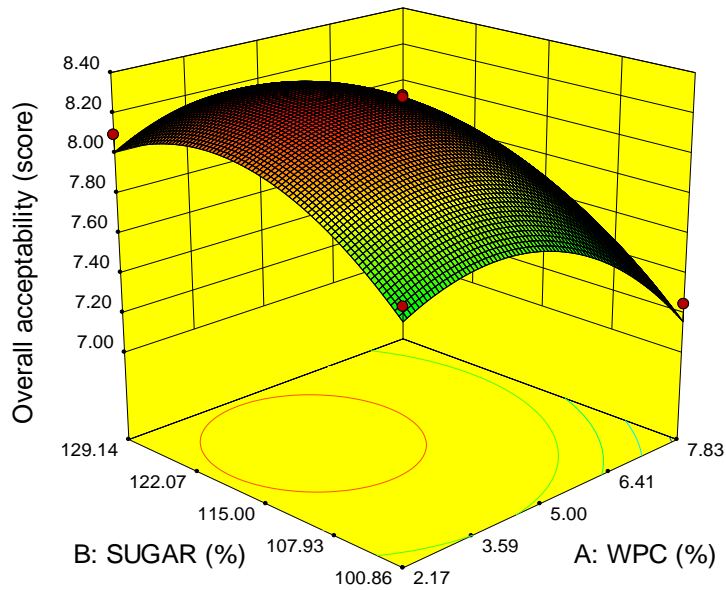


Fig. 4.4 3D graph for effect of WPC and sugar on overall acceptability score of *shrikhandwadi*

Similar findings were presented by Wani *et al* (2015), who reported that the mean score regarding overall acceptability of cookies with (4% WPC supplemented) got the maximum score of 4.76, while 6% WPC supplemented cookies was obtained minimum score of 3.38. Addition of 5 per cent WPC has shown to improve the flavour, body and texture, colour and appearance and thereby overall sensory attributes of cow milk khoa was reported by Patel *et al.* (1993)

The response surface equation derived for predicting overall acceptability score could be given as:

$$\text{Overall acceptability} = - 12.85336 + 0.26491 * \text{WPC} + 0.34538 * \text{SUGAR} + 6.25000\text{E} - 004 - 003 * \text{WPC} * \text{SUGAR} - 0.042031 * \text{WPC}^2 - 1.45625\text{E} - 003 * \text{SUGAR}^2$$

The Fig. 4.4 shows that as the sugar and WPC level increased the overall acceptability increased rapidly up to certain point and beyond that it start decline, this nature of graph means that at the highest level of WPC (7.84 per cent) and sugar (129.14 per cent) had low overall acceptability score and at

lowest level of WPC (2.17 per cent) and sugar (100.85 per cent) had also low overall acceptability score but at middle level of WPC (5 per cent) and sugar (115 per cent) had maximum overall acceptability score.

4.5 Physico-chemical analysis of *Shrikhandwadi*.

The *shrikhandwadi* prepared by using different levels of WPC and sugar as per standard of RSM and it were analyzed for moisture, fat, protein, lactose, total sugar, ash, acidity and solubility The results are furnished in Table 4.10.

4.5.1 Moisture

The Moisture content in *shrikhandwadi* was ranged from 8.3 to 10.79 per cent. (Table 4.10) The minimum per cent of moisture content in *shrikhandwadi* was obtained for formulation, which had 1 per cent WPC and 115 per cent sugar of run 5th run. While, the maximum per cent of moisture content in *shrikhandwadi* was obtained for formulation, which had 9 per cent WPC and 115 per cent sugar of 10th run.

The regression analysis of a data presented in Table 4.11 reveals that the coefficient of determination (R^2) was 0.9975. The adequate precision was found to be 69.70, appreciably higher than the minimum desirable (4) for high prediction ability. The model 'F' value is 455.90 implies the model is significant.

The coefficient for moisture content of *shrikhandwadi* model shows that the level of different variables had significant effect. The moisture content of *shrikhandwadi* had affected due to linear terms i.e. WPC and sugar level. The linear terms were significantly affected on moisture content of *shrikhandwadi* with positive sign. The interaction effect of WPC and sugar level on the moisture content of *shrikhandwadi* had positively affected. However, the quadratic terms of WPC level had positively affected on moisture content of *shrikhandwadi*. It can be seen from Fig. 4.5, as the WPC level increased the moisture content in *shrikhandwadi* was increased.

Table 4.10 Effect of ingredients levels on physico-chemical attributes of *Shrikhandwadi*.

Std	Run	Factor 1 A:WPC %	Factor 2 B:SUGAR %	Moisture %	Protein %	Fat %	Lactose %	Total sugar %	Ash %	Acidity %	Solubility Min
9	1	5	115	9.55	12.10	6.00	22.15	71.15	1.12	1.2	76
2	2	7.82	100.85	10.55	13.40	4.80	22.65	71.65	1.2	1.15	93
4	3	7.82	129.14	10.40	13.25	4.00	22.55	72.30	1.23	1.15	77
8	4	5	135	9.30	11.90	5.50	22.00	71.65	1.15	1.21	83
5	5	1	115	8.30	9.10	8.50	21.21	70.21	0.93	1.01	37
10	6	5	115	9.55	12.05	6.10	22.90	71.10	1.11	1.19	75
12	7	5	115	9.52	12.05	6.00	22.10	71.10	1.1	1.2	75
7	8	5	95	9.60	12.40	6.90	22.10	71.20	1.09	1.2	52
13	9	5	115	9.55	12.10	6.10	22.15	71.15	1.13	1.19	76
6	10	9	115	10.79	14.10	4.50	22.90	71.90	1.25	1.24	62
1	11	2.17	100.85	8.70	10.05	8.70	21.45	70.45	0.98	1.04	41
3	12	2.17	129.14	8.60	9.90	8.00	21.35	71.10	1.1	1.04	42
11	13	5	115	9.50	12.10	6.20	22.15	71.15	1.12	1.2	78

Table 4.11 Coefficients of quadratic polynomial model for coded physico-chemical attributes

Factor	Moisture	Protein	Fat	Lactose	Total sugar	Ash	Acidity	Solubility
Intercept	9.53	12.08	6.08	22.29	71.13	1.12	1.20	76.00
WPC (A)	0.90*	1.72*	-1.69*	0.60*	0.60*	0.10*	0.068	15.29*
SUGAR (B)	-0.084*	-0.13*	-0.43*	-0.043	-0.042*	0.029*	1.768E-003	3.61
AB	-0.012	0.000	-0.025	0.000	0.000	-0.023	0.000	-4.25
A²	0.022	-0.30*	0.22	-0.13	0.059	-7.375E-003	-0.053*	-12.06*
B²	-0.026	-0.021	0.066	-0.13	-6.250E-003	-7.625E-003	-0.013*	-3.06
R²	0.9975	0.9942	0.9731	0.8675	0.9207	0.9640	0.8342	0.7900
F-value	553.33	240.70	50.59	9.17	16.23	37.44	7.04	5.27
Mean	9.53	11.88	6.25	22.13	71.16	1.12	1.16	66.69
Adequate precision	77.02	50.28	22.52	9.59	13.03	19.014	7.549	6.344

(*Significant at 5%)

Design-Expert® Software
 Factor Coding: Actual
 Moisture (%)
 ● Design points above predicted value
 ○ Design points below predicted value
 10.79
 8.30
 X1 = A: WPC
 X2 = B: SUGAR

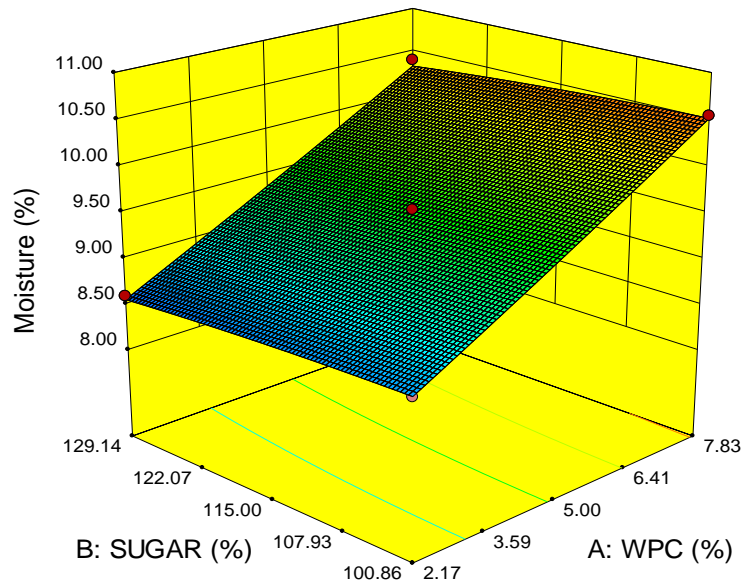


Fig. 4.5 3D graph for effect of WPC and sugar on moisture content of *shrikhandwadi*.

The similar findings were reported by Munaza *et al.* (2012) during preparation of *biscuits*. Observed that moisture content of *biscuits* increased with increase the WPC level due to water holding capacity of WPC. O'Brien *et al* (2003), also reported that increased in moisture content with increasing WPC supplementation level may be due to more bound water in the system.

The response surface equation derived for predicting moisture content could be given as:

$$\text{Moisture} = +6.82026 + 0.32568 * \text{WPC} + 0.025215 * \text{sugar} - 3.12500\text{E-}004 * \text{WPC} * \text{sugar} + 2.71875\text{E-}003 * \text{WPC}^2 - 1.28750\text{E-}004 * \text{sugar}^2.$$

4.5.2 Protein

The protein content in *shrikhandwadi* was (Table 4.10) ranged from 9.1 to 14.1 per cent. The minimum per cent of protein content in *shrikhandwadi* was obtained for formulation, which had WPC 1 per cent and sugar 115 per cent of chakka. While the maximum per cent of protein content in *shrikhandwadi* was obtained for formulation, which had WPC 9 per cent and sugar 115 per cent of chakka. The regression analysis of a data presented in

Table 4.11 revealed that the coefficient of determination (R^2) was 0.9942. The adequate precision was found to be 50.28, appreciably higher than the minimum desirable (4) for high prediction ability. The model 'F' value is 240.70 implies the model is significant.

The protein per cent of *shrikhandwadi* increased with increased in WPC level. The protein content of WPC was 70 per cent so that, the protein per cent in *shrikhandwadi* was increased with increased in WPC level. From the Fig. 4.6 it can be seen that protein per cent increased with increased in WPC level rapidly.

The similar findings were stated by Pinto *et al.*, (2007), in cheese spread wherein protein content was increased, as the level of WPC increased. The protein content in *biscuits* was increased as the WPC level increased (Munaza *et al.* 2012). The maillard reaction, or non enzymatic browning reaction, between reducing sugars and proteins, is known to cause serious deterioration of food quality during processing and storage (Adrian, 1974). The protein content in *basundi* was decreased as the sugar level increased, reported by Patel and Upadhyay (2003b).

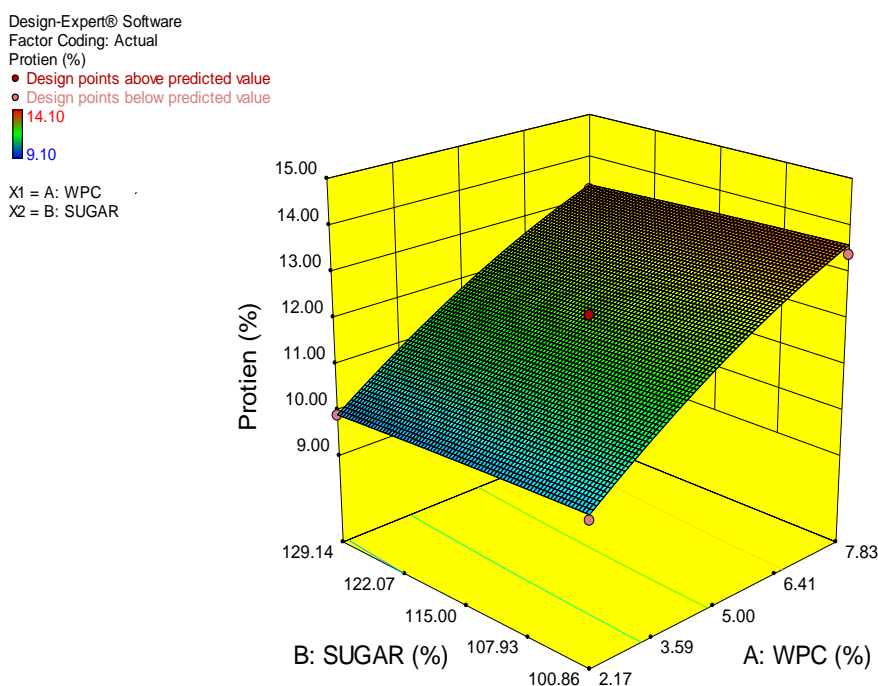


Fig. 4.6 3D graph for effect of WPC and sugar on protein content of *shrikhandwadi*

The response surface equation derived for predicting protein content could be given as:

$$\text{Protein} = +7.72975 + 0.97891 * \text{WPC} + 0.015536 * \text{sugar} - 4.59269\text{E-}017 * \text{WPC} * \text{sugar} - 0.037031 * \text{WPC}^2 - 1.06250\text{E-}004 * \text{sugar}^2$$

4.5.3 Fat

The fat per cent of *shrikhandwadi* was depicted in Table 4.10. The minimum per cent of fat content in *shrikhandwadi* was obtained for formulation, which had 9 per cent WPC and 115 per cent sugar of 10th run. The maximum per cent of fat content in *shrikhandwadi* was obtained for formulation, which had 1 per cent WPC and 115 per cent sugar of 5th run. The regression analysis of a data presented in Table no. 4.11 reveals that the coefficient of determination (R^2) was 0.9731. The adequate precision was found to be 22.52, appreciably higher than the minimum desirable (4) for high prediction ability. The model 'F' value is 50.59 implies the model is significant.

Design-Expert® Software
 Factor Coding: Actual
 Fat (%)
 ● Design points above predicted value
 ○ Design points below predicted value
 0
 0
 X1 = A: WPC
 X2 = B: SUGAR

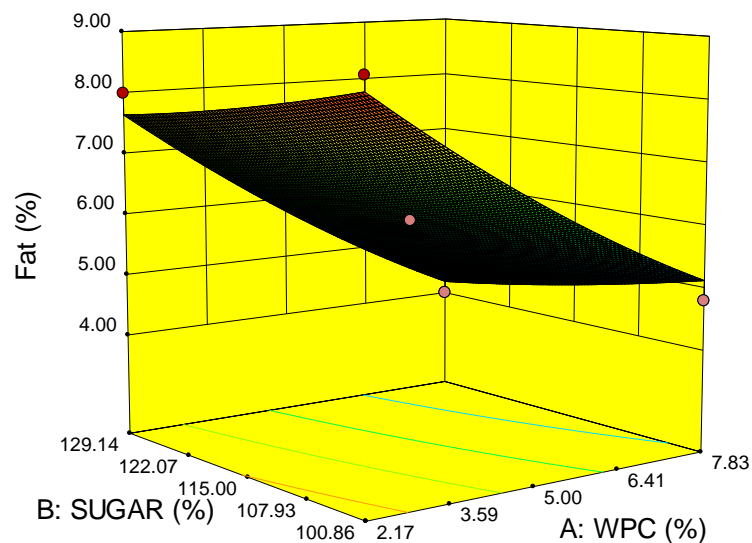


Fig. 4.7 3D graph for effect of WPC and sugar on fat content of *shrikhandwadi*.

The fat per cent of *shrikhandwadi* was significantly affected due to linear term WPC level with positive sign. It can be seen from Fig.4.7, as the WPC level increased the fat per cent was decreased while, it was slowly decreased with WPC level.

The similar effect on fat content of *biscuits* was reported by Munaza *et al.* (2012), stated that as the WPC level increased, the fat content was decreased in *biscuits*, therefore the total fat content of *biscuits* is majorily a function of externally added fat during biscuits preparation.

The response surface equation derived for predicting fat content could be given as:

$$\text{Fat} = +11.95710 - 0.75999 * \text{WPC} - 0.049464 * \text{sugar} + 1.25000\text{E-}003 * \text{WPC} * \text{sugar} + 0.011875 * \text{WPC}^2 + 2.25000\text{E-}004 * \text{sugar}^2$$

4.5.4 Lactose

The lactose content in *shrikhandwadi* was (Table 4.10) ranged from 21.21 to 22.90 per cent. The minimum per cent of lactose content in *shrikhandwadi* was obtained for treatment, which was prepared by addition of WPC and sugar at the rate of 1 and 115 per cent of chakka, respectively. The maximum per cent of lactose content in *shrikhandwadi* was obtained for formulation, which had major ingredients like WPC and sugar at the rate of 9 and 115 per cent of chakka, respectively. The regression analysis of a data presented in Table 4.11 reveals that the coefficient of determination (R^2) was 0.8675. The adequate precision was found to be 9.59, appreciably higher than the minimum desirable (4) for high prediction ability. The model 'F' value is 9.17 implies the model was significant.

The lactose content in a *shrikhandwadi* is depicted in Table 4.11. The lactose content in *shrikhandwadi* was significantly affected due to linear terms. There was positive effect of WPC and sugar level on lactose content of *shrikhandwadi*. It can be seen from WPC (70%) contain 21.1 as the lactose percentage increased the lactose content increased slowly and sugar level increased, the lactose content was decreased slowly in *shrikhandwadi*.

Similar effect of the lactose percentage in *shrikhandwadi* was significantly affected due to level of WPC with positive sign might be due to the WPC contain lactose in large amount than chakka so that lactose content of WPC was more (Renner and Abd El-Salam,1991).

The response surface equation derived for predicting lactose content could be given as:

$$\text{Lactose} = +12.36749 + 0.37497 * \text{WPC} + 0.15008 * \text{sugar} + 4.58994\text{E-}017 * \text{WPC} * \text{sugar} - 0.016328 * \text{WPC}^2 - 6.65625\text{E-}004 * \text{sugar}^2$$

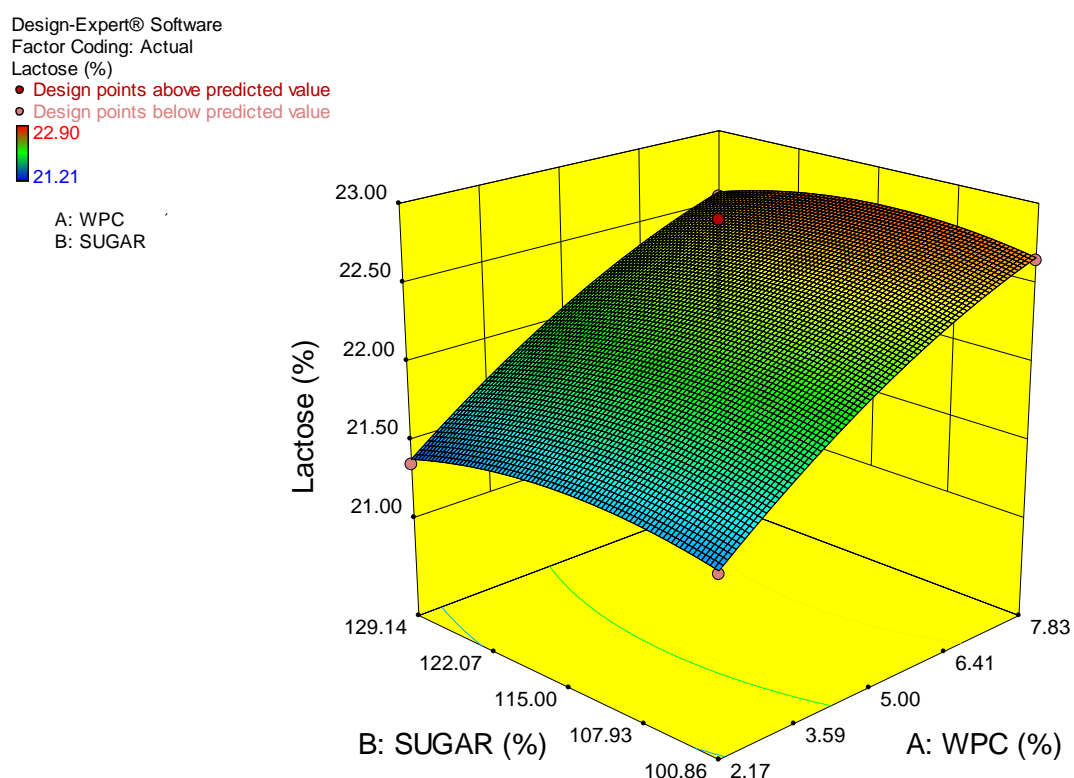


Fig. 4.8 3D graph for effect of WPC and sugar on lactose content of *shrikhandwadi*

4.5.5 Total sugar

The total sugar content in *shrikhandwadi* is depicted in Table 4.10. From the table, it was observed that the minimum per cent of total sugar content in *shrikhandwadi* was obtained for formulation, which had 5 per cent WPC and 95 per cent sugar. Whereas, the maximum per cent of total sugar content in *shrikhandwadi* was obtained by it prepared with addition of WPC

and sugar in milk at the rate of 7.84 and 129.14 per cent of chakka, respectively. The regression analysis of a data presented in Table 4.11 reveals that the coefficient of determination (R^2) was 0.9207. The adequate precision was found to be 13.03, appreciably higher than the minimum desirable (4) for high prediction ability. The model 'F' value is 16.23 implies the model was significant.

The total sugar content in *shrikhandwadi* is depicted in Table 4.11. The total sugar content in *shrikhandwadi* was significantly affected due to linear terms. There was positive effect of WPC and sugar level on total sugar percentage. At linear terms of WPC and sugar had effect on total sugar content of *shrikhandwadi*.

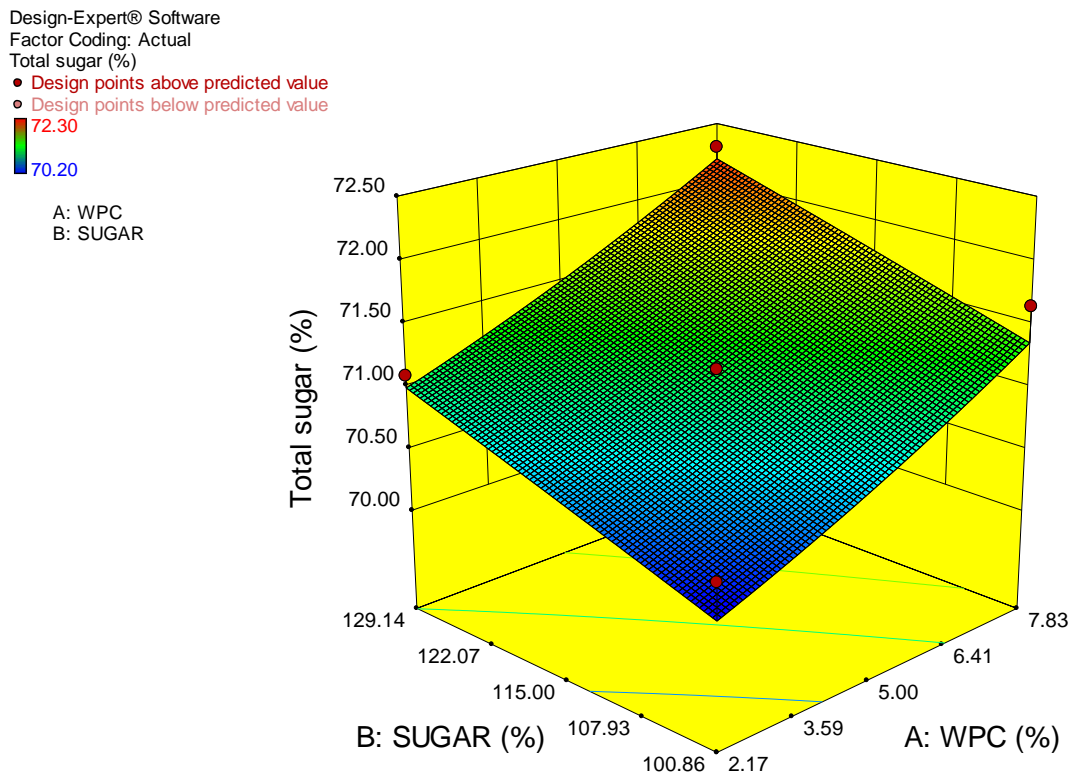


Fig. 4.9 3D graph for effect of WPC and sugar on total sugar content of *shrikhandwadi*

It can be seen from Fig. 4.12 as the WPC and SMP percentage increased the total sugar content increased in *shrikhandwadi*. The similar effect were reported by Patel and Upadhyay (2003), in *basundi* as sugar level increased in *basundi*, the total sugar per cent was also increased. WPC contain lactose

present in large amount than chakka so that lactose content of WPC was more might be due to increase the percentage of total sugar (Renner and Abd El-Salam, 1991).

The response surface equation derived for predicting total sugar content could be given as:

$$\text{Total sugar} = +66.43608 + 0.13825 * \text{WPC} + 0.036803 * \text{sugar} - 5.74587\text{E-}017 * \text{WPC} * \text{sugar} + 7.34375\text{E-}003 * \text{WPC}^2 - 3.12500\text{E-}005 * \text{sugar}^2$$

4.5.6 Ash

The ash content in *shrikhandwadi* was (Table 4.10) ranged from 0.93 to 1.25 per cent. The highest per cent of ash content in *shrikhandwadi* was recorded for the treatment which had WPC and sugar level at the rate of 9 per cent of WPC and 115 per cent of sugar and the minimum per cent of ash content in *shrikhandwadi* was obtained for formulation, which had 1 per cent WPC and 115 per cent sugar of 5th run The regression analysis of a data presented in Table 4.11 reveals that the coefficient of determination (R^2) was 0.9640. The adequate precision was found to be 19.01, appreciably higher than the minimum desirable (4) for high prediction ability. The model 'F' value is 37.44 implies the model was significant.

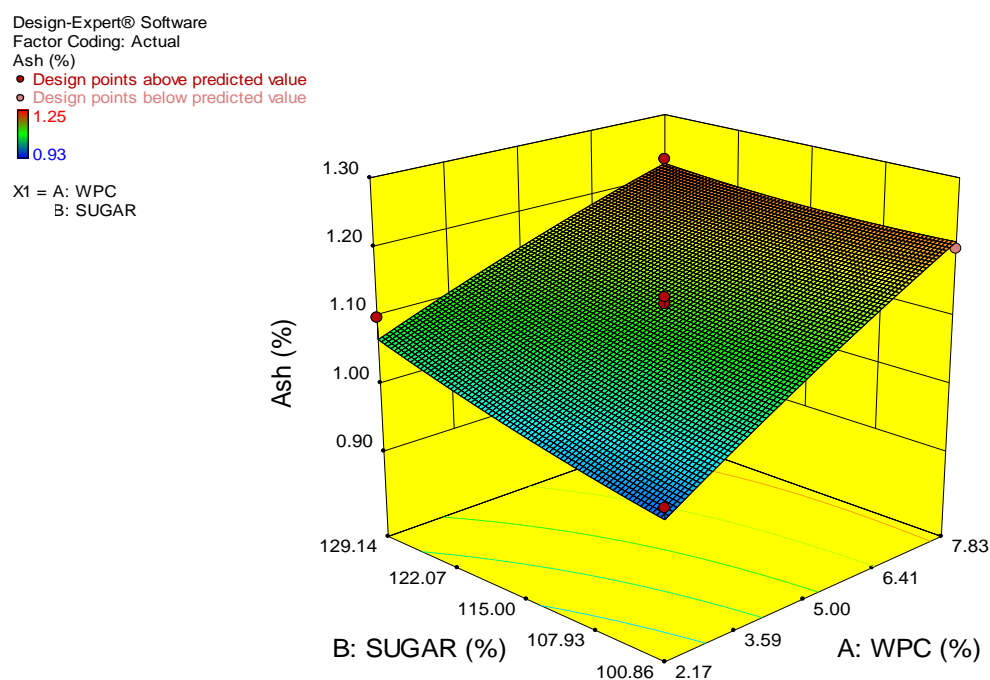


Fig. 4.10 3D graph for effect of WPC and sugar on ash content of *shrikhandwadi*

The ash percentage in *shrikhandwadi* was significantly affected due to level of WPC with positive sign might be due to the WPC contains minerals and fibers in large amount so that ash content of WPC was more (Renner and Abd El-Salam,1991). All other terms were negatively affected on ash percentage of *shrikhandwadi*. It can be seen from Fig. 4.10, the ash percentage at the initial level shows that the lowest per cent and it was increased with increased in WPC level but ash content was slowly increased with sugar level.

The response surface equation derived for predicting ash content could be given as:

$$\text{Ash} = +0.85766 + 0.10937 * \text{WPC} - 3.88042\text{E-}003 * \text{sugar} - 5.62500\text{E-}004 * \text{WPC} * \text{sugar} - 9.21875\text{E-}004 * \text{WPC}^2 + 3.81250\text{E-}005 * \text{sugar}^2$$

The similar effect on ash content of *biscuits* was reported by Munaza *et al.* (2012), and stated that the increased ash content was due to high percentage of mineral content present in WPC.

4.5.7 Acidity

The acidity of *shrikhandwadi* was (Table 4.10) ranged from 1.01 to 1.24 per cent. The minimum per cent of acidity of *shrikhandwadi* was obtained by the addition of WPC and sugar in milk at the rate of 1 and 115 per cent respectively, of milk of 5th run. The maximum per cent of acidity of *shrikhandwadi* was obtained for formulation, which had 9 per cent WPC and 115 per cent sugar levels. The regression analysis of a data presented in Table 4.11 reveals that the coefficient of determination (R^2) was 0.8342. The adequate precision was found to be 7.54, appreciably higher than the minimum desirable (4) for high prediction ability. The model 'F' value was 7.04 implies the model was significant.

The acidity of *shrikhandwadi* was affected due to WPC level significantly but in positive term. However, the quadratic terms were also positively affected on acidity of *shrikhandwadi*. It can be seen from Fig. 4.11 at the highest level of WPC, the acidity was observed highest and it was start decline up to lowest level of WPC.

The response surface equation derived for predicting acidity content could be given as:

$$\text{Acidity} = +0.035886 + 0.090348 * \text{WPC} + 0.015075 * \text{sugar} + 2.52473\text{E-}018 * \text{WPC} * \text{sugar} - 6.62500\text{E-}003 * \text{WPC}^2 - 6.50000\text{E-}005 * \text{sugar}^2$$

Pandiyan *et al* (2010) studied on increase in the titratable acidity was found in the treatments when the concentration of WPC was increased compared to the control. Pinto *et al* (2007), similar effect of acidity increased in cheese spread with increased level of WPC.

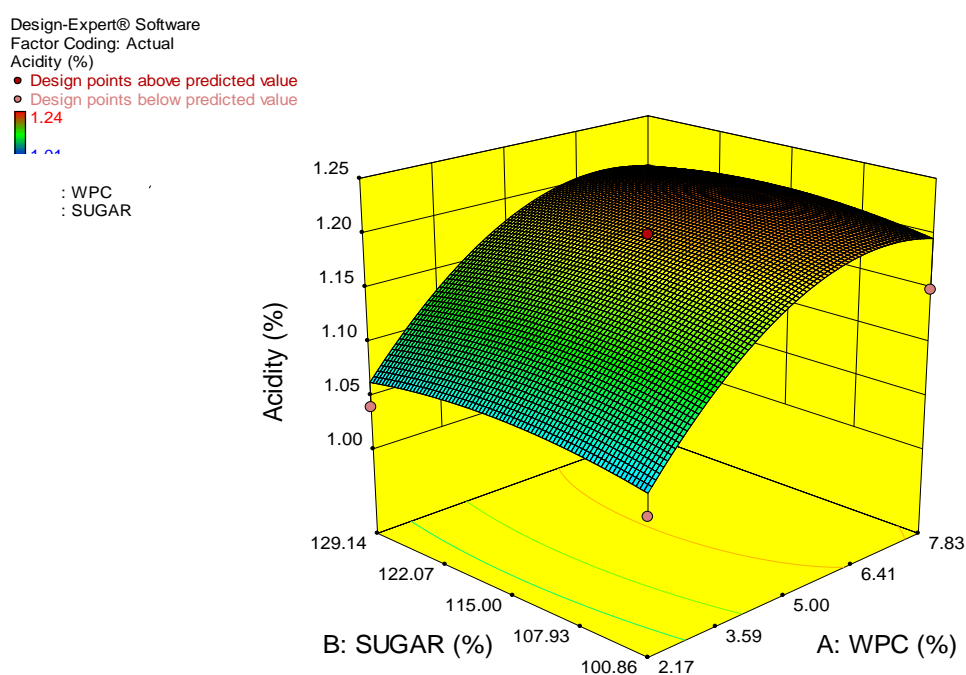


Fig. 4.11 3D graph for effect of WPC and sugar on acidity of *shrikhandwadi*

4.5.8 Solubility

The solubility of *shrikhandwadi* was (Table 4.10) ranged from 37 to 193 min. The minimum time required of solubility of *shrikhandwadi* was obtained by the addition of WPC and sugar in milk at the rate of 1 and 115 per cent respectively, of chakka of 5th run. The maximum time required for solubility of *shrikhandwadi* was obtained for formulation, which had 9 per cent WPC and 115 per cent sugar levels. The regression analysis of a data presented in Table 4.11 reveals that the coefficient of determination (R^2) was 0.7900. The

adequate precision was found to be 6.34, appreciably higher than the minimum desirable (4) for high prediction ability. The model 'F' value was 5.27 implies the model was significant.

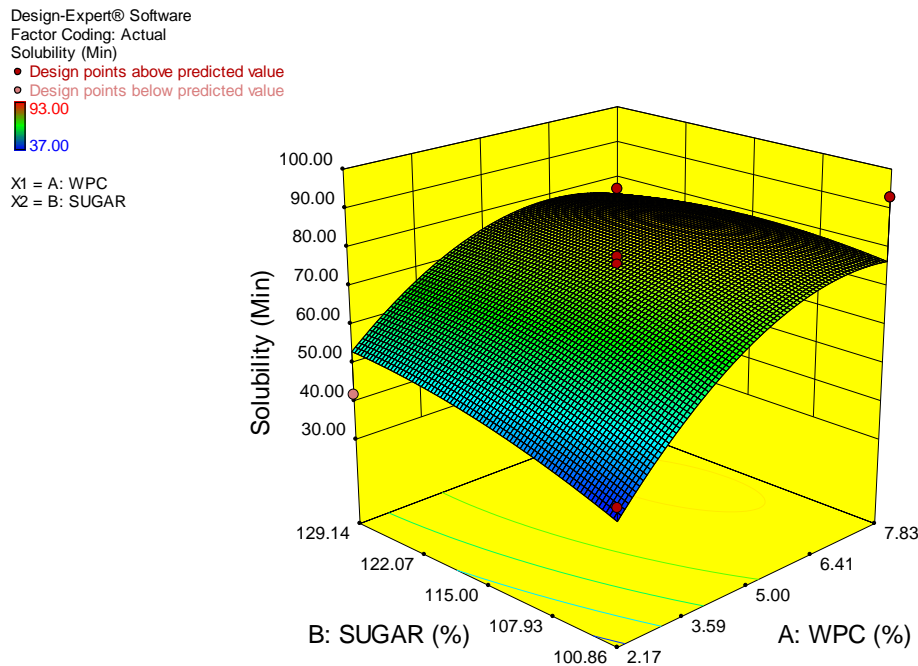


Fig. 4.12 3D graph for effect of WPC and sugar on solubility of *shrikhandwadi*

The solubility of *shrikhandwadi* was affected due to WPC level significantly but in positive term. However, the quadratic terms were also positively affected on solubility of *shrikhandwadi*. It can be seen from Fig. 4.12 at the highest level of WPC, the solubility was observed highest.

The response surface equation derived for predicting solubility content could be given as:

$$\text{Solubility} = -281.64935 + 32.70427 * \text{WPC} + 4.30804 * \text{sugar} - 0.10625 * \text{WPC} * \text{sugar} - 1.50781 * \text{WPC}^2 - 0.015312 * \text{sugar}^2$$

Pinto *et al.* (2007), concluded that processed cheese spread with good meltability and improved spreadability can be prepared by addition of WPC. Pandiyan *et al.*, (2010), where as reported that as the percentage of WPC increased, the melting time of ice cream were decreased.

4.6 Verification of optimized product formulation

From the results obtained through sensory evaluation of *shrikhandwadi* with optimized level of WPC and sugar as ingredient were selected for further investigations by verification of their sensory status. The selection was made using the Design Expert 10.0.0 package using the optimization command. The goals of sensory quality were chosen to be in the range from minimum to maximum scores with the relevant ranges of a factor during optimization (Table 4.12). The factors viz. WPC and sugar were kept in a range to achieve the best product. The two formulations like predicted and actual values of sensory attributes was optimized which was presented in a Table 4.13 and 4.14.

Table 4.12 Predicted sensory score of suggested formulation by Design Expert 10.0.0 package.

Suggested formulation No.	Ingredient	Optimized level (%)	Sensory parameters (score*)			
			Colour and appearance	Body and texture	Flavour	Overall acceptability
Formulation 1	1.WPC	4.12	8.21	8.32	8.26	8.42
	2.Sugar	125.96				
Formulation 2	1.WPC	4.55	8.25	8.29	8.21	8.25
	2.sugar	125.45				

Verification of the quantity of the selected/ optimized formulations was done by preparing the same for two times and evaluating for their sensory status.

Table 4.13 Actual sensory score of suggested formulation by Design Expert 10.0.0 package.

Suggested formulation No.	Ingredient	Optimized level (%)	Sensory parameters (score*)			
			Colour and appearance	Body and texture	Flavour	Overall acceptability
Formulation 1	1.WPC	4.12	8.16±0.02	8.22±0.02	8.20±0.03	8.19±0.01
	2.Sugar	125.96				
Formulation 2	1.WPC	4.55	8.14±0.02	8.21±0.02	8.09±0.03	8.14±0.01
	2.Sugar	125.45				

* mean ± SE of five replications (within column followed by same letter are non-significantly different at $p < 0.05$.)

Results presented in Table 4.13 and 4.14 shows that the actual observed sensory data for suggested formulation by Design Expert 10.0.0 package was closed to predict sensory responses score, the measured responses were very much closed to predicted ones. Therefore, the optimized set of combination was recommended for the preparation of *shrikhandwadi*.

4.7 Effect of time-temperature required for drying on sensory quality of *Shrikhandwadi*.

Various conventional methods of drying such as air drying, sun drying and so on are used to increase the shelf life of foods. Air drying has been reported to be frequently used in the food industry for drying various fruits and vegetables (Konopacka, 2006) as it is a feasible method to preserve them. However, drying is an energy-intensive process and a proper knowledge is required to maximize the drying efficiency while maintaining the product quality. In any drying process the main aim will always be to obtain a product of desired quality at a minimum cost and to optimize these factors (Rakshit *et al.*, 2015) Considering the importance of air drying, in the present investigation the *Shrikhandwadi* was dried in cabinet air dryer at various time temperature combinations.

The *Shrikhandwadi* prepared by above formulations was keep in cabinet air dryer for partial evaporation of moisture at 40-60°C. The quality of *Shrikhandwadi* was evaluated at 15 and 30 min. regular interval. The temperature and minimum time with superior quality of *Shrikhandwadi* was optimized based on the sensory evaluation (Table 4.14).

The result depicted in table 4.16 revealed that the effect of time temperature required for drying of *Shrikhandwadi* were significantly affected all the sensory attributes under study. The colour and appearance score affected by time temperature required for drying revealed that the product heated at 40°C for 30 min. had maximum score (8.44) where as the product dried at 40°C for 15 min. scored minimum (7.29). Interestingly to score for *Shrikhandwadi* dried at 40°C for 15 min., 60°C for 30 min. where shown the score 7.29 and 7.35, respectively and which was at par with each other it means it might be

due to at lower time temperature the product shown pale yellow colour with loose appearance where as the product dried at 60°C for 15 min. recorded dark brown colour.

Table 4.14 Effect of time-temperature required for drying on sensory qualities (score) of *shrikhandwadi*

Temperature (°C) /Time (min)	Scores* for sensory attributes with impression by Judges			
	Colour and appearance	Body and Texture	Flavour	Overall acceptability
T ₁ 40°C(15min) Impression	7.29 ^a ±0.04 (Slightly yellow)	7.2 ^a ± 0.04 (Too soft, Not firm)	7.24 ^a ±0.05 (Acidic flavour)	7.26 ^a ±0.03
T ₂ 40°C(30min) Impression	8.44 ^e ±0.04 (yellowish brown, Slightly brown)	8.35 ^d ±0.03 (Slightly soft)	8.5 ^f ±0.03 (Caramel flavour)	8.45 ^e ±0.02
T ₃ 50°C(15min) Impression	8.0 ^d ±0.03 (Medium brown)	8.1 ^d ±0.04 (Slightly hard)	8.16 ^e ±0.04 (Less caramel flavour)	8.0 ^d ±0.07
T ₄ 50°C(30min) Impression	7.75 ^c ±0.05 (Dark brown)	7.8 ^c ±0.03 (Hard)	7.9 ^d ±0.07 (Pronounced Caramel chalky flavour)	7.78 ^c ±0.03
T ₅ 60°C(15min) Impression	7.5 ^b ±0.05 (Medium brown)	7.6 ^{bc} ±0.03 (Too hard)	7.65 ^c ±0.05 (Less caramel chalky flavour)	7.58 ^b ±0.02
T ₆ 60°C(30min) Impression	7.35 ^a ±0.03 (Dark brown)	7.4 ^{ab} ±0.03 (Too hard)	7.3 ^b ±0.05 (More cooked flavour)	7.35 ^a ±0.03
CD (P<0.05)	0.13	0.21	0.16	0.12

* mean ± SE of five replications (within column followed by same letter are non- significantly different at p< 0.05.)

The score for body and texture was ranged from 7.20 to 8.35. The maximum score for body and texture was recorded to the *Shrikhandwadi* dried at 40°C temperature for 30 min. which was at par with *Shrikhandwadi* dried at 50°C for 15 min. (8.10). The score for the product was decreases as the temperature and time increased beyond 40°C for 30 min. at the lower temperature of drying the product was observed as too soft, too loose where as at higher temperature it was to hard and difficult to break.

The flavour score of the *Shrikhandwadi* under various treatment where ranged from 7.24 to 8.50. The maximum flavour score recorded to the product heated at 40°C for 30 min. followed by in the product heated at 50°C for 30 min. at elevated time temperature the product had score from 7.30 to 7.90 which was significantly low than the product heated at 40°C for 30 min.

The score for overall acceptability of *Shrikhandwadi* as influenced by the drying time temperature showed the significant effect. The score for all the treatments where range from 7.26 to 8.45 hence this study revealed that the optimum product would get if dried at 40°C for 30 min.

4.8 Chemical composition of optimized level of WPC enriched *shrikhandwadi*

The chemical composition of *shrikhandwadi* of optimized level of WPC and sugar were given by Design Expert 10.0.0 package it was presented in Table 4.15 The *shrikhandwadi* prepared by using WPC (4.12 per cent) and sugar (125.96 per cent) was analyzed for moisture, fat, protein, lactose, total sugar, ash and acidity.

Table 4.15 Physico-chemical composition of *Shrikhandwadi* prepared by optimized levels of WPC and sugar

Physico-Chemical parameters	Values*
Moisture (%)	9.55±0.03
Protein (%)	12.10±0.04
Fat (%)	6.4±0.03
Lactose (%)	22.15±0.02
Total Sugar (%)	71.15±0.02
Ash (%)	01.12±0.03
Acidity (% LA)	1.2±0.01

* mean ± SE of five replications

The chemical composition of *shrikhandwadi* depends on initial composition of chakka, the degree of concentration of total solids and the quantity of ingredients added. The protein, total carbohydrates and total solid of present investigate were higher than the *shrikhandwadi* presented by Bramhapurkar *et al.*2007 and stated that the protein, total carbohydrates and total solid content present in *shrikhandwadi* was 8.4, 69.7 and 91.7, respectively.

4.6.1 Optimize flow diagram for manufacture of *shrikhandwadi*

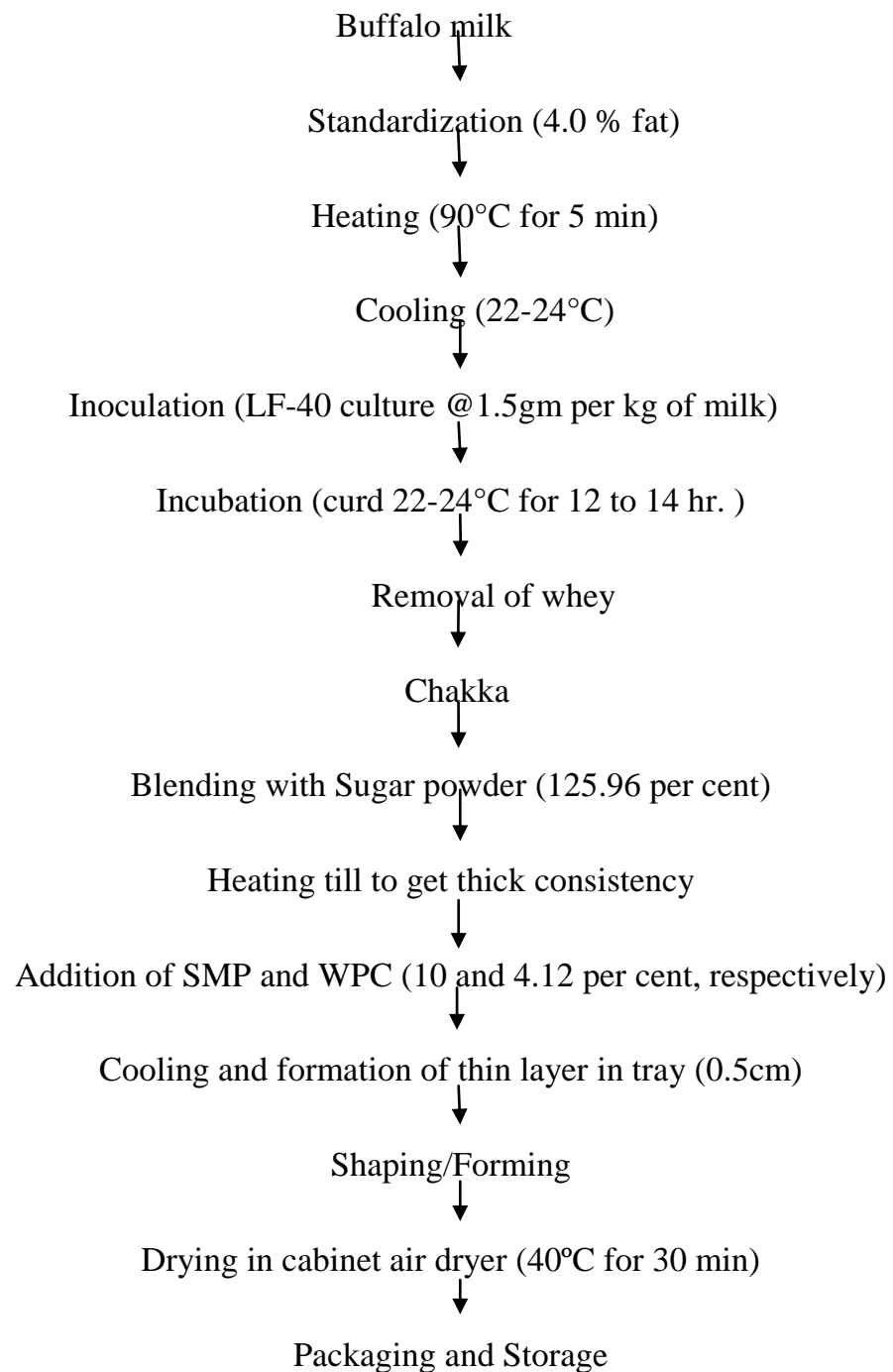


Fig 4.13: Flow diagram for preparation *Shrikhandwadi*

5. SUMMARY AND CONCLUSIONS

5.1 Summary

The shelf life of *Shrikhand* is 1 to 2 days at ambient temperature and its freshness is lost beyond 1 week storage under refrigerated conditions due to it contain high percentage of moisture and microbial activity. People in other country like Indian fermented dairy products but it is difficult to export due to its short storage stability. The partial evaporation of moisture by fortification into solid confection (*Shrikhandwadi*) can be excellent mean extend shelf life of *Shrikhand*. In the course of manufacture of *Shrikhand* and *Shrikhandwadi* the whey lost during the preparation of chakka as a result the protein quality of such product in hampered.

Whey in the form of whey protein concentrate (WPC) has gained importance as a nutritional and functional ingredient. Whey proteins are rich in essential amino acids and have a high Protein Efficiency Ratio, Biological Value and Net Protein Utilization. The investigation was carried out in the Division of Animal Husbandry and Dairy Science, College of Agriculture, Kolhapur. The *shrikhandwadi* prepared with addition of WPC at 2.17, 5 and 7.84 per cent and sugar at 100, 115 and 129 per cent (w/w basis) of chakka. The treatment combination was given as per Response surface Methodology by using Design Expert 10.0.0 software.

Shrikhandwadi was tested for its sensory qualities like colour and appearance, body and texture, flavour and overall acceptability were judged by semi trained panel of judges and chemical properties viz., moisture, protein, fat, lactose, total sugar, ash, acidity and solubility were evaluated. Drying study was also studied by taking various time temperature combinations. The statistical analysis was carried out by using Randomized Block Design and Design Expert 10.0.0 package. The results of the present study are summarized in the following paragraphs.

5.1.1 Chemical quality of milk used for *shrikhandwadi* preparation

The buffalo milk used for preparation of *shrikhandwadi* in present study contained on an average 4 per cent fat, 12.5 per cent total solids, 3.4 per cent protein, 4.8 per cent lactose and 0.15 per cent acidity.

5.1.2 Chemical quality of chakka

The chakka was prepared from buffalo milk, skim milk and was analyzed for on an average 31.7 per cent total solid, 13.2 per cent fat, 10.8 per cent protein, 3.1 per cent lactose and 2.1 per cent acidity.

5.1.3 Process Optimization

During the preliminary studies of process standardization, the levels of WPC and SMP were optimized individually, followed by the stage of addition of these ingredients were finalized. Latter on study was concentrate on interaction effect of sugar and WPC using Response Surface Methodology (RSM). At last the drying parameters were also studied to produce the best quality *shrikhandwadi*.

5.1.2.1 Effect of level of WPC

The highest score for colour and appearance, body and texture, flavour, and overall acceptability of *shrikhandwadi* were 7.76 ± 0.05 , 8.02 ± 0.09 , 8.00 ± 0.07 , and 7.92 ± 0.05 , respectively recorded for W_3 level i.e. Addition of 5 per cent WPC level.

5.1.2.2 Effect of level of SMP

The highest score for colour and appearance, body and texture, flavour, and overall acceptability of *shrikhandwadi* were 8.04 ± 0.05 , 8.21 ± 0.05 , 8.07 ± 0.06 , and 8.03 ± 0.06 , respectively recorded for SMP_2 level i.e. Addition of 10 per cent SMP level.

5.1.2.3 Selection of stage of addition of WPC

The highest score for colour and appearance, body and texture, flavour, and overall acceptability of *shrikhandwadi* were 8.18 ± 0.04 , 8.11 ± 0.05 , 8.24 ± 0.04 , and 8.17 ± 0.03 , respectively recorded for SW_2 level i.e. Stage of addition of WPC at last stage of heating.

5.1.2.4 Selection of stage of addition of SMP

The highest score for colour and appearance, body and texture, flavour, and overall acceptability of *shrikhandwadi* were 7.93 ± 0.08 , 8.27 ± 0.04 , 8.16 ± 0.06 , and 8.31 ± 0.05 , respectively recorded for SM₂ level i.e. Stage of addition of SMP at last stage of heating.

5.1.3 Optimization of Level of WPC and Sugar

5.1.3.1 Sensory quality of *shrikhandwadi*

5.1.3.1.1 Colour and appearance

The maximum score for colour and appearance (8.40) of *shrikhandwadi* was recorded for the treatment combination of WPC and sugar at the rate of 5 and 115 per cent of chakka, respectively.

5.1.3.1.2 Body and Texture

The highest score (8.50) for body and texture of *shrikhandwadi* prepared by addition of WPC and sugar in chakka, 2.17 and 129.14 per cent of milk of 12th run. Followed by treatment combination of 1st run and after that 7th run which had score 8.45 and 8.25, respectively. The lowest (6.50) score was observed for *shrikhandwadi* prepared with 5 per cent WPC and 95 per cent sugar of 8th run.

5.1.3.1.3 Flavour

In case of flavour the *shrikhandwadi* prepared with 2.17 per cent WPC and 129.14 per cent sugar of 12th run was recorded highest 8.30 score. The *shrikhandwadi* prepared by addition of 7.82 per cent WPC and 100 per cent sugar which recorded significantly lowest score (7.25).

5.1.3.1.4 Overall acceptability

Most acceptable product in the present study was observed to be *shrikhandwadi* prepared by using 5 per cent WPC and 115 per cent sugar level of 1st run with overall acceptability score of 8.29.

5.1.3.2 Chemical qualities of *shrikhandwadi*

5.1.3.2.1 Moisture

The highest per cent of moisture content of *shrikhandwadi* was 10.79 per cent of *shrikhandwadi* prepared by the 9 per cent WPC and 115 per cent sugar. The lowest per cent of moisture content of *shrikhandwadi* was 8.30, prepared with 1 per cent WPC and 115 per cent sugar of chakka.

5.1.3.2.2 Protein

In case of protein, the highest per cent of protein content in *shrikhandwadi* was 14.10 per cent prepared by the use of 9 per cent WPC and 115 per cent sugar. The lowest per cent of protein content of *shrikhandwadi* was 9.10 per cent for 5th run.

5.1.3.2.3 Fat

The maximum per cent of fat in *shrikhandwadi* was 8.70 per cent for 11th run which had 2.17 per cent WPC and 100 per cent sugar added in chakka for preparation of *shrikhandwadi*. The lowest per cent of fat of *shrikhandwadi* was recorded 4.00 per cent for 3rd run.

5.1.3.2.4 Lactose

The maximum per cent of lactose content in *shrikhandwadi* was ranged between 21.21-22.90 per cent. The maximum per cent of lactose content were recorded for treatment combination of 9 per cent WPC and 115 per cent sugar of chakka.

5.1.3.2.5 Total Sugar

The maximum per cent of total sugar content of *shrikhandwadi* was recorded 71.90 per cent for treatment combination of 9 per cent WPC and 115 per cent sugar of chakka. The minimum per cent of total sugar content of *shrikhandwadi* was 70.21 per cent prepared by 1 per cent WPC and 115 per cent sugar of chakka.

5.1.3.2.7 Ash

The maximum per cent of ash content in *shrikhandwadi* was 1.25 prepared by 9 per cent WPC and 115 per cent sugar of chakka. The

minimum per cent of ash content of *shrikhandwadi* was 0.93 per cent made by 1 per cent WPC and 115 per cent sugar of chakka.

5.1.3.2.8 Acidity

The maximum per cent of titratable acidity of *shrikhandwadi* was recorded 1.24 per cent and it was prepared with 9 per cent WPC and 115 per cent sugar. The lowest per cent of titratable acidity of *shrikhandwadi* was 1.01 per cent prepared with 1 per cent WPC and 115 per cent sugar of 5th run.

5.1.3.2.8 Solubility

The highest time required for *shrikhandwadi* soluble in water was 93 min. recorded for treatment combination of 7.82 per cent WPC and 100 per cent sugar of chakka. The lowest time required for *shrikhandwadi* soluble in water was 37 min. recorded for treatment combination of 1 per cent WPC and 115 per cent sugar of chakka.

5.1.3.3 Effect of time-temperature required for drying of *Shrikhandwadi*.

The highest score for colour and appearance, body and texture, flavour, and overall acceptability of *shrikhandwadi* were 8.44 ± 0.04 , 8.35 ± 0.03 , 8.50 ± 0.03 , and 8.45 ± 0.02 , respectively recorded for T₂ level i.e. drying of *shrikhandwadi* 40°C for 30 min. superior quality of *shrikhandwadi* was optimized based on the sensory evaluation.

5.2 Conclusion

1. The best quality *shrikhandwadi* could be prepared by addition of WPC and sugar at the rate 4 and 125.95 per cent of chakka, respectively.
2. The optimized product had 8.22 ± 0.02 , 8.16 ± 0.02 , 8.20 ± 0.03 and 8.19 ± 0.01 score for colour and appearance, body and texture, flavour, and overall acceptability, respectively.
3. The *shrikhandwadi* prepared by optimized formulation contained 9.55, 12.10, 6.4, 22.15, 71.15, 1.12, and 1.2 per cent moisture, protein, fat, lactose, total sugar, ash and acidity, respectively.
4. The optimized time-temperature required for drying i.e. 40°C for 30 min. in cabinet air dryer in preparation of *shrikhandwadi*.

6. LITERATURE CITED

- Adrian, J. (1974). Nutritional and physiological consequences of the maillard reaction. *World Rev. of Nutr. And Diet.* 19:71.
- A.O.A.C. (1995). Official methods of analysis, 16th Edn. Association of Official Analytical Chemists, Washington, D.C., U.S.A.
- Amerine, M.A. Pangborn, R.M. and Roesster, E.B. (1965). Principles of Sensory Evaluation of Food. Academic press, INC, New York, USA.
- Aneja, R. P., Mathur, B. N., Chandan, R. C. and Banerjee, A. K. (2002). Technology of Indian Milk Products. A Dairy India Publication, Delhi, India.
- Ansari, I. A., Rai, P., Sahoo, P. K. and Datta, A. K. (2006). Manufacture of Shrikhand from ultrafiltered skim milk retentates. *J. Food Sci. Technol.*, **43**(1): 49 – 52.
- Biyabani, S. A., Patil, G. R., Patange, U. L. and Mitkari, K. R. (1998) Studies on the manufacture of chakka in Shrikhand by direct acidification. *Ind. J. DairyBio.sci.*, **9**: 44-48.
- Bramhapurkar, V.R., Zanjad, P.N., Raziuddin, M., Rathod, K.S. (2007). Process optimization for preparation of *Shrikhandwadi* from buffalo milk. *J Food Sci. Technol.*, 44(1) pp 110-111.
- Date, W. B. and Bhatia, D. S. (1955). Preservation of Indian milk sweets some preliminary studies on shrikhandwadi and milk burfee. *Indian J. Dairy Sci.*, **8**:pp 61-66.
- De, S. (1980). Dried milk products. *Outline of Dairy Tech.*, pp. 410-411
- De, S. (2009). Outline of Dairy Technology. Oxford University Press. New Delhi, India.

- Dewani, P. P. and Jayaprakasha, H. M. (2002). Effect of addition of whey protein concentrate on the physico-chemical and sensory characteristics of khoa and khoa based sweets. *J. Food Sci. Technol.*, **39**(5): 502 -506.
- FSSAI (2011). Food safety Standard Authority of India., Cited from www.fssai.gov.in
- Gallagher, E., Kenny, S. and Arendt, E. K. (2005). Impact of dairy protein powders on biscuit quality. *Eur Food Res. Technol.* 221:237.
- Ganbahadur, N. A. (2016). Preparation of *shrikhand* blended with pomegranate juice. M.Sc. (Agri) thesis submitted to Mahatma Phule Krushi Vidhyapeeth, Rahuri.
- Gupta, P., Jadhav, S.B. and Singhal, R.S. (2015). Development of Shrikhand premix using microencapsulated rice bran-oil as fat alternative and hydrocolloids as texture modifier. *Food Hydrocolloids*, **48**: 220-227.
- IS:1224 part I. (1977). Determination of fat by Gerber's method (revised) Indian Standards institution, Manak Bhavan, New Delhi.
- IS:1479, Part-I. (1960) Methods for test for Dairy industry rapid examination of milk. Indian standards institution, Manak Bhavan, New Delhi.
- IS: 1479, Part-II. (1961). Methods of test for dairy industry, Chemical analysis for milk. Indian Standard Institution, Manak Bhavan, New Delhi, India.
- Jogalekar, N.V. (1973). Studies on standardization of *Shrikhand* preparation. M.Sc. (Agri) Thesis submitted to Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra).
- Kanawajia, S.K. (2006). Technological innovation in the manufacture of dahi and mesti dahi. In lecture compendium on developments in traditional dairy products., NDRI, Karnal, pp:55-63.

- Konopacka, D. (2006). The effect of enzymatic treatments on dried vegetable color. *Drying Technol.*, **24**:1173–1178.
- Kulkarni, C., Belsare, N. and Lele, A. (2006). Studies on *Shrikhand* rheology. *Journal of Food Engineering*, **74**:169-177.
- Kumar, P. and Mishra, H. N. (2004). Yoghurt powder –A review of process technology, storage and utilization, *Food and Bioproducts Processing*, **82**(C2): 133-142.
- Mathur, M. P., Datta, D. R. and Dinakar, P. (1999). Determination of protein. text book of dairy chemistry. Directorate of information and Pubs., ICAR, New Delhi.
- Mehta, M. (2013). Proximate analysis of branded shrikhand. *J. Food. Sci. and Tech.*, **1** (2): 9-12.
- Mishra S., Nayak, S.K., Singh, R.R.B., Patel, A.A. and Patil, G.R. (2004). Development of a process for ready-to-reconstitute Rasmalai mix. Paper presented at the XXXIII Dairy Industry Conference held at New Delhi, September 26-28, (Souvenir: Poster Abstracts, DP-34, .108).
- Montgomery, D. C. (2005). Design and Analysis of Experiments, 6th Ed., John Wiley & Sons, New York, NY.
- Munaza, B., Prasad, S. G. M. and Gayas, B. (2012). Whey protein concentrate enriched Biscuits. *International J. of Scientific and Research Publications.*, **2** (8):1-4.
- Nigam, N., Singh, R. and Upadhyay, P.K. (2009). Incorporation of chakka by papaya pulp in the manufacture of *Shrikhand*. *J. Dairying, Food & Home Sci.*, **28**: 115-118.
- O'Brien, C. M., Chapman, D., Neville, D. P., Keogh, M. K., and Arendt, E. K. (2003). Effect of varying the microencapsulation process on the functionality of hydrogenated vegetable fat in short dough biscuits. *Food Research International.*, **36**, 215-221.

- Pal, D. and Raju, P. N. (2006). Developments in the manufacture of heat desiccated traditional milk desserts. In lecture compendium on Developments in Traditional Dairy products. 21st Short Course, Centre of Advanced Studies, DT Division, NDRI, Karnal, pp 18-25.
- Pal, D., Rajorhia, G.S., Garg, F.C. and Verma, B.B. (1993). Development of technology for dried rasogolla mix. NDRI Annual Report 1992-93, pp 90.
- Pandiyani, C., Kumaresan, R. and Rajarajan, G. (2010) Incorporation of whey protein concentrate in Ice cream. *Int. J. Chem. Sci.*, 8(5): 563-567.
- Panase, V.G. and Sukhatme, P.V. (1985). Statistical methods for Agricultural workers. ICAR, New Delhi, pp. 143-147.
- Patel, R. S., Gupta, V. K , Singh, S. and Reuter, H. (1993). Effect of addition of whey protein concentrate on the sensory and instron texture profile of khoa made from cow milk. *J. Food Sci.*, 30: 64-65.
- Patel, H. G. and Upadhyay, K.G. (2003b). Standardization of compositional recipe of basundi - level of sugar addition. *J. Food Sci. Technol.*, **40** (1): 89-92.
- Pinto, S., Rathour, A. K., Prajapati, J. P., Jana, A. H. and Solanky, M. J. (2007) Utilization of whey protein concentrate in processed cheese spread. *Natural Product Radiance*, **6**(5): 398-401.
- Rajorhia, G.S. (1989) Innovative technology for the manufacture of khoa powder and gulabjamun mix. *Indian Dairyman*, 41 (1): 31.
- Rakshit, M., Saha, J. and Sarkar, P. K., (2015). Response surface optimization of mechanized drying of *wadi*, A legume-fermented food condiments. *Journal of Food Processing and Preservation*. DOI:10.1111. pp.12202
- Ranganadham, M. (1988). Process innovation in the manufacturing of khoa powder Ph.D Thesis Kurukshetra University, Kurukshetra.

- Reddy, P., (2005). Influence of whey protein concentrated on the viability of lactobacillus acidophilus in probiotic yoghurt. *Indian J. Dairy Sci.* **58** (5): 333-334.
- Renner, E. and Abd El-Salam. (1991). Application of ultrafiltration in the dairy industry. *Elsevier Applied Sci. London.*, New york. pp. 158-161.
- Sanjay, K.R., Kumaresan, N., Manohar, B., Umeshkumar, S. and Vijayalakshmi, G., (2007), Optimization of carotenoid production by *Aspergillus carbonarius* in submerged fermentation using RSM. *Int. J. Food Eng.*, **3**, 19–27.
- Sarabhai, S., Indrani, D., Vijaykrishnaraj, M., Milind, Arun Kumar, Prabhasankar, p. (2015). Effect of protein concentrates, emulsifiers on textural and sensory characteristics of gluten free cookies and its immunochemical validation. *J Food Sci. Technol.* **52**(6):3763–3772
- Sharma, A., Jana, A. H., Chavan, R. S. (2012). Functionality of milk powders and milk-based powders for end use applications-A review. *Comprehensive Reviews in Food Sci. and food safety.* **11**(5):518-528
- Sharma, Singh, R.R.B., Patel, A.A. and Patil, G.R. (2004). Development of ready-to-reconstitute Basundi mix. Paper presented at the XXXIII Dairy Industry Conference held at New Delhi, September 26-28, (Souvenir: Poster Abstracts, DP-35, p.108).
- Shiby, V. K. and Mishra H. N. (2007). Thin layer modelling of recirculatory convective air drying of curd (Indian yoghurt). *Food and Bioproducts Processing*, **85**(C3): 193-201.
- Shiby, V. K. and Pandey, M. C. (2015) Development of Freeze Dried Fruit Lassi (Indian Fruit Yoghurt) Powders Using D-Optimal Mixture Design. *MOJ Food Process Technol.*, **1**(3).
- Shinde, S.N. (1995) Utilization of skim milk powder for preparation of shrikhand. M.Sc.(Agri) thesis submitted to Konkan Krishi Vidyapeeth, Dapoli.

- Shrinavasa, H., Arun Kumar., H. G. Ramchandra Rao and M. Venkatesh. (2012). Effect of whey protein concentrate on the quality of enriched probiotic shrikhand. *J. Mysore J. Agric, Sci.*, 46 (4): 836-841.
- Shukla, K. K., Gupta, V. K. and Patil, G. R. (2007). Studies on the production of shrikhand using ultra filtration process. *Indian J. Dairy Sci.* 60 (6): 393-398.
- Singh, D and Singh, J. (2014). Shrikhand: A Delicious and Healthful Traditional Indian Fermented Dairy Dessert. *Trends in Biosciences* 7(3): 153-155.
- Singh, R. and Jha, Y. K. (2005). Effect of sugar replacers on sensory attributes, biochemical changes and shelf-life of *Shrikhand*. *J. Food. Sci. Technol.*, 42(2): 199-202.
- Singh, R. R. B. (2006). Technologies for ready-to-reconstitute traditional milk desserts. In lecture compendium on Developments in Traditional Dairy products. 21st Short Course, Centre of Advanced Studies, DT Division, NDRI, Karnal, PP 18-205-211.
- Smithers G.W., Ballard F.J., Copeland, A.D., De Silva, K.J., Dionysius, D.A., Francis,G.L., Godard,C., Grieces,P.A., McIntosh,G.H.,Mitchell, I.R.,Pearce, R.J.,Regester, G.O. (1996). New opportunities from the isolation and utilization of whey proteins. *Dairy Science*. 79. 1454-1460.
- Snedecor, W. G. and Cochran, G. W. (1994). Statistical methods. East-West Press Pvt. Ltd., New Delhi.
- Sodini, I., Montella, J. and Tong, P. S. (2005). Physical properties of yogurt fortified with various commercial whey protein concentrates. *J. Sci. Food Agric.*, 85: 853–859.
- SP: 18 (Part XI) (1981). Determination of moisture. Handbook of Food Analysis. pp. 176.

- Sudhir, V. K. (2002). Studies on improvement of quality of khoa using ultrafiltration technique. M.Sc. Thesis submitted to NDRI Deemed University, Karnal.
- Swapna, G., and Chavannavar, S. V. (2013). Shrikhand-value added traditional dairy product. *Inte. J. of Food and Nutritional Sci.*, **2**(4), 45-51.
- Thapa, T. B. and Gupta, V. K. (1996). Chemical and sensory qualities of processed cheese food prepared with added whey protein concentrate *Indian J. Dairy Sci.*, **49**(2): 129-137.
- Waghmare, P. S., (1977). Shrikhandgolla: A new milk based sweet meat. *Indian Dairyman*, **29**:759-760.
- Wani, S. H., Gull, A., Allaie, F. and Safapuri, T. A. (2015). Effects of incorporation of whey protein concentrate on physic-chemical, texture, and microbial evaluation of developed cookies. *Cogent Food & Agriculture*, **1**: 109

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