RETORT PROCESS FOR LONG-LIFE DALIA DESSERT

THESIS SUBMITTED TO THE
NATIONAL DAIRY RESEARCH INSTITUTE, KARNAL
(DEEMED UNIVERSITY)
IN PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE AWARD OF THE DEGREE OF

MASTER OF TECHNOLOGY
IN
DAIRYING
(DAIRY TECHNOLOGY)

BY
MURLI KUMAR
B.Sc. (Dairy Technology)

DIVISION OF DAIRY TECHNOLOGY
NATIONAL DAIRY RESEARCH INSTITUTE
(I. C. A. R.)
KARNAL - 132001 (HARYANA), INDIA
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CERTIFICATE

This is to certify that the thesis entitled, " **RETORT PROCESS FOR LONG-LIFE DALIA DESSERT** " submitted by **Mr. MURLI KUMAR** towards the partial fulfilment of the award of the degree of **MASTER OF TECHNOLOGY** in **DAIRYING (DAIRY TECHNOLOGY)** of the **NATIONAL DAIRY RESEARCH INSTITUTE (DEEMED UNIVERSITY)**, Karnal (Haryana), India, is a bonafide research work carried out by him under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

Dated: **JUNE 17 , 2004**

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DEDICATED TO

MY

BELOVED PARENTS

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Date: 17 June 2004 *(Murli Kumar)*

Place: Karnal

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List of abbreviations and symbols

J_h	:	The time lag before the heating curve assumes a straight lin semilog paper (dimensionless intercept parameter)
f_h	:	The slope of the straight line portion of the heating curve. The slo the curve is expressed as the number of minutes required for the to traverse one logarithmic cycle
U	:	The equivalent, in minutes, at retort temperature, of all lethal received by some designated point in the container during the proc
F_o	:	The number of minutes required to destroy a given number of spo 121.1°C when z = 10°C
C_g	:	Cook value is the measure of chemical and organoleptic changes the reference temperature is 100°C and z = 33
PID	:	Pseudo-initial deficit
ID	:	Initial temperature deficit (difference between the set retort tempe and the core temperature)
Z	:	The slope of the thermal death time curve. It represents the numb degrees F required for the curve to traverse one logarithmic cycle measures the change in thermal death time or death rate with cha temperature
J_c	:	The slope of the straight line portion of the semilogarithmic co curve (dimensionless intercept parameter)
G	:	Difference between retort temperature and the maximum temper reached by the food at the point of concern during the heating cycle
B	:	Thermal process time, uncorrected for time required to bring the to processing temperature
D	:	Time required at any temperature to destroy 90 % of the spor vegetative cells of a given microorganism
$ID_{(h)}$	:	Initial deficit which represents the difference between retort temper and food temperature when heating is started.
$ID_{(c)}$	:	Difference between cooling water temperature and food temper when cooling is started
TCA	:	Tri-chloroacetic acid
PLC	:	Programmable logic controller
µ moles	:	Micromoles
SNF	:	Solid not fat
Rpm	:	rotation per minute
HMF	:	Hydroxy methyl furfural
TBA	:	Thiobarbutaric acid

ABSTRACT

Consumer convenience along with safety is key to value addition in dairy and food processing industries. In this context, technology development for certain traditional dairy products is obviously the topical area of research geared to cater to the need of the industry for avenues to diversify its activity with local and export markets in view. With this background in mind the present project was undertaken to develop an in-can retort process for shelf-stable ready-to-serve *dalia* dessert, a popular Indian dairy delicacy.

Screening of five different wheat varieties of durum (3) and non-durum (2) types helped select the *Triticum durum* variety WH-896 as the most suitable one for *dalia* making. Preliminary studies involving various formulation aspects of retort processing of canned *dalia* dessert without adverse effects on the product enabled quality, enabled identification of the range of nisin level (0-800) and thermal process value F_0 (4-8) to be integrated into a two-factor Response Surface Methodology (RSM) design. Thirteen experiments planned using the Central Composite Rotatable Design (CCRD) were conducted and the product monitored for fresh-status quality and changes during storage at 37°C. The data were analyzed employing the Design Expert software which yielded an optimized response in terms of product's sensory acceptability and shelf life. The optimally processed *dalia* dessert in 175 ml tin-free steel cans employing a rotary retort would keep well for at least 72 days at 37°C, i.e. at an average ambient temperature of 30°C it would have a shelf life of several months. The product contained on an average 3.7% fat, 3.6% protein, 0.8% ash, 21.5% total carbohydrate and 29.6% total solids. Such a processing option could be expected to help commercial production and wide scale marketing of the product along modern lines thus effectively serving the purpose of value addition and market expansion for the dairy industry.

सारांश

डेयरी एवं खाद्य प्रसंस्करण उद्योग में उपभोग में सहजता, खाद्य सुरक्षा के साथ एक महत्वपूर्ण मूल्य संवर्द्धन का तरीका है। इस सन्दर्भ में कुछ विशेष परम्परागत डेरी उत्पादों का तकनीकी विकास एक शोध का विषय है। जो कि उधोग की जरूरतों को ध्यान मे रखते हुए विविधिकरण करके स्थानीय और विदेशी व्यापार को गतिविधियों को विस्तृत बनानें में सहायक बन सकता है। इस भूमिका को ध्यान मे रखते हुये वर्तमान शोध कार्य दलिया के लिये एक डिब्बा बन्द रिटार्ट प्रोसेस विकसित करने के लिये प्रारम्भ किया गया।

गेहूँ की विभिन्न नस्लें प्राथमिक आवश्यकताओं के आधार पर छांटी गई। जिनमें से 3, ड्यूरम नस्ल और 2 गैर ड्यूरम प्रजाति की थी। उक्त पांच मे से ट्राटिकम डयूरम नस्ल की डब्ल्यू एच. 896 वैराइटी दलिया बनाने में सबसे उपयुक्त पाई गई।

प्राथमिक अध्ययन में विभिन्न प्रसंस्करण सम्बन्धी पैमाने इस प्रकार स्थिर किये गये कि उत्पाद की सुगमता यथावत बनी रहें। लाईसिन का स्तर (0- 800 पी. पी. एम.) तापीय प्रसंस्करण मान एफ शून्य (4-8) को दो पैमानिक केन्द्रीय संयुक्त धूर्णक डिजाईन (सी. सी. आर. डी.) में रखवाया गया और प्रत्युत्तर तल प्राविधि की मदद से विश्लेषित किया गया तथा उत्पाद को 37^0 ताप पर संग्रहण के लिये रखा गया। दोनो अनुप्रयोगों से प्राप्त आंकडों को डिजाइन एक्सपर्ट साफटवेयर की सहायता से परखा गया और अनुकूलतम हल प्राप्त किया गया।

ज्ञानेन्द्रिय परीक्षण और गुणवता के आधार पर अनुकूलतम प्रसंसाधित दलिया डेजर्ट को टिन रहित स्टील के डिब्बों में पैक करके रोटरी रिटार्ट में उपचार देने के उपरान्त तथा 37^0 सेन्टीग्रेड पर 72 दिनों तक संग्रहित रखनें पर उत्पाद की गुणवत्ता पर कोई भी प्रतिकूल प्रभाव नही पाया गया अर्थात औसत वातावरण तापमान (37^0 से.) पर इसकी संग्रहण आयु कई महीनो तक की होने की प्रबल सम्भावना है। अन्तिम उत्पाद में 3.7 प्रतिशत वसा, 3.6 प्रतिशत प्रोटीन, 0.8 प्रतिशत भस्म, 21.5 प्रतिशत कार्बोहाईड्रेट तथा 29.6 प्रलिशत कुल ठोस पदार्थ पायें गये। इस तरह के प्रसंस्करण विकल्प, इस उत्पाद के व्यवसायिकरण तथा विशाल पैमाने पर विपणन के लिये सहायक सिद्व होंगे, जिससे दुग्ध उधोग का व्यापार विकास तथा मूल्य संवर्द्धन के उद्वेश्य पूर्ति होगी।

1. INTRODUCTION

In the Indian food ethos, cereal, pulses and milk have been strongly engrained as staple foods. References abound in the ancient Indian literature on blending of these staple foods for their ‘’satvic’’ (godly) attributes. These have been recommended as ideal foods for persons pursuing religious and higher academics.

With the change in socio-economic scenario in India, the markets are becoming increasingly evident in the dairy and food sectors. Packaged foods ensure not only safety to the consumers but also offer an improved quality together with convenience in terms of purchase, storage and consumption. The changes in traditional family structure and hasty life style have influenced the eating patterns and food choices in the society. Ready-to-eat and ready-to-reconstitute, commonly known as convenience foods, are becoming more and more popular. The time-scanty professionals, double income households and hurried house-wives form an instant market for these products, especially in the metros.

India has emerged as the largest milk producing country in the world with an annual figure of 84.6 million tones estimated for year 2001 (Aneja, 2002). Out of this only 10.6% (approx.) (Aneja, 2002) of the total milk produced is routed through the organized sector. Exports have been negligible. It has been emphasized that to provide a fillip to the Indian dairy industry, the huge potential of unorganized sector of traditional dairy products will have to be tapped. Suitable technological innovations aimed at value addition product diversification, export promotion, elimination of cold chain for distribution and marketing and ensuring safety and high quality of traditional products would provide tremendous boost to the dairy industry.

Traditional dairy desserts seem to have a great potential to provide the much-needed opportunity to the milk processing industry for product diversification and value addition as well as for export promotion. Desserts based on cereals such as rice and wheat is popular throughout the country and occupies a valued position in the Indian diet, not only for their taste and delight of eating but also for their high nutritional quality. The combination of Lysine- rich milk protein with lysine-deficient cereal protein has a kind of synergistic effect which imparts a high nutritional value to the mixed protein in the product. Cereals also constitute a source of calcium, iron and the B-group vitamins. In this manner, the cereals containing dairy desserts bring together the nutritional virtues and savour to the delight of the consumer.

Dalia, a wheat based particulate dairy dessert is a unique product representing dairy and food processing going hand in hand. Popular throughout Northern India, limited shelf life even under refrigeration impose severe restrictions on its organized manufacture and marketing. It was envisaged that if a process could be developed for *dalia* dessert in a shelf stable form, most of the hindrance in commercialization of the product the organized channel could be eliminated. Problems associated with thermal processing of heterogeneous products such as a milk–wheat mixture that *dalia* dessert represent may be sought to be circumvented by adopting retort processing as demonstrated by Jha *et al*.(2000) who produced long-life rice kheer packaged in retortable pouches. In-package thermal processing offers certain unique advantages viz. flexibility of scale of operation, absence of need for aseptic packaging etc.

The advent of retort processing technology has made the availability of shelf stable Ready-to-Eat (RTE) foods a reality in the Indian market. A variety of lip- smacking Indian dishes such as Dal Makhani, Aluchhole, Chana Masala, Navrattan Korma, Palak Paneer, Sambar Rice etc. are now readily available off the shelf (Rangarao, 2002). With food processors like Tasty Bite Eatables, MTR Foods, ITC Foods, Satnam overseas, ADF Foods and many others dishing out newer and newer products to meet the demands of the Indian palate, the RTE foods business is reported to have reached a turnover of Rs. 60–80 crore during the current year (Menon, 2003; Bhushan, 2003). It is even said that we are in the midst of a Ready-To-Eat revolution (Gupta, 2003). Thanks to the retort process, many prized vegetarian and non-vegetarian dishes of both North and South India have entered the super market chains abroad offering an opportunity of the millennium for the Indian processed food Industry (Rao, 2003). This category of products also assumes importance among processed foods due to the fact that they do not contain any chemical preservatives and remain shelf stable without refrigeration for a year or more.

Thermally processed and packaged desserts are expected to have adequate shelf life to facilitate their transportation and shipping over long distances and thereby helps extensive marketing. This would bring the cereal based dairy desserts out of the confines of the domestic kitchen. In the context of the facts stated above the present study was undertaken with a broad objective of developing retort process for the manufacture of a long-life *dalia* dessert, the specific objectives being:

- Suitability of different varieties of wheat for the preparation of the *dalia* dessert
- Process optimization for in- package retort cooking
- Evaluation of storage stability

2. REVIEW OF LITRATURE

Present study was undertaken to develop retort process for production of long-life *dalia* dessert, so that a value-added dairy product could be offered to the consumer as a convenience food. The relevant aspects are reviewed in this chapter.

2.1 CEREAL BASED DAIRY DESSERTS

In India, apart from traditional, milk based sweets, cereal and legume-based sweets are also popular. They are relished by the consumer for their unique organoleptic quality. Cereal-based dairy desserts, traditional or otherwise, may be obtained from rice or wheat in different forms viz., whole or broken grains, grain fraction such as semolina, and cereal flour.

2.1.1 Wheat Based Dairy Desserts

Dalia or porridge is a product which is obtained by cooking wheat grits in boiling water or milk along with some sugar to sweeten the product. The grits, upon heating, gelatinize increasing the consistency of the product (Gujral and Sodhi, 2002). A non-milk Wheat porridge or dalia was obtained from coarsely ground and fried in desired amount of edible fat for a short period, water, sugar and / or salt were added and cooked into porridge of desired thickness (Khan *et al.*, 1986).

Vijay Rao *et al.* (1994) prepared freeze dried wheat porridge (*dalia*) and carried out its chemical analysis and shelf life studies. Before freeze drying *dalia* or cracked wheat was roasted in vegetable fat at 100 ± 10^0C then pressure cooked (15 psi) for 30 min. Softened *dalia* was cooked along with milk and sugar and then the product was cooled to room temperature. The cooled *dalia* was frozen in a blast freezer at -20^0C and freeze dried at 60^0C and vacuum of 0.3 mm of Hg for 16 hours. The freeze dried product contained 12.2 g protein, 9.3 g fat and provided 428 kcal per 100 g. It had a shelf life upto 6–9 months at 37^0C when packaged in paper/foil/polyethylene laminated flexible pouches.

It was found that semolina-milk powder based ready mixes, when packed in polypropylene (200 gauge) and metallized polyester/polyethylene pouches, kept well for 120-150 days at 65% RH and 27^{o}C and for 46 days at 92% RH and 38^{o}C (Singh *et al.* 1990). Arya (1990) reported that the defence Food Research Laboratory in Mysore had developed an instant porridge based on precook *dalia* and milk solids for space astronauts.

A ready-mix for kheer (Payasam) based on 30 per cent wheat *suji* (semolina) roasted in a grain roaster at 145^{o}C, 30 per cent powdered sugar and 40 per cent WMP, which could be easily converted into kheer of desired taste, aroma and consistency was reported by Singh and Shurpalekar (1989).

A product called 'gnocchi' containing wheat semolina, dehydrated potato, skim milk powder, powdered egg yolk, refined salt and monosodium glutamate has been reported to give a paste with unique texture, taste, odour, palatability and colour upon reconstitution in hot water (Venturelli, 1999).

Sevian is a sweet dish relished all over India and is a variant of kheer (Aneja *et al.*, 2002). It is usually made in households. *Sevian* is prepared by cooking and roasted vermicelli in milk. In northern India, thicker and shorter variety of vermicelli made from hard wheat is used to make this delicacy.

A ready-to-eat breakfast cereal containing instant milk powder, wherein milk powder is uniformly distributed among the cereal pieces, resulted in a uniform proportion of cereal and liquid milk in each serving when water was added (Bodkin, 1998).

Sohan Halwa is a hotter wheat based product characterized by extremely chewy texture attributed to wheat gluten. The wheat used for preparing sohan halwa is allowed to germinate and it is used in the ratio of 1:2 with normal wheat flour. The methodology followed in preparation of sohan halwa in northern India involves boiling of whole milk , cooling and leaving at room temperature to develop some acidity (approximately 0.18% as lactic acid). The blended flour is added to milk, keeping the flour to milk ratio at 15:10 and the mixture continuously stirred; sugar (10 to 15 %) is added to facilitate stir-frying when the Halwa has attained a brown colour. It is then turned onto a flat surface and leveled (Aneja *et al.*, 2002).

A milk sweet preparation based on wheat flour and called *ghever* is rare delicacy of northern India. It is a disc shaped sweet having cream yellow to orange brown shades of colour (attributable to the surface colour of caramelized sugar). For the manufacturing ghever, a thin slurry of refined wheat flour (maida) in emulsified fat (oil-in-water emulsion), is deep fat fried into a doughnut shaped honey comb structure and sweetened with sugar syrup (Saxena et al., 1996 ; Aneja *et al.*, 2002). Dressing the product with dried fruits, nuts or a thin layer of rabri may optionally. The doughnut was placed to remove excess fat and sugar syrup was slowly poured over the ghever, cooled and packed. There was significant difference between the LDPE packed and open tray stored samples and remained acceptable for 60 days.

Rheology and other properties

Gujral and Sodhi (2002) investigated the effect of wheat grits, sugar concentration and temperature on the rheological characteristics of *dalia* using back extrusion method. The porridge was back extruded at temperatures of 20°C, 40°C and 60°C. Plunger speeds varying from 1000 to 2500 mm per minute were used so that the porridge could be back extruded over a wide range of shear rates. The study revealed the non-Newtonian and pseudoplastic behaviour of wheat porridge. Wheat grits concentration had the most pronounced effect on the consistency followed by temperature and sugar concentration. Consistency coefficient increased with increasing grits and sugar concentration but decreased with increasing temperature. The consistency coefficient of the porridge samples varied from 5.9 to 241.6 Pa.s and activation energy varied from 9.23 to 33.57 kJ/mole. The porridge samples exhibited yield stress only at the highest grit concentration of 15% and lowest temperature of 20°C.

2.1.2 Rice based dairy desserts

Rice-based milk cereal, commonly referred to as kheer, is an Indian traditional dessert prepared by partial dehydration of whole milk, with sugar and rice added to it, in an open pan over direct fire (De *et al.*, 1976), the commonly consumed in the West (Aneja, 1997). Mani *et al.* (1955), in probably the earliest work on kheer, studied the nutritional value of traditional kheer made from rice and milk containing 4.1 per cent fat and 12.5 per cent total solids. According to Aneja (1997), preparation of kheer involves immersion of pre-soaked rice in simmering milk (6 per cent by wt.) followed by sugar addition (6-8 per cent) and heating the mixture further till rice softens up and shows signs of gelatinization, leading to substantial thickening. Chopped nuts and cardamom are then usually added. The method of kheer-making has undergone a limited modification in that the open pan process employing direct fire has been successfully replaced by the steam-kettle one.

De *et al*. (1976) were the first to study the method of manufacture of kheer using the steam-kettle process. They made kheer from cow milk with 4 per cent fat using 2.4 per cent rice (presoaked) and 5 per cent sugar. Later, Chaudhary (1989) who studied different compositional variables, observed that the best quality kheer could be prepared from buffalo milk containing 5 per cent fat and 9.7 per cent SNF, and added with 5 per cent rice and 12 per cent sugar. The composition of rice kheer is presented in Table 2.1. In further attempts to modify the kheer-making process, Chaudhary (1989) obtained an acceptable product by mixing sweetened condensed milk (diluted to 30 per cent TS by adding buffalo milk) with pre-cooked rice (6 %). Jha (2000) developed a rotary retort process for in-pouch cooking-cum-sterilization for long-life kheer comprising milk and Basmati brokens. He also reported a process for a dry mix suitable to be reconstituted in an acceptable quality kheer.

Table 2.1 Chemical composition of kheer reported by different workers

Constituent	**(% by wt.)**			
	Mani *et al.* (1955)	De *et al.* (1976)	Chaudhary (1989)	Jha (2000)
Total solids	31.0	32.98	38.23	33.25
Fat	12.2	7.83	6.38	8.35
Protein	5.9	6.34	5.44	11.35
Ash	2.3	1.41	0.74	1.14
carbohydrates	11.3	17.40	25.68	12.25

Rheological studies on kheer were conducted by Bandyopadhyay (1995) with regard to effects of the rice variety and cooking time. Higher visual consistency and lower grain hardness contributed to appreciably higher texture acceptability score of the Basmati rice kheer. Viscosity of the milk-rice mixture increased logarithmically with increase in TS. It was also observed that the creamy consistency of the shear-thinning liquid fraction was generally preferred. However, the overall textural acceptability of the product appeared to be determined by both the liquid phase viscosity and cooked grain tenderness. According to Jha (2000), both the liquid phase and the mixed phase liquid and rice ground together of the in-pouch processed long-life kheer revealed a Power Law (shear thinning) flow behaviour. The consistency coefficient (k) of the liquid phase increased with the increasing rice-to-milk solids (RMS) ratio which indicated that the product gained in apparent viscosity (consistency). The flow behaviour index (n), on the other hand decreased with the rising RMS ratio, which indicated that the shear-thinning behaviour became more prominent at higher RMS ratios.

Payasam, the South Indian counterpart of kheer is made in several variations with distinct characteristics attributed to area-specific traditional methods of preparation (Unnikrishnan, 1997).It may widely range in consistency. It can be made from pulses, cereals, tuber crop and fruits. All these *payasams* differ in their physico-chemical characteristics (Kulkarni, 1999). The different types of the *payasam* are given in the Table 2.2.

A delicious variant of kheer, *firni* is prepared by cooking milk with rice paste and sugar (Aneja *et al.*, 2002) it is believed to be introduced by Mughals and one of the essential food items at religious and auspicious occasions. To prepare phirni, milk and rice paste are mixed in the ratio of 10:1 along with 15% sugar (w/w) and cooked with continuous stirring until the milk starts to thicken. The cooking is continued till a desired consistency is achieved and product is cooled to room temperature, dispensed into individual containers and further cooled to 4^0C (Mathur *et al.*, 1985).

In-can sterilized 'creamed-rice' dessert was reported by Keogh (1970) in which short-grained rice releasing starch on cooking was used. Homogenization of milk was found to improve the product quality. Gradual heating up periods and agitation were necessary during autoclaving to prevent localized overheating. Even though browning and age thickening were reported, the product had a shelf life of 12 months.

Table 2.2 Product profiles of cereal-based *Payasams*

Type	Name	Characteristics
Cereal Based	*Rice Payasam (Halu Kheeru type)*	Viscous, free flowing, non-homogeneous product with rice settling at the bottom, contains liberal amounts of raisins and cashew nuts.
	Pal Payasam	Highly viscous, rice uniformly distributed, light brown in colour, pleasant caramelized flavour.
	Gil –a - firdaus	Creamy rich, highly viscous homogeneous product, light brown in colour, pleasant nutty flavour, garnished with high levels of fruits and nuts.
	Wheat *Payasam* (*Godhi type*)	Highly viscous, pasty, semi-solid product with visible coconut gratings, brown in colour, nutty cardamom flavour.
Cereal Product Based	Beaten rice *Payasam*	Low viscous, free flowing white product with visible coconut gratings, cooked flavour
	Rice *Suji Payasam*	Homogeneous, thick, viscous product with suspended dry fruits, light cream in colour, cooked and pleasant flavour of added spices.
	Wheat *Suji Payasam*	Thick, viscous, homogeneous product with suspended raisins and cashew nuts.
	Firni	Highly viscous, homogeneous product, light yellowish brown, nutty / fruity flavour.

Ref.: Unnikrishnan (1997)

aBell (1994) noted that selection of rice for several convenience products including rice pudding depends on taste, appearance and nutritional criteria. Various types of rice used for preparing puddings include brown rice, long grain rice, and medium grain rice. Ebel (1986) produced a rice pudding employing a Contherm scraped surface heat exchanger. Rice and milk were pumped into the Contherm system, heated up to 115oC, held for 26 min in a holding tube and then cooled down to 80oC in another Contherm cylinder. The rice pudding was transferred to a sterile buffer tank, and then filled into plastic pots a rice pudding was made using sterilization at 137.8ºC for 30-60 sec; the two components of the rice pudding, the rice kernels in a small amount of liquid and the sauce, were sterilized individually and then combined in the can as necessitated by different sterilization treatments required for the two components (Kester and Matz, 1970). Casimir and Lewis (1972) described the process of flame sterilization, which has been highly successful for canned milk-rice puddings. The pudding mix was packed in cans, which were immediately closed and run into the heating section (137.8ºC for 40-60 s).

The shelf life of conventional rice kheer is very limited. De *et al.* (1976), found the shelf life of kheer, hot packed in tin cans, to be only 2-3 days at 37 ^{o}C which could be extended, up to 3-4 days by adopting in-can thermal treatment, and up to 8-10 days by employing nisin as a preservative. Chaudhary (1989) observed the shelf life of steam kettle-process kheer to be only 7-8 hours at 30^{o}C and 9 days at 5^{o}C. Even the use of sodium-metabisulphite could not appreciably improve the shelf life of kheer at 30^{o}C. Jha (2000) observed the shelf life of the retort pouch kheer to be 115 days at 37^{0} C and instant kheer mix powder have six months at room temperature.

2.2 WHEAT

2.2.1 General

Historic documents confirm that wheat is the earliest field crop used for human food processing (Swanson, 1928) it also became the leading grain used for human consumption due to its nutritive value and relatively easy harvesting, storage, transportation and processing, as compared to other grains (Posner, 2000). Currently about 4000 different varieties of wheat are grown around the world the main varieties being *Triticum aestivum* and *Triticum durum*. Wheat is characterized and classified primarily by its colour and appearance, and hardness. For example, Durum wheat are of three types: (1) hard amber durum wheat – with 75% or more of hard and vitreous kernels of amber color; (2) amber durum wheat – with 60% or more but less than 75% hard and vitreous kernels of amber color; (3) durum wheat – with less than 60% hard and vitreous kernels of amber color (USDF, 1995).

Chemical composition of wheat is as follows: Fat, 2.9%; protein (N × 5.7), 16%; soluble carbohydrate, 74.1%; crude fiber, 2.9%, and mineral matter, 1.8% (Mc Cance et al., 1945).

2.2.2 Grain quality indicators

Grain quality is an important factor and determines the wheat grade. It should be free from live insects, of an amber–yellow to brown color, dry, vitreous, with a translucent and horny cross section (EEC) while other varieties are opaque, mealy or floury. Wheat endosperm traditionally vitreousness had been associated with hardness high protein content and opacity with softness and low protein. In durum wheat, a much larger numbers of broken starch granules occur when the kernel is fractured. The strength of the protein-starch bond appears to explain the kernel hardness. In the soft wheat; the starch-protein bond ruptures easily (Bradbury, 1956).

Ash content of is Important in the assessment of the semolina quality in term of appearance etc. Yellow pigments are a major quality factor in durum wheat and are often referred to as caretenoids, which could include both carotene and xanthophylls (Laignelet, 1983). Brownness is correlated with peroxidase and polyphenoloxidase activity (Laignelet, 1972; Kobrehel *et al*., 1974).

2.2.3 Cooking quality indicators

Resmini and Pagani (1983) and Feillet (1986) reported that the cooking quality of durum wheat (cracked) was related to the greater or lower capacity of their protein network: a loose network allows starch granules to escape during cooking. Relation with protein showed that water soluble proteins favours water absorption during cooking, whereas other fractions depress absorption (D`Egidio *et al*., 1976a). Cooking quality tended to improve with increasing protein content; at a given protein content, the cooking quality and firmness and absolute recovery of the gluten increased in parallel (Cubadda, 1988). The protein composition particularly the ratio of alcohol-soluble to water-soluble fractions is also important to the cooking behavior.

Chemical and rheological tests can be used to evaluate the suitability of soft wheat for bread making and for other types of processing. With regard to rheological on tests, the most popular are the farinograph tests (Irvin et al., 1961; Dexter and Matsuo, 1980).

2.3 THERMAL PROCESSING FOR PARTICULATE FOODS

2.3.1 General

Thermal processing of canned foods has been one of the most widely used methods of food preservation during the twentieth century and has contributed significantly to the nutritional well-being of much of the world's population. Processing of canned foods consists of heating food containers in a pressurized retort at a specified temperature for a prescribed length of time so that sufficient bacterial inactivation is achieved in each container to comply with public health standards and to ensure that the probability of spoilage will be less than some minimum (Teixeira, 1992) .Unlike, aseptic processing systems involving sterilization by high-temperature short-time heating followed by aseptic packaging, retort processing is particularly suitable for fluid foods that contain solid chunks of meat and vegetables, etc. such as soups and stews. For many years, attempts have been made to develop an aseptic process for food products containing particles but the progress has been hindered by the requirement to demonstrate an adequate thermal treatment for every portion of the product (Larkin, 1997). Scraped surface heat exchangers (SSHE), ohmic heating etc. have been studied as systems for such products (Harrod, 1986; Sastry and Palaniappan, 1992; Reznick, 1996; Zoltai, 1996). However, retort processing of portion-packed products has its own advantages viz., flexibility of scale of operation, simple handling, no need for aseptic packaging etc.

A batch retort model was developed by Almonacid-Merino *et al.* (1993) for food sterilization, which uses a heat transfer equation for heat conduction in cylindrical cans, 1st order kinetics for microbial inactivation, 1st order kinetics for quality losses and a transient energy balance to estimate steam consumption. Forced convection heat transfer in cans was studied experimentally by Sablani and Ramaswamy, (1996), using model foods during end-over-end sterilization in a full-immersion, hot water rotary sterilizer. Computer-aided methods have been applied for the thermal processing of foods to improve nutrient retention and to automate the process by Fastag *et al.* (1996).

2.3.2 Retorts – types and modes of processing

Just as with most industrial processing operations, both batch and continuous systems are used in the food canning industry. As the name implies, batch systems are made of individual batch retorts that operate intermittently. In continuous systems, cans are automatically fed into and out of retort systems that operate continuously (Jackson and Shinn, 1979).

Some of the factors which affect the sterilization efficiency of a vertical still retort are: can size, food consistency, retort temperature, initial food temperature and target lethality (Bhowmik, 1983). An alternative to the vertical still cook retort is the horizontal still cook retort. Parchomchuk (1977) developed a system for agitating cans to cause rapid heat penetration during thermal processing in retorts, in which cans are oscillated in a circular path in such a way that the can orientation remains fixed.

Batch rotary retorts are used to induce forced convection to optimize the heat penetration throughout the product (Scott, 1992). The provision of an adequate head-space when the container is filled is critical if optimal agitation is to be realized. The choice of method and rotation speed depends upon the nature of the product. The more fluid the product is, the slower the rotational speeds used could be. For heterogeneous products, rotation at 12-18 rpm has been recommended (Larousse and Brown, 1997).

Continuous retort operations require some means by which cans are automatically and continuously moved from atmospheric conditions into a pressurized steam environment, held or conveyed through that environment for the specified process time, and then returned to atmospheric conditions for further handling operations (Tung, 1974). The best known commercially available systems that accomplish these requirements are the crateless retort, continuous rotary cooker, and hydrostatic sterilizer (Yamano, 1976).

Retort operating procedures must ensure that uniform processing temperature is achieved and maintained throughout the location of containers during the process. Achievement of uniform temperature occurs by the end of come-up time, which is the period from the time steam is admitted into the retort until process time begins (Somers, 1944). The operating procedures used during come-up time vary for each type of retort. However, each steam retort will have a venting schedule (NFPA, 1982).

It is widely recognized that overpressure thermal processes are necessary to commercially sterilize food in glass as well as flexible and semi-rigid plastic containers (Tung *et al.*, 1990). Steam/air mixtures and water immersion methods with overpressure are commonly used because of their ability to maintain pressure in the retort greater than the saturated vapour pressure within the package during processing (Kisaalita *et al.*, 1985). This is necessary during the heating period to overcome the tendency of gases within flexible or semi-rigid packages to expand and retard heat transfer, and during the cooling period to counteract internal vapour pressure which could otherwise tend to distort or burst the container (Weintraub *et al.*, 1989). Steam/air mixtures have many advantages in terms of achieving heat transfer by steam condensation at essentially a constant temperature, in contrast to water systems where the heating medium must experience a drop in temperature to transfer heat to packages (Tung *et al.*, 1984).

The use of forced-convection retorts has permitted increased load densities and greater throughput in commercial operations (Ramaswamy and Tung, 1986). The gaseous nature of steam/air mixtures enable them to be circulated readily in turbulent flow (Ramaswamy *et al.*, 1983). Steam/air mixtures are adaptable for modern packaging forms which require overpressure sterilization with variable pressure / temperature throughout the process cycle. For processing in steam/air mixtures, Davis *et al.* (1972) stated that the same steam/air ratio must be reproducible every time a retort load is processed, and this mixture must be uniform throughout the retort load at all times. Rigid cans generally do not require counter-pressure, but certain types with a relatively low rigidity are exceptions.

Varga and Oliveira (2000) conducted studies to determine experimentally the overall heat transfer coefficient describing heat transfer from the heating and cooling media of a retort to the inner surface of packed containers in fully loaded retorts and to analyze the possibility of using numerical models to calculate a time varying heat transfer coefficient and the impact on lethality achieved in a conduction heating product was also studied. Effects of four processing variables (initial temperature, heating time, headspace and external heat transfer coefficient) on the F-value (sterilization value) distribution in an industrial scale batch retort systems were investigated by Varga *et al.* (2000). Effects of various processing conditions (rotation, come-up and pressure build-up) on temperature distribution in static and rotary cascading retorts have been studied by Smout *et al.* (2001).

2.3.3 Sterilization value and thermal process calculations

The establishment of a thermal process should always involve two phases (Hayakawa, 1970). The first is the determination of the heating time at a specific retort temperature to achieve the required $F_{o.}$ This involves heat penetration measurements and mathematical analysis of the data. The F_o value of a thermal process as applied to a food is defined as the time in min at 121.1^{o}C, assuming the whole can to be raised simultaneously to this temperature and cooled instantaneously to a sub-lethal temperature afterwards, that would give the same degree of sterility as the process to be valued (Gillespy, 1951). The second phase is a follow-up test employing microbiological methods to confirm the calculated process by either the inoculated pack system or the count reduction system (Cleland and Robertson, 1985).

The factors that govern the F_o value of a process include dimensions of the can, thermal diffusivity of the can, differential translocation of material in the can either due to convection currents or to rotation/agitation of the can, initial temperature of food, time for the retort temperature to rise to the processing temperature and the order of that rise (linear or logarithmic), processing temperature in the retort, time of processing, time between the end of the heating process and the start of water-cooling, temperature of the cooling water and the relationship between temperature and the rate of destruction of organisms i.e. the thermal death-time factor (Ball, 1923; Bigelow, 1921; Gillespy, 1951; Xezones and Hutchings, 1965; Hayakawa, 1978; Odlaug and Pflug, 1978)

The transient temperature of food needs to be accurately predicted during its heating and cooling treatment in order to design a proper device for this treatment or in order to accurately evaluate its efficiency. In all containers undergoing thermal processing the temperature varies with time, even if the external conditions such as steam temperature remain constant (Stumbo, 1973). There are two ways in which temperature profiles can be determined such as direct measurement by placing thermocouples in a can or pouch and by predictions using heat transfer models such as pure convection or pure conduction (FDA, 1973; Stumbo *et al.*, 1975).

2.3.4 Process lethalities for food products

Zardetto (1999) reported a F_o value of 7-10 for fresh filled pasta used in several commercial installations in Europe and USA. A thermal process designed for acidified canned papaya (pH 3.8) gave a satisfactory product at 97^oC/12.9 min giving a F_o value of 1.7 (Magalhaes *et al.*, 1999). Ready-to-eat paneer curry in cans/pouches was developed using hurdle technology with a relatively low F_o value of 0.8, the product had a shelf-life of approx. 1 month and better quality as compared to the conventionally sterilized (F_o =15) product stored under similar conditions (Rao and Patil, 1999).Retort-pouch long-life kheer processed at F_0 value 12.4-14.8 in a rotary system had a shelf-life of 115 days at 37°C (Jha, 2000).

Canned smoked-oyster in cottonseed-oil processed with an F_o of 5.92 was found to show no significant change in pH &TBA values upon storage (Han *et al.*, 1995). Studies conducted on heat sterilization of cooked ham indicated that F_o value might not be an unreliable parameter for assessment of heat treatment of slowly-heated products (Quintavalla *et al.*, 1995). Heat treatment equivalent to F_o of 5 was found to be satisfactory with regard to emulsion stability and fat separation during the manufacture of liver sausage (Hilmes *et al.*, 1993).

Besides rice kheer and paneer certain Indian food products have also been successfully canned and processed in stationary retorts with long shelf-life such as ready-to-serve parottas and cutlets (Kannur *et al.*, 1973) in rotary retort long-life kheer (Jha, 2000). Other retort sterilized products include mango beverage (Saini *et al.*, 1996), whey-tomato soup (Sudheer, 2000), paneer *curry* (Surinder, 2004), ghee *Rice*, puliogere, sweet *Pongal*, chicken *Biryani*, vegetable *Kurma*, Shahi *Paneer*, chicken *curry*, kesari *Bhath*, vegetable *Palao* and tomato *Bhath* (Rangarao *et al.*,2004)

2.4 PACKAGING FOR RETORT PROCESSING – TIN-FREE STEEL CANS

2.4.1 General

In the early sixties, a worldwide development was started in Japan with the objective of providing a material, which did not require tin as surface coating materials. This gave birth to the so-called tin-free steel (TFS). The steel for TFS is produced in much the same way as steel for tinplate and has the same specification for gauge and temper. The deposition of either chromium / chromium-oxide or chromium/ phosphate on the surface is done both in cathodic and anodic-cathodic manner. The various TFS materials differ mainly with respect to surface treatments applied to the steel and the resulting differences in corrosion resistance, appearance and enamel adhesion (Anon, 1974).

Commercial developments of chrome-plated and chromate-treated steels for food cans began in Japan and materials of this type are now being manufactured in Japan, Europe and Britain. Typical examples of these materials are; 'Can Super' made by Fuji Iron and Steel Co. Ltd., and 'Hi-Top' made by Toya Kohan,Japan. The US Steel Corporation has developed 'TFS-210' which is made by a cathodic chromate phosphate process (Mahadeviah and Gowramma, 1996 a).

Naresh *et al.* (1989) have reviewed the chromium coated steel plate as an alternative to tinplate for canning food products and fabrication of TFS cans and different properties of TFS, and have compared the economics of TFS with aluminium and tin cans. Barbeiri *et al.*, (1970) studied the suitability of various type of chromium-coated steel against tinned steel for packaging food product.

Rice (1992) reported that microwaveable steel cans have a number of benefits including ensuring a 2 year non-refrigerated shelf-life for products contained within them and being easy to secure and stated that it may be a problem of consumer acceptance because of seemingly placing metal in the microwave. A new easy to open all steel can (TFS) offered by Continental Can Company was introduced in the U.S.A. during 1970 for canning of a number of vegetables, meat and fish products (Anon, 1971). Mathews *et al.* (1998) studied groundnut oil packed in tin-free steel and tin plate container. They observed that there was no significant difference in the peroxide value, FFA and the quality of oil between the two types of containers.

Charbonneau (1997) reported that filiform corrosion resulted on the out side surface of two-piece tin-free steel cans in which tuna was packed. The cause of the corrosion was related to scratch defects on the exterior coating and the presence of chloride and sulphate canning residues in the corroded areas. Enamel adhesion failure was noticed inside the two piece tin-free steel cans that contained mushrooms.

Anon (1992a) discussed a new packaging material called Ferrolite, which is a steel product coated on one or both sides with a high quality polymer, produced by British Steel Tin Plate Co. It can be used for microwaveable metal tray as well as DRD cans and easy-open ends. Anon (1992b) described the all-steel beverage can that will be down gauged and fully recyclable. Morries (1993) reported different packaging materials using polyester as a coating material for processing different food products.

2.4.2 Types of tin-free steel plates [The different types of TFS packaging material (Mahadeviah and Gowramma, 1996b)]:

Can super: - This is manufactured by electroplating cold-rolled steel sheet with chromic acid. Bending, drawn and impact tests show that the coated material on the plate doesn't peel off or flake. This type of container is used for mineral oils, gasoline tanks, paints, organic solution, dehydrated foodstuffs etc.

Hinac coat: - This is manufactured by treating cold-rolled steel strip with an emulsion containing chromic acid and an organic high polymer as main constituents with high-temperature baking for a short time. These types of containers have high corrosion resistance, supreme paintability, great chemical and thermal resistance and good workability. It is used for packing sugar, cake, soap, motor oil, solvents, paint, ink electrical cases, crown caps, etc.

Hi-top: - The process of manufacture of this type of sheet was developed by Toya Kohan's technical research in co-operation with its affiliated firm, Toyoseikan Kaisha Ltd., in Japan. Hi-top is a tin free steel sheet manufactured by treating electrolytically, cold-rolled steel strip with chromic acid. Container prepared by these types of sheet can be used for packing beer and carbonated beverages.

Stainless weirchrome: - This is a steel plate deposited eletrolytically with metallic chrome on both sides. The chrome film coating ranges from $0.1x10^{6}$ to 0.510^{6} in thickness (0.1-0.5 micron in).

2.4.3 Fabrication of TFS cans

Cans are fabricated from TFS sheet just as in the case of tin-plate. The surface film remains unpeeled after ordinary bending, curling, seaming and deep-drawing operations. The side seam parts of cans are normally joined by plastic cement derived from polyamide resin (Fidler, 1967; Mahadeviah and Gowramma, 1996b). Mira Seam and Conweld methods have been developed in the USA for manufacture of cans. In Mira seam method, a body blank pre-coated on both sides with a tailored epoxy enamel receives a thin ribbon of thermoplastic (nylon) adhesive along the pre-heated edge. In Conweld method, the coating on the blank is stripped away to the base metal along the narrow edge to be welded. This system operates in the range of 450 to 600 cans per min (Naresh *et al.*, 1980).

2.4.4 Advantages of TFS cans

- The base layer of chromium acts as corrosion barrier.
- The super-imposed layer of chrome oxide prevents rusting and iron taste pick up.
- Organic coatings adhere exceptionally well.
- Suitable for attractive printing.
- Strong resistance to Sulphur staining.
- Ease of fabrication
- It can be joined by welding or cementing
- Good chemical and thermal resistance.
- Tolerance to high processing temperatures
- Resistance to greater internal pressure.
- Flexibility in can shape.
- Improved and more reliable double seam.

2.4.5 Disadvantages of TFS

- Limitations for packaging of acid products.
- Compulsory lacquering.
- Not suitable for soldering.

2.5 NISIN

Nisin is a polypeptide antibacterial substance or bacteriocin produced by the fermentation of a modified milk residue by certain strains of the lactic acid bacterium, *Lactococcus lactis*. It shows antimicrobial activity against a range of Gram positive bacteria, particularly spore formers (Broughton, 1990). The inhibitory effects of nisin were first noticed about sixty years ago when inhibitory streptococci were considered to be a problem in cheese making. It was based on its therapeutic effect in veterinary and clinical uses (Hurst, 1983).

The potential applications for nisin in food preservation were first suggested in 1951 by Hirsch the Alpin & Barret in Dorset, England were produce the nisin concentrate, known commercially as Nisaplin®, which possesses a high and consistent activity (expressed in international unit (IU)). Addition level may vary from as low as 25 IU/g to 750 IU/g depending on the nature of application. The nisin molecules are acidic in nature and exhibits greater stability under acidic conditions and is also more soluble at lower pH (Hurst, 1981). Loss of nisin activity occurs during storage of foods. Losses were more pronounced at high pH and high temperature (McClintock *et al.*, 1952) observed in canned mushrooms (Denny *et al.*, 1961), chocolate milk (Fowler and Mc Cann, 1971) and simulated cooked ham (Rayman *et al.*, 1981).

In India, nisin is permitted under current legislation for use in cheese and processed cheese at levels of up to 1000 IU/g. Nisin has been successfully used in a variety of dairy products, including pasteurized milk, flavored milks, processed cheese, creams, chilled dairy desserts, canned milk puddings (kheer, 200 IU/g) (Singh *et al.*, 1987), khoa (100-200 IU/g), yoghurt (25-100 IU/g) (Gupta *et al.*, 1989) and more recently in heat processed and packaged paneer (150 IU/g). Other nisin uses included canned soups, canned vegetables, pasteurized liquid egg, some bakery products and alcoholic beverages (Broughton, 1990).

Nisin has been found to have a number of benefits when used in canned foods, permitting lower heat treatment resulting in substantial reduction in process value, improvement in organoleptic qualities, increased vitamin retention and enhanced keeping quality. In low acid food such as kheer higher nisin levels are required. Kheer containing 400 IU/g nisin processing in an agitated retort at 115^0C/6min. was sufficient for a satisfactory shelf life in contrast to the normal process of 15 min at 115^0C (Eapan *et al.*,1988). The keeping quality of sterilized milk, autoclaving at 15 psi momentary, in presence of nisin was extended up to 60 days in comparison to non nisin sample spoiled within 3-7 days (Wazid and Kalra, 1976).

Singh *et al*. (1987) reported an increase in shelf life of thermally processed kheer to more than 6 months at room temperature by using nisin at a concentration of 200 IU/g of the product. Eapen *et al*. (1988) reported that nisin has been used to lower the process value for some canned Indian dishes including kheer. Products were processed at different temperature after the addition of nisin and following inoculation with *Bacillus stearothermophillus* NCA 1518. Results indicated that the level of nisin required for adequate processing and the required processing time for kheer were 400 IU/g and 6 min, respectively.

2.6 RESPONSE SURFACE METHODOLOGY (RSM)

Response surface methodology (RSM) is reported to be an effective tool for optimizing a process when the independent variables have joint effect on the derived response (Hunter, 1959). Several workers have used it for optimization of cake formulations and fraction and reconstitution studies (Donelson and Wilson, 1960; MacDonald & Bly, 1968; Kissel, 1967; Kissel & Marshall, 1967).

The RSM can be successfully used to optimize a process (Madahar et al., 1989; Vaisely-Genser et al., 1987). Henika (1972) described response surface analysis as a useful statistical tool for analyzing experimental data to optimize the physical properties of the food products using different levels of ingredients. Since, then the RSM has been used in several areas like studies of protein denaturation (Nielson et al., 1973), bacterial growth (Schroder and Busta, 1973), high protein bread (Henselmen et al., 1994), enzyme-aided extraction of soybean (Kashyap et al., 1997), properties of fried paneer (Rao and Patil, 2001), Tandoori roti (Saxena and Rao, 1995), Dehydrated carrot halwa (Basantpare et al., 2003), Diabetic Ice-cream (Verma, 2002) and reconstituted paneer curry mix (Kumar, 2003). Prasad (2001) used central composite rotatable Design (CCRD) to optimize the level of sugar and whey to develop whey based mango beverage. Jha(2003) used RSM for the optimization ingredient level and processing variables for development of protein rich *sevian*.

3. SCOPE AND PLAN OF WORK

3.1 SCOPE OF THE STUDY

The review of literature in the foregoing chapter would reveal that there is not much published information available on various aspect of production of dalia dessert. Although the product is a popular cereal-based milk dessert in the Northern part of the country. Its physico-chemical properties have not been established, nor has any standard method been developed for its manufacture. Traditional dalia dessert processing techniques are localized, and hence, there is no readymade technology specifically designed for adoption of these processes in the organized sector or the industry. Traditional technologies are limited to household and consume time and require great effort. Limited shelf life of the conventionally made dalia dessert prevents its commercial marketing. Hence a process that would extend the shelf life of the product especially under ambient conditions would make wide-scale marketing possible.

The broad objective of the present study was, therefore, to increase the shelf-life of the dalia dessert by employing an in-can retort, for cooking cum sterilization, which would help the organized sector to undertake commercial production and marketing of dalia dessert without any safety risk.

3.2 PLAN OF WORK

The experimental work under the safety was to be conducted in three major phases: First, daila dessert as obtained by the traditional kitchen method as influenced by the wheat variety. Secondly, preliminary studies would be conducted towards product formulation. The third phase comprised retort process optimization and shelf life evaluation.

3.2.1 Comparative study of wheat varieties

3.2.1.1 Five varieties of dalia grains *viz. PDW-233, HD-2687, PDW-274, WH-896 and PBW-343 to the assessment for suitability for dalia making by the traditional.*

3.2.2 Formulation of the product (Rotary Retort Process)

3.2.2.1 Suitability of whole milk powder

In order to have a uniform formulation and consistent quality of milk in the dalia, whole milk powder (WMP) would employed to obtain reconstituted milk concentrate of the desired solids concentration. Alternatively milk standardized to the required TS using WMP would be used for product formulation intended for in-can retorting.

3.2.2.2 Roasting v/s Sautéing of dalia grains

The preliminary studies would also involve a study on the effect of different levels of dalia grains on product quality. Roasting would be compared with sautéing of the grains before cooking in milk.

3.2.3 Process optimization

3.2.3.1 F_0 and nisin levels

Based on the preliminary studies on retortability of dalia dessert for effecting cooking-cum-sterilization, the most desirable dessert formulation was to be employed for optimization of the rotary retort process (CIFT, Cochin) in terms of Fo value in the range of 4-8 (lower than the normal 12-16, in order to reduce the brown discoloration and stale flavour development) in conjugation with bacteriocin nisin (0-800 IU/g) cast into a 2 factor .Central Composite Rotatable Design (CCRD) for response surface methodology (RSM) experimentation (Table 3.1 and 3.2).

3.2.3.2 Shelf life evaluation

All the 13 lots representing different process variability levels would be subjected storage studied at 37 ºC. The products would be evaluated fortnightly for the following shelf life limiting physio-chemical changes.

3.2.3.2.1 Colour

3.2.3.2.2 HMF (Hydroxy Mehtyl Furfural)

3.2.3.2.3 TBA (Thio Barbutyric Acid)

3.2.3.2.4 pH

3.2.3.2.5 Viscosity

3.2.3.2.6 Sensory attributes

Table 3.1 Levels of parameters Used for Central Composite Ratatable Design

Parameter	Code	Levels tested				
		-1.414	**-1**	**0**	**+1**	**+1.414**
F_0	A	4.00	4.59	6	7.41	8.00
Nisin(IU/g)	B	0.00	117.16	400	682.84	800

Table 3.2 The Central composite Rotatable Design for Two Independent Variables

Point No.	Variable levels (Coded value)	
	A	**B**
1	-1.000	-1.000
2	1.000	-1.000
3	-1.000	1.000
4	1.000	1.000
5	-1.414	0.000
6	1.414	0.000
7	0.000	-1.414
8	0.000	1.414
9	0.000	0.000
10	0.000	0.000
11	0.000	0.000
12	0.000	0.000
13	0.000	0.000

4. MATERIALS AND METHODS

To develop a retort process for long-life *dalia* dessert experiments were carried out as per the plan of work given in Chapter 3, following a systematic approach and standard analytical methods. The materials and equipment employed in the present study are described in this chapter in four different sections:

4.1 MATERIAL

4.1.1 Milk

For the preparation of *dalia* dessert by the traditional method, Buffalo milk was obtained from the Experimental Dairy, of the Institute and standardized to 5% fat and 9% SNF. For the studies on in-can processed long-life *dalia* dessert, toned milk (3.0% fat and 8.5% SNF) essentially comprising cow milk, processed by the Ernakulam Co-operative Milk Producers' Union Ltd., Kochi was procured from the local market.

4.1.2 Whole milk powder

Whole milk powder used to increase the total solid content in the milk for long life *dalia* dessert was prepared at Experimental Dairy from mixed milks (cow and buffalo milks, 50:50) employing the spray process. It contained 23.5% fat, 25.9% protein, 39.35% lactose, 5.92% ash and 2.25% moisture. When needed it was approximately 7 weeks old, stored at –18°C in heat sealed polyethylene bags.

4.1.3 *Dalia* grains

Cracked wheat (*dalia*) was obtained from Directorate of Wheat Research (DWR), Karnal. Whole wheat of five different varieties PDW-233, WH-896 and PDW-274 (*Triticum durum*) and HD-2687 and PBW-343 (*Triticum aestivum)* converted into *dalia* grains by using Lab Con, *dalia* making machine, packaged in tightly closed 10kg polyethylene bags and held in a cool and dry place for about a year. The chemical composition of these grain dalia is presented in table 4.1

Table 4.1 Chemical composition of *dalia* grain

Characteristic	PDW-233	HD-2687	WH-896	PDW-274	PDW-343
Moisture (%)	5.50	5.55	5.71	5.71	5.90
Fat (%)	2.27	2.16	2.15	2.22	2.16
Protein (%)	13.31	11.46	10.24	12.57	15.57
Ash (%)	1.91	1.89	1.54	1.90	1.57
Total Carbohydrate (%)	77.01	79.29	80.36	77.60	74.80

4.1.4 Sugar

Commercially available cane sugar was procured from the local market of Kochi or obtained from the Experimental Dairy store of the Institute was used.

4.1.5 Cardamom

Commercially available cardamom was procured from the local market. It was dehusked and ground to a fine powder in a plastic pouch and stored under refrigeration.

4.1.6 Nisin

Nisaplin brand nisin used as a preservative in long-life *dalia* dessert was procured from Alpin & Barrett Ltd. (UK).

4.1.7 Ghee

Commercially available ghee (Nestle India Ltd.) used for sautéing of *dalia* was procured from the local market of Kochi.

4.1.8 Chemicals

All the chemicals used in analysis were of AR grade.

4.2 EQUIPMENTS AND PACKAGING

4.2.1 Pilot-scale Millwall model 24 rotary retort

For experiments on process development for long-life *dalia,* the pilot-scale Millwall Model 24 Rotary Retorting System (John Fraser Co., UK) located at the Central Institute of Fisheries Technology, Kochi (Kerala) was used.

The retorting system (Photo-plate: 4.1) which could perform in different modes viz., pure steam, steam / air and overpressure water immersion, comprised three major components viz., a retort, receiver for pressurization and a control system. In the present study the steam-air system without over pressure was used. The retort represented a chamber in which the product held on the shelves of a cage could be subjected to the required thermal process. The control system provided the means to sequence process events, regulate energy flows and document the retort temperature and pressure.

4.2.2.1 Retort

Constructed of mild steel, the retort could withstand a working pressure of 3.5 bars. It had a standard square cage, which was perforated with side slots. The speed of rotation of the cage ranged from 0 to 51 rpm and was electronically controlled and provided with a digital display. A 4-blade stainless steel fan (1500 rpm) fitted to the second retort door inside provided steam / air mixing and turbulence within the retort.

4.2.1.2 Programmable logic controller (PLC) for process safety

The retort employed PLC-assisted manual controls i.e. retort operation was performed manually but with the help of discrete electronic programmable input detector controllers for temperature and pressure. The controllers and a number of other components were integrated into a PLC managed safety system.

A Mitsubishi F1 series 60 I/O PLC ensured operation safety. The PLC observed retort door interlocks, temperature and pressure alarms, and acted upon the automatic valves, pump and cage drive. It prompted the operator to take action if an unsafe situation occurred. Pneumatically operated automatic valves were all designed to close in the event of a loss of either electrical power or compressed air.

4.2.1.3 Process parameters for the retort operation

The retort was operated in the steam-air mixture mode during the sterilization cycle. It was set at 121.1^{o}C, with a steam pressure of 1.05 bars. The retort cage was rotated at a speed of 2 rpm during the operation cycle.

4.2.2 Cans

Tin free steel (TFS) cans of 309 x 119 size and 6 oz fluid (or approx. 177 ml) capacity meant for in-package processing of long-life *dalia* dessert were obtained from Am-Tech Pack, Mysore/ M/s DNI International Inc., Bangalore

4.2.3 Can Seamer

A semi-automatic double-seaming machine (Metal Box, USA) was used for sealing of filled cans.

4.3 METHODS

4.3.1 *Dalia* preparation by traditional method

Dalia dessert was prepared by traditional method for the select of the wheat quality. For this taken 20g *dalia* grain and roasted at low flame for 5 min. Thereafter, 400ml of pre-standardized milk was added and cooked for 30 min. with continuous stirring.

4.3.2 Process for the production of long-life *dalia* dessert

The production protocol for long-life *dalia* dessert (fig4.1) consisted in preparation of the liquid phage comprising preconcentrated milk with sugar added to it, dosing the sweetened milk concentrate, sauted *dalia* grain, etc. into individual cans, exhausting the can headspace, sealing and retorting.

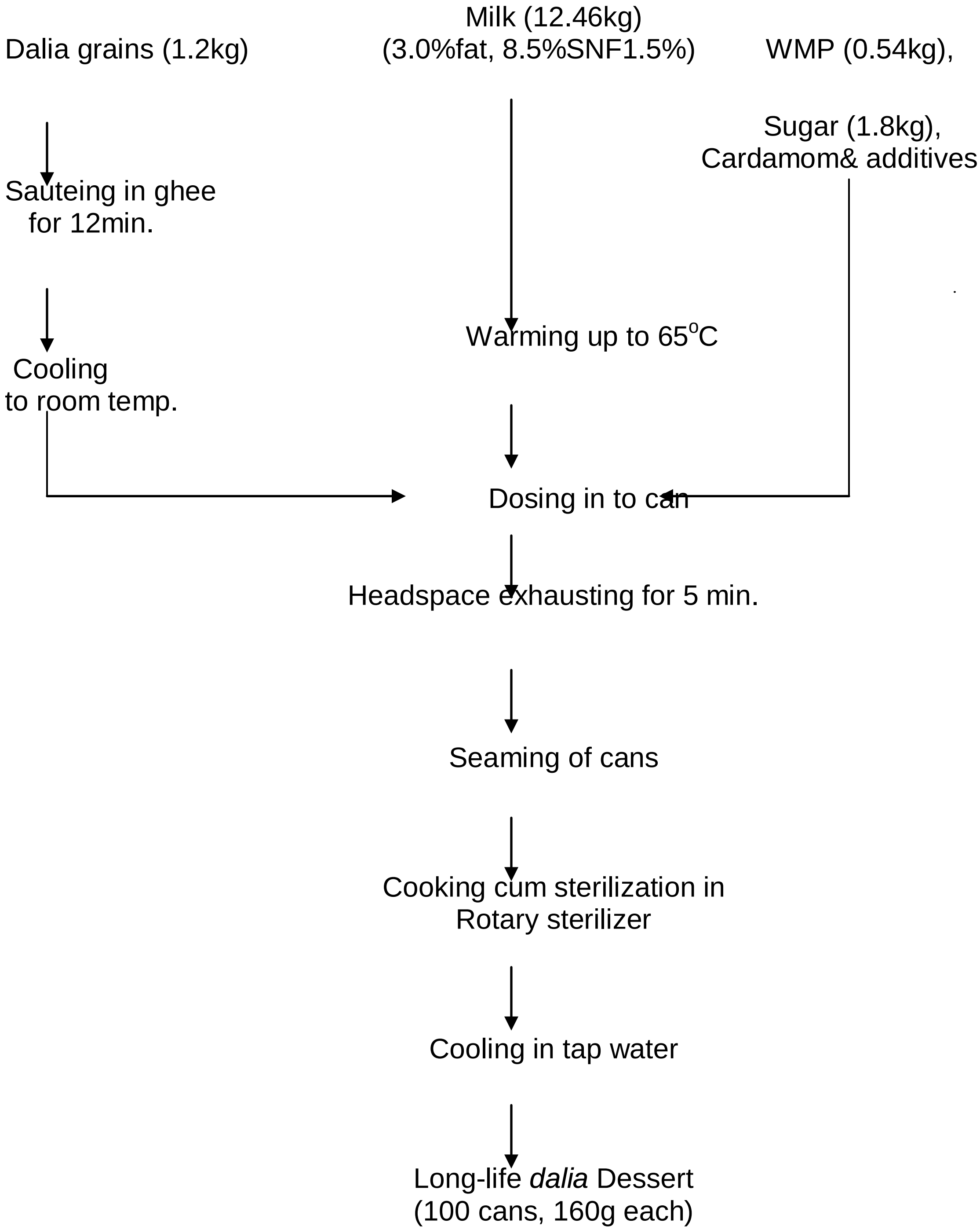


Fig. 4.1 FLOW DIAGRAM OF PRODUCTION OF LONG-LIFE DALIA DESSERT

4.3.2.1 *Preparation of the liquid phase*

In order to obtain the desired level of solids in the liquid phase, Pasteurized toned milk was added with the calculated quantity of whole milk powder in a stainless steel pail and heated to approx. 70 ^{o}C .

4.3.2.2 *Preparation of dalia grain*

Dalia was sauted in 5% ghee for 10 minutes at low flame and was taken out form the pan and was left for cooling to room temperature.

4.3.2.3 *Ingredient dosing into retort cans*

Weighed quantities of lightly fried *dalia* grains, TS-adjusted milk containing added sugar, cardamom were transferred to individual cans.

4.3.2.4 *Exhausting*

Air from the can headspace was removed by exhausting the cans partly covered with leads by steaming then in the retort for 5 min.

4.3.2.5 *Seaming*

Exhausted cans were immediately sealed and transferred to the retort cage.

4.3.2.6 Cooking-cum-sterilization

The filled and sealed cans were transferred to perforated aluminium retort trays. The cans were held in position by means of perforated cover plate designed to fit on the tray rack, which was then fastened with cotton thread to prevent dislocation of cans during rotation of the retort cage. In each batch, one can was inserted with a thermocouple in a manner described in the later section (vide 4.3.2.7) for obtaining the heat penetration data. Sterilization was performed using steam-air mixture (steam pressure 1.04 bar). The retort was operated (2 rpm) as per the guidelines of the equipment supplier. Process lethality in terms of F_o value was measured for each trial.

4.3.2.7 Cooling of cans

At the end of the heating cycle, cooling was done with water. Cooling water at a temperature of 27^{o}C containing 50 ppm chlorine was pumped into the retort to bring down the retort and can temperature immediately. When the core temperature had reached 70-60^{o}C, water was drained out and retort door opened. Cans were inspected for any deformation and other visual defects. All the cans were transferred to a tray with running tap water and held for 30 min to cool them further to room temperature. The cooled cans were then removed from water trays and wiped dry with the help of a clean, dry cloth.

4.3.2.8 Generation of heat penetration data

For every production trial one of the cans, transferred to the retort was fitted with thermocouples for measurement of the product temperature every minute during the process. A specially designed packing gland (Type GTK-21009-C000, ELLAB Co. Denmark) was used to enable the penetration of thermocouples into the retort can (Photo-plate: 4.2).

A Cu/CuNi thermocouple wire (Type SSE-12100-G700-SF; ELLAB, Denmark) which was capable of measuring temperature in the range of - 45^{o}C to 135^{o}C with an accuracy of $\pm$ 0.1^{o}C and a response time of 0.8s was used. The threaded electrode used in the assembly was made of stainless steel and had a length of 100 mm. The connecting cable was made of Teflon. Another thermocouple was placed in the retort tray.

Sets of thermocouple wires placed inside the can and the retort were linked to a precision data logging device (Model CTF 9008; ELLAB, Denmark) which was capable of converting the temperature input data into corresponding process lethality values. These process lethalities values were expressed as F_o values. A printout indicating core temperature, retort temperature, F_o and cook value (C_g) was obtained from the device.

4.3.2.9 Construction of a heat penetration curve

Heat penetration data were plotted on semi-logarithmic paper. The paper was inverted and time was represented on the linear scale (abscissa) and the difference between the set retort temperature and sample core temperature as the temperature deficit was given on the logarithmic scale (ordinate) as shown in Fig: 4.2.

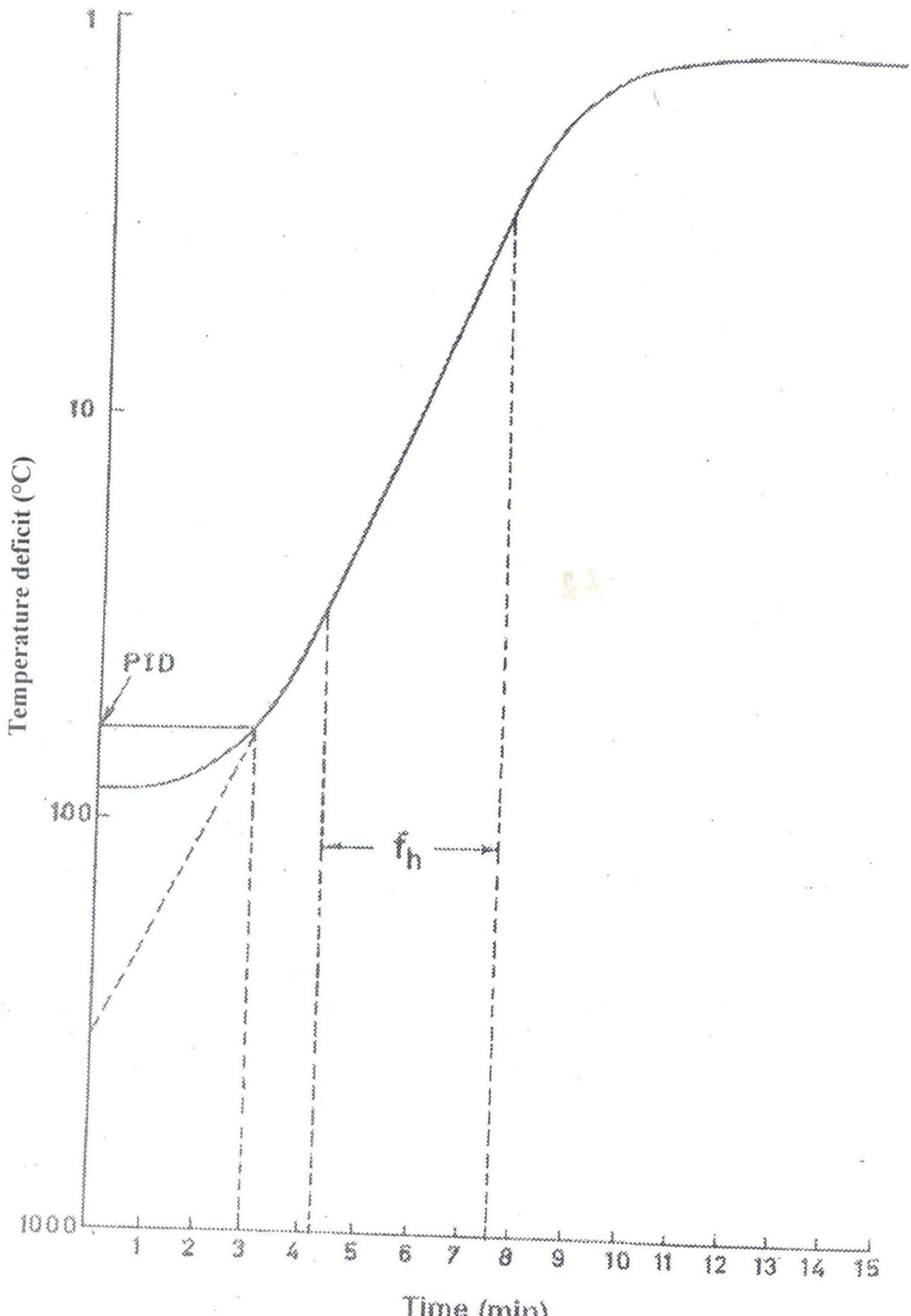


Fig 4.2 Heat penetration curve (heating cycle) for in-can retort processing of *dalia*

Plate 4.2 Empty cans with thermocouple

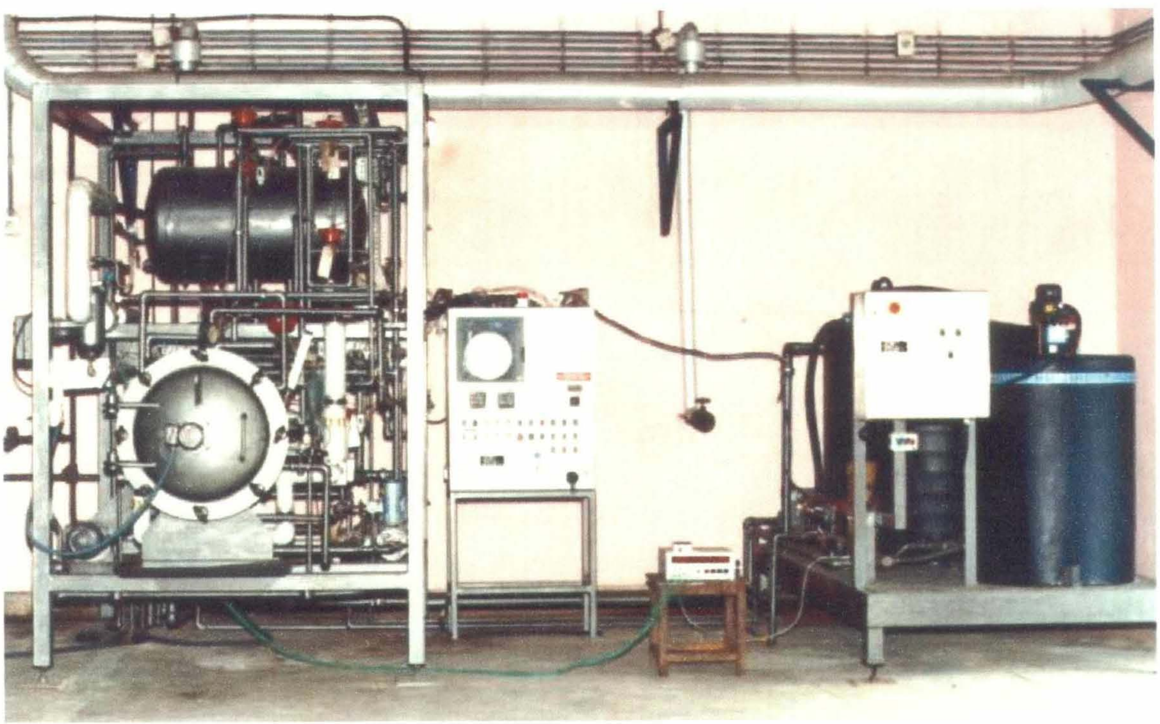


Plate 4.1 Overpressure autoclave (John Fraser Ltd, Model 24 Rotary Pilot Scale Retorting System)

The linear portion of the curve representing the come-up period was extrapolated downward and made to intersect with a vertical line drawn from the point corresponding to 42 per cent of the come-up time (defined as the time for the retort to reach the process temperature after steam was turned on) on the abscissa, the point of intersection representing pseudo-initial deficit (PID). The difference between set retort temperature and the core temperature at zero time was taken as initial deficit (ID). j_h (lag factor in the heating curve) was calculated by dividing PID by ID. f_h (time in minutes for the straight line portion of the heating curve to traverse one log cycle) was obtained from heat penetration curve.

While F_o value was obtained from the software used along with the data logger, the following formula was employed to calculate the sterilization time (U defined as the equivalent, in minutes at retort temperature, of all lethal heat received during the process) at 121.1°C:

$$\mathbf{U = F_o . 10^{\frac{(121.1 - T)}{z}}}$$

where,

T = Set retort temperature (°C)

Z = 10°C for *Clostridium botulinum*

As for the heating curve, the cooling curve was also obtained on an inverted semi long paper using the heat penetration data from the point the steam was turned off and cooling water was pumped in to the retort (Fig4.3). The temperature deficit (the difference between the core temperature and the cooling water temperature) was given on the Y-axis and time on the X-axis. The linear portion of the curve was extrapolated downward and the point at which it intersected at Y-axis gave the PID for the cooling curve. ID for the cooling curve was obtained by taking the difference between the core temperature and cooling water temperature at the beginning of cooling. Lag in the cooling cycle represented by J_c was calculated as PID divided by ID for the cooling curve.

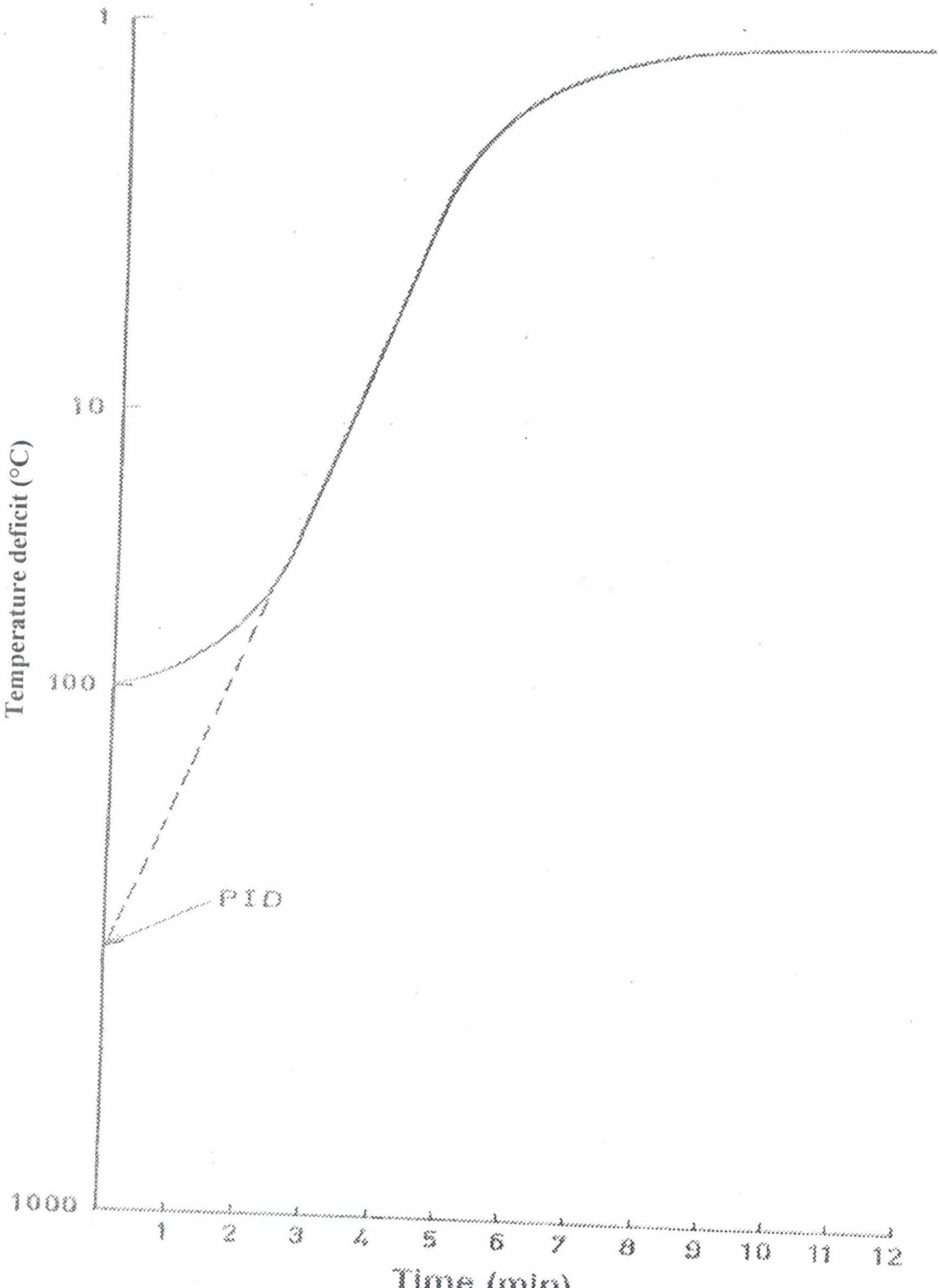


Fig 4.3 Heat penetration curve (cooling cycle) for in-can retort processing of *dalia*

The thermal process time (B) i.e. time in minutes, when no time is required to bring the retort to processing temperature, was calculated, as under:

$$B = f_h (\log J_h . ID - \log g)$$

Where,

B = process time to achieve final temperature deficit

g = final temperature deficit at the end of heating obtained from

f_h /U : g and J_c tables.

Total process time (B') was calculated by adding to 58 per cent of the come-up time (CUT) to B: (B' = B + 0.58 × CUT)

4.3.3 Storage of long-life *dalia* dessert

Long-life dalia dessert in TFS cans were stored at 37 $^oC \pm 2$ ^oC and analyzed with respect to various shelf-life parameters at an interval of 15 days for a period of 3 months.

4.4 ANALYSIS OF LONG-LIFE DALIA DESSERT

4.4.1 Chemical composition

4.4.1.1 *Sample preparation*

The entire content of a can was ground in a INALSA Food Processor mixer (Model: Maxie wet grinding blade-speed code: 3) for 5 min. This ground sample was then analyzed for various physico-chemical properties.

4.4.1.2 *Total solids*

The TS content of *dalia* dessert was determined by the gravimetric method (IS: SP: 18(Part XI) 1981).

4.4.1.3 *Fat*

The fat content was determined by Mojonnier method (IS: SP: 18(Part XI) 1981).

4.4.1.4 *Protein*

The Kjeldahl procedure employing the Kjeltec apparatus was used (AOAC, 1995). For conversion of nitrogen into protein a factor of 6.25 was used.

4**.4.1.5 *Ash***

Approx. 3 g of ground sample was accurately weighed into a silica crucible and ash content determined as per AOAC (1995), the sample being ashed in a muffle furnace at $550 \pm 5^{o}C$ (dull red) for 3 hours.

4.4.1.6 *Amylose Content*

Amylose was determined following the colorimetric method described by Sowbhagya and Bhattacharya (1979).

Preparation of the stock standard amylose solution:

Accurately weighed 100 mg of the amylose, and dissolved in 10.0 ml of 1M NaOH solution by gentle heating for few minutes. Diluted to 50.0 ml and added $3/4^{th}$ volume of the calculated amount of 1N and 0.1N Hcl required to neutralize 10.0 ml of 1N NaOH solution. The volume was made upto 100.0 ml stored in the refrigerator (can be used for a month).

Determination of the amylose content in the sample:

Weighed 150.0 mg of the ground sample, added 1.0ml of 95% Ethanol and 10.0 ml of 1M NaOH. Left overnight at room temperature, made up the volume 100.0 ml. and transferred 20.0 ml to the glass stoppered tube. Added 7.0 ml of Petroleum ether (60°C-80°C) as first extractant, shook for 10.0 min. and allowed to stand for 10-15 min. The top ether layer was sucked off using a suction pump and repeated the extraction using 7.0 ml of Carbon tetrachloride. 5.0 ml the top aqueous layer was pipetted in a 100.0 ml volumetric flask, added 50.0 ml of distilled water and 3-4 drops of phenolphthalein solution (indicator). Neutralized first with 1.0 N and then with 0.01 N HCl solutions till colour is discharged. Added 2.0 ml of the Iodine solution (0.2% Iodine in 2% aqueous Potassium iodide solution) and the volume was made upto 100.0 ml.

Preparation of the Blank solution: 2.0 ml of the Iodine solution was made to 100.0 ml. with distilled water.

Preparation of the Standard amylose solution: Added 2.0 ml of the Iodine solution to 1.0 ml of the stock solution, and made the volume to 100.0 ml.

The absorbance of the colour developed was measured at 630 nm.

Calculation of the Amylose content:

$$\text{Amylose content} = \frac{R}{A} \times \frac{a}{r} \times 20 \times 100$$

Where,

A - Absorbance of standard amylase.

R- Absorbance of *dalia* sample.

a- Amount of standard amylase in mg.

r- Amount of *dalia* sample in mg.

4.4.2 Shelf-life parameters of long-life *dalia* dessert

4.4.2.1 *Colour*

The colour of the *dalia* dessert was measured using a Colourflex supplied by Hunterlab (Hunter Association Laboratory, Inc., Reston, VA, USA) along with the universal software (version 4.10). Before the test, instrument was calibrated with standard black glass and white tile as specified by the manufacturer. The light source was dual beam xenon flash lamp. Data was received through the software in terms of L* (lightness, ranges zero (black) to 100 (white)), a* (redness, ranges from +60 (red) to –60 (green)) and b* (yellowness, ranges +60 (yellow) to –60 (blue)) in values of the international colour system.

4.4.2.2 *TBA value*

The extent of fat oxidation in the product was measured in terms of TBA (thiobarbituric acid) value following the procedure of Strange et al. (1972).

4.4.2.3 *HMF*

The total HMF content was estimated as per the procedure described by Keeny and Bassette (1959). Three grammes of the ground sample was pipetted into a 50 ml test tube, to which 7ml distilled water and 5 ml of 0.3 N oxalic acid (18.9 g oxalic acid diluted to 1 lit. distilled water) were added and mixed well. The tubes were closed with lids and placed in a boiling water-bath for 1 h. The tubes were cooled to room temperature using tap water. Then 5 ml of 40 per cent TCA was added and mixed well. The tubes content were filtered through Whatman No. 42 filter-paper and 0.5 ml of filtrate was pipetted in a test tube, to which 3.5 ml distilled water and 1 ml of 0.05 M freshly prepared TBA solution (0.72 g TBA in 100 ml distilled water), were added. The tubes were added in a water-bath maintained at 40^{o}C for 50 min, following which they were cooled to room temperature. Absorbance was measured at 443 nm against blank by using Thermospectronic (GENESYS^{TM} 10 Series Spectrophotometers).

4.4.2.4 *pH*

The pH was measured by a microprocessor controlled pH meter (Lab India Instruments Pvt. Ltd., Mumbai) fitted with an Orion gel-filled combined electrode.

4.4.3 Rheological parameters of long-life *dalia* dessert

Apparent viscosity of *dalia* dessert at 25ºC was measured using a Visco-Star Plus programmable rotational viscometer (FUNGILAB, S.A., Spain) fitted with the spindles L2 or L3 and PB, PC, PD or PE with Heldal mechanism raising and lowering the spindle within the sample during the measurement. Viscosity was readout from digital display.

4.4.4 Sensory evaluation of long-life *dalia* dessert

A proforma devised for texture profile analysis, degree of brown discolouration and intensity of flavour attributes (10-cm long structured linear scale) (Shone *et. al*, 1979), as well as hedonic rating (9-point scale) of *dalia* dessert (Annexure I) was used.

4.5 STATISTICAL ANALYSIS

Analysis of data generated during the present investigation was carried out using response surface methodology (RSM) by employing central composite random design (CCRD). In this two independent variables F_0 -value and nisin level were integrated into the matrix design is illustrated in earlier table- 3.1 and 3.2.

5. RESULTS AND DISCUSSION

The present study was conducted with the main objective of optimizing retort process conditions for production of an acceptable dessert from *dalia* (cracked wheat) that would have a satisfactory shelf life at ambient temperature. Preliminary studies were followed by response surface experimentation. The results obtained during the course of this investigation are presented and discussed in this chapter under the following major sub headings:

I. Effect of wheat variety on the quality of *dalia* dessert prepared by traditional method

II. Preliminary observation on the quality of in-can retorted *dalia* dessert as influenced by process conditions

III. Optimization of the retort process for long life *dalia* dessert

5.1 EFFECT OF WHEAT VARIETY ON THE QUALITY OF *DALIA* DESSERT PREPARED BY TRADITIONAL METHOD

The physical properties of wheat are known to vary with variety (Shallenberger, 1950). Hard wheat varieties are considered to be particularly suitable for certain food applications. In the present study five different varieties of wheat belonging to two species viz., *Triticum durum* and *Triticum sativum* were converted into *dalia*. The dessert made from this *dalia* using the traditional open-pan method was examined sensorily and the data are presented in Table 5.1.

It can be seen from Table 5.1 that the durum variety WH-896 gave a *dalia* dessert with highly acceptable colour, texture and flavour as also the overall acceptability. This product was distinctly superior to the next best dessert obtained from non-durum variety PBW-343 in terms of all attributes. The remaining two durum varieties and one non-durum variety were

Table 5.1 Effect of wheat variety on sensory attributes* of *dalia* dessert made by the traditional method

Wheat variety	Attribute**				
	Colour	Texture	Sweetness	Flavour	Overall acceptability
PBW-343	7.40 ± 0.31	7.50 ± 0.21	7.80 ± 0.41	7.38 ± 0.51	7.34 ± 0.68
HD-2687	6.90 ± 0.26	6.43 ± 0.47	7.70 ± 0.49	7.01 ± 0.44	6.51 ± 0.53
*WH-896	8.00 ± 0.27	8.12 ± 0.51	8.00 ± 0.3	8.12 ± 0.7	8.22 ± 0.48
PDW-233	6.80 ± 0.71	6.71 ± 0.57	7.75 ± 0.29	7.05 ± 0.75	6.77 ± 0.75
PDW-274	6.91 ± 0.53	6.5 0 ± 0.43	7.70 ± 0.31	7.00 ± 0.43	6.71 ± 0.27

* Scored on a 9-point hedonic scale (vide Appendix-I)
** Mean ± standard deviation (from 7 judges in each of two replicates)

appreciably less desirable from the product quality point of view. The high sensory acceptability of WH-896 *dalia* could be attributed primarily to its grain texture and thickening effect on the milk fraction, and to a superior colour and appearance of the product. It was therefore, selected for use in the production of long-life *dalia* dessert using the retort process.

5.2 PRELIMINARY OBSERVATIONS ON THE QUALITY OF IN-CAN RETORTED *DALIA* DESSERT AS INFLUENCED BY PROCESS CONDITIONS

In-can retort processing has been found to be an effective approach towards manufacture of shelf-stable foods comprising solid particles / chunks in a liquid / gravy (Larkin, 1997). In order to capitalize on the merits of the retort process technology, in the present study long life *dalia* was intended to be produced by employing in-can sterilization.

The conventional sterilization process for milk and milk products employing relatively severe treatment conditions, namely, 115-120 ^{0}C for 10-20 min equivalent to an F_0-value of 10 or more such a treatment while ensuring effective microbial inactivation brings about excessive browning stale flavour development, accompanied by high nutrient losses ((Walsta *et al*., 1999; Renner, 1983) especially during subsequent ambient storage.

Further, the presence of cereal grains contributing to starch in cereal-based desserts tends to reduce the heat stability, due to gelatinisation of starch resulting in absorption of water and thereby increase in the concentration of milk solids in the liquid phase (Tzibula and Muir, 1993). It therefore, becomes imperative to go for reduced heat treatment for sterilization. However F_0 value lower than 10 might be inadequate to produce the desired sterilizing effect in the product with a consequent risk of increased spoilage of the products. Bacteriocins such as nisin, which can resist thermal treatment, have been found to extend the shelf life of products processed at low F_0 values (Eapen *et al*., 1988). Accordingly, in the present study nisin was used in combination with a reduced process intensity for in-can cooking-cum-sterilization of retort sterilization *dalia* dessert formulated by combining milk concentrate, raw *dalia* grains, sugar and flavouring.

Before a response surface experiment could be planned, preliminary studies were carried out in order to determine the feasible range of process variables with regard to the product quality, particularly in terms of lumping of grains and destabilization of the milk colloid. The variables studied included source of milk solids and its concentration, level of *dalia* grains, pretreatment of *dalia* and presence of agitation during retort sterilization.

When whole milk powder (WMP) was used as the source of milk solids (17 % TS in reconstituted milk concentrate, 6.6% *dalia* and *dalia*-to-milk solid ratio of 0.43, retort processing in a stationary or rotary system (F_o-value, 6-8) resulted in extensive lumping of grains and destabilization of milk irrespective of whether the grains were preroasted or not. Reduced levels of TS in milk (13 %) and grain (5.3 % *dalia*, and grain-to-milk solids ratio, 0.34) did not help prevent grain lumping or milk coagulation. Use of di-sodium phosphate (0.05-0.1%) in the concentrate also failed to prevent destabilization during retort processing.

Apparently, the reconstituted milk concentrate had a poor heat stability and the cracked wheat grains tended to result in unacceptable lumping. It was therefore; deemed necessary to use fresh milk i.e. pasteurized toned milk increasing the total solids to the desired level by adding WMP. A 15% TS milk concentrate thus obtained was used with 7.4% *dalia* grains (grain-to-milk solids ratio, 0.54) which was pre-sauted using ghee (5%). The product upon retorting (F_0 - 9.6) in a rotary system appeared to be essentially free from grain lumping and milk coagulation. Presumably, the oil coating around individual *dalia* grains protected them against adhering to one another thereby resulting in much reduced lumping. Using fresh milk as the main source of milk solids and WMP only as the supplementary source helped preventing coagulation during retort processing. This suggested that fresh milk had a higher heat stability as compared to reconstituted milk concentrate which at a level of 15% TS attained by fortification with WMP yielded a product stable to retorting conditions. Very little is known about the heat stability of reconstituted milk and virtually no literature information is available on buffalo milk in this regard. The above formulation comprising 11% cane sugar was used in further studies.

5.3 OPTIMIZATION OF THE RETORT PROCESS FOR LONG-LIFE DALIA DESSERT

As mentioned above, use of nisin was resorted to for obtaining long-life *dalia* dessert by retort processing using a low F_0-value. A two-factor RSM experimental design was followed. Since a minimum F_0 value of 3.0 is necessary to ensure adequate inactivation of anaerobic spore formers, particularly *Clostridium botulinum* in low-acid foods (Stumbo *et al*., 1975) and since a nisin level of 300-400 ppm has been reported to be useful in certain retort-processed semisolid foods (Eapen *et al*., 1988; Singh *et al*., 1987), the respective ranges selected for these factors were 4.0 - 8.0 and 0 to 800 IU/g to be incorporated into a 13-experiment Central Composite Rotatable Design (CCRD).

5.3.1 Chemical composition of *dalia* dessert

The mean composition of the 13 lots of *dalia* dessert prepared during this study is presented in Table 5.2. Both the fat and protein contents of the product were lower than those reported for rice kheer (Jha, 2000).

Table 5.2 Proximate chemical composition of *dalia* dessert

Sr. No	Constituent	% by weight
1	Total solids	29.6 (28.15-31.06)
2	Fat	3.66 (3.65-3.68)
3	Protein	3.56 (3.49-3.64)
4	Ash	0.84 (0.82-0.87)
5	Amylose	2.88 (2.75-3.01)
6	Total carbohydrates*	21.54 (20.19-22.87)

* Figure in the parenthesis indicate the range by difference

5.3.2 Heat penetration characteristics of long-life *dalia* dessert

Thee physical status of a food in terms of fluidity or solidity greatly influences its heating pattern in a retort. Since no heat penetration studies have ever been reported on *dalia* dessert, an attempt was made to generate heat penetration data for in the product present study. Essentially a semi-solid suspension of *dalia* grains in partly concentrated milk is expected to heat by convection during retorting. Thermal process data recorded during the retort sterilization trials conducted process optimization of long-life *dalia* dessert a rotary retort are presented in Table 5.3.

5.3.2.1 Lag period for heating curve (j_h)

The j_h value given as pseudo-initial temperature deficit (PID) divided by the actual initial temperature deficit (ID) ranged from 0.40 to 0.85. The *dalia* dessert mix subjected to thermal processing could be considered as essentially a liquid product and the mode of heating could be said to be convective. For purely convective packs, there is little or no lag period (i.e. the come-up time is very short); hence, PID and ID coincide, so that j_h is equal to 1(Jones, 1968). However, in actual practice, there is always some gap in time period before a product could reach the retort temperature, leading to differences in come up time depending on the composition, size etc. and hence, to variations in j_h value. Condensed cream of celery soup was reported to have a j_h value of 1.3 (Berry and Bradshaw, 1980). Large j_h values for agitated processes indicate that product agitation processes did not commence with heating, but only after some time are (Berry and Bradshaw, 1980). The j_h value for retorted long-life kheer in pouch ranged from 0.44 to 1.17 (Jha, 2000).

5.3.2.2 Heating rate index (f_h)

The time taken for a heat penetration curve to traverse one log cycle is called the f_h value. In the present study, f_h values were found to be in the range of 3.2 to 5.5 min (Table 5.3). These values are in the range of the values reported for convection heating products, in contrast to conduction heating products whose f_h values are reported to be 15 or more times higher than this viz. 30-40 min (Horner, 1992). Heating rate index (f_h) for convective heating products has been reported to be dependent upon temperature of heating medium and condensing surface, steam-air flow rate and direction, surface size and orientation, viscosity, film thickness and stagnant air layer thickness (Tung *et al*., 1990).

Compared to conduction-heating products, convection heating products have a large heat capacity and thermal diffusivity, and reach retort temperature very quickly after which they remain essentially inert with respect to heat transfer (Weintraub *et al*., 1989). The f_h value for mushrooms in brine was also found to be in the range of 4.7 to 5.8 min depending on the can size and weight of the product (Berry and Bradshaw, 1982).The f_h value for long-life kheer in pouch was found to be in the range of 2.82 - 8.70 min (Jha, 2000).

5.3.2.3 Lag factor for cooling curve (j_c)

Lag factor in cooling curve is because of the fact that the product temperature does not fall as rapidly as the retort temperature falls. j_c values for convective heating products are reported to be close to 1, whereas for conducting heating packs the values could be much higher as the cooling process is much slower for these products. As shown in Table 5.3, j_c values for the long-life *dalia* dessert ranged from 0.908 to 1.10, which were in conformity with the values reported for convective heating liquid products (Horner, 1992).

5.3.2.4 Process time (B)

The total process time (B) and operator's process time (P_t) depend greatly on f_h and j_h values obtained for each process. B for *dalia* dessert ranged from 10.20 to 15.78 min (Table 5.3) depending on the F_o value (3.9-8.22) and related factors. Process time for products heated in conduction-heating regime are generally very long as compared to the ones observed in this study (Thijssen *et al*., 1978). The low process time coincided with the low values for f_h and j_h for the convection heating *dalia* dessert as compared to conduction heating products. Mango juice had a process time of 45 min corresponding to an F_o of 11.0 (Nanjundaswamy *et al.,* 1973). Process time for long life kheer in retort pouch, (thickness 115 µm) was found to be 14.89-21.52 min for a F_0 in the range of 12.4-14.8 (Jha, 2000).

5.3.2.5 Cook value (C_g)

While process value (F_o) may be defined with respect to the effect of exposure time at a specific temperature (121.1^{o}C) on a specific organism (Z value, 10^{o}C), cook value (C_g) encompasses a multiplicity of physical and biochemical changes. This value (reference temperature, 100^{o}C and z value, 33^{o}C) for long-life *dalia* dessert ranged from 28.95 to 54.03 min (Table 5.3).

Table: 5.3 Thermal process parameter of long-life *dalia* dessert

Run	Nisin(IU/g)	Fo	j_h	f_h	j_c	B	C_g
1	800.00	5.95	0.43	5.00	0.93	15.23	43.85
2	400.00	3.90	0.41	4.25	1.01	10.20	28.95
3	682.84	7.63	0.40	4.30	0.97	14.27	48.13
4	682.84	4.73	0.82	5.00	0.99	12.87	35.61
5	0.00	6.02	0.68	4.10	1.00	14.23	41.67
6	400.00	5.95	0.84	4.40	1.00	14.58	40.01
7	117.16	4.70	0.82	5.00	0.98	13.11	32.44
8	400.00	8.22	0.75	4.50	1.00	15.78	49.39
9	117.16	7.45	0.85	3.20	0.96	15.61	54.03
10	400.00	5.98	0.52	5.40	0.91	13.93	46.76
11	400.00	5.97	0.56	4.50	0.97	13.70	42.67
12	400.00	6.24	0.40	5.10	0.98	15.31	48.97
13	400.00	6.01	0.84	5.50	0.97	15.77	46.52

Such a large cook value was expected to result in extensive softening of *dalia* grains. Also, the product, as anticipated, underwent appreciable browning.

5.3.3 Effect of F_0 and Nisin

Considering lethality effect of F_0- value and inhibitory effect of nisin in the heat processed product the major aim of the present RSM experiment was to optimize the levels of two factors. So that with minimum possible levels shelf stable *dalia* dessert could be produced. The criteria for this optimization included sensory attributes of the freshly prepared product and physiochemical changes in the stored product.

5.3.3.*1 Sensory attributes of freshly prepared dalia dessert as influenced by the levels of F_0 and Nisin*

Acceptability of any product is assessed by its sensory evaluation by trained panel of Judges. Good quality *dalia* dessert should have white to creamy colour, sweetish pleasant cooked flavour, and creamy consistency with soft cracked wheat grain. For evaluating sensory attributes of *dalia* dessert, the 9 – point hedonic scale was used (Appendix-1): The sensory characteristics judged included colour, texture, sweetness, flavour and overall acceptability. The average sensory scores for different attributes are given in Table 5.4. The data were analyzed to fit a quadrate model and the results of regression analysis are presented in Table 5.5. The output result showed that model had a efficiency of 65.2 % which is more than the minimum required level of 50%. The Levarge was 0.462, which is less than the value of 1, desirable in developing model. The condition number of coefficient matrix was 1.622, which is less than 100. a value higher than 100 indicates moderate multicolinearity problem in the model. It can therefore, be concluded that the developed model for sensory attributes fits well in all model.

Colour score: The average colour score of *dalia* dessert ranged from 7.00 to 7.71 corresponding to F_0/nisin values of 8.22/400 IU/g and 3.90/400 IU/g respectively (Exp. No. 6 and vide Table 5.4). It is evident from the table that the colour score was mainly an inverse function of F_0-value, the relationship being significant ($P< 0.01$) (Table 5.5). Further, the effect of nisin alone was also negative but not significant as was the interaction effect between F_0 and nisin. The data depicted in Fig.5.1 confirms the above observation. The regression equation for prediction of colour score based on F_0 and nisin could be given as follows:

Table 5.4 Effect of F_0 and nisin level on sensory properties* of freshly prepared long-life *dalia* dessert

Exp. No.	F_0	Nisin (IU/g)	Colour score	Texture score	Sweetness score	Flavour score	Overall acceptability score
1	4.70	117.16	7.66	7.41	7.16	7.33	7.34
2	7.45	117.16	7.07	6.78	7.64	7.21	7.14
3	4.73	682.84	7.56	6.41	7.33	7.08	7.10
4	7.63	682.84	7.10	7.19	7.37	7.19	7.29
5	3.90	400.00	7.71	6.78	7.71	7.21	7.28
6	8.22	400.00	7.00	7.28	7.71	7.28	7.30
7	6.02	0.00	7.50	6.83	7.33	7.25	7.19
8	5.95	800.00	7.00	7.33	7.50	7.25	7.22
9	5.98	400.00	7.06	6.98	7.44	7.06	7.10
10	5.95	400.00	7.30	6.81	7.37	7.00	7.12
11	5.97	400.00	7.28	7.00	7.28	6.95	7.07
12	6.01	400.00	7.07	6.71	7.57	7.07	7.06
13	6.24	400.00	7.07	7.21	7.78	7.00	7.10

* Means of rating by seven panelists using the standard 9-point hedonic scale

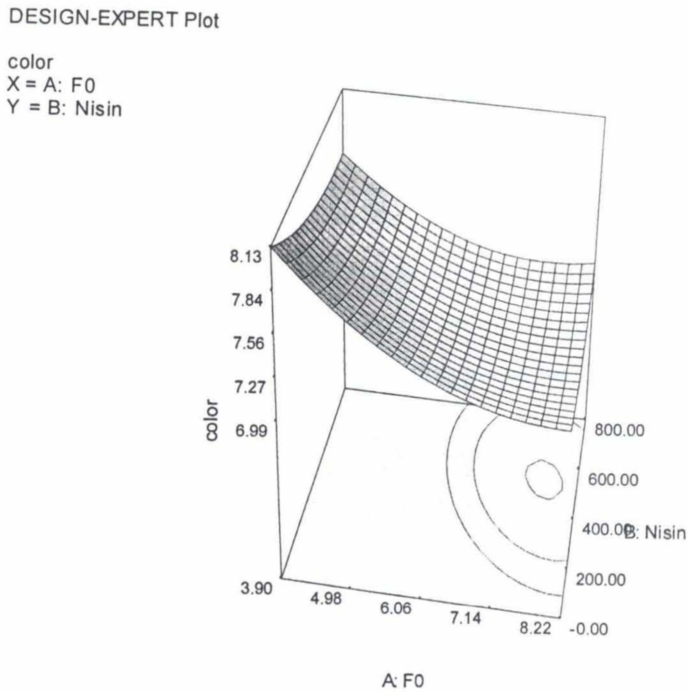
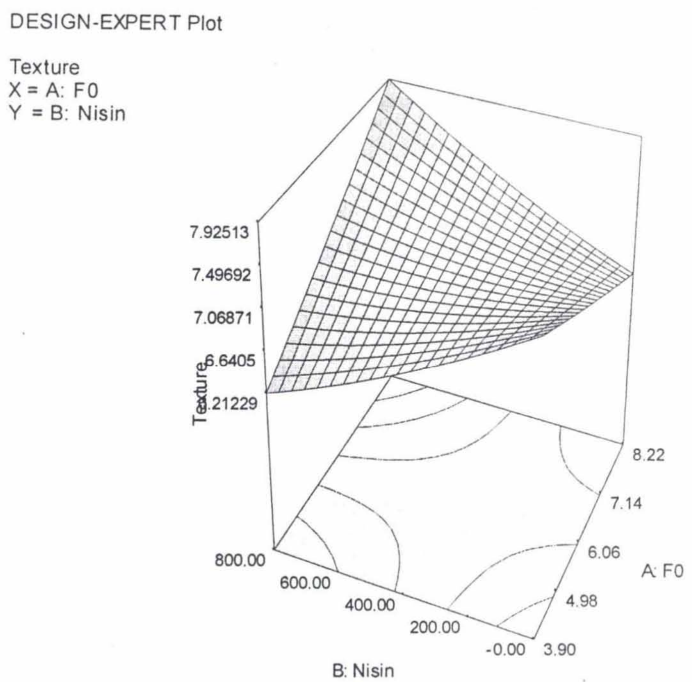


Fig 5.1 Response surface relating colour as influenced by level of F_0 and nisin in long life dalia dessert



5.2 Response surface relating texture as influenced by level of F_0 and nisin in long life dalia dessert

Table 5.5 Coefficients of Full Second Order Polynomial Model for sensory responses to coded factors (F_0 and Nisin) in retort processed *dalia* dessert

Factor	Sensory Attribute				
	Colour score	**Texture score**	**Sweetness score**	**Flavour score**	**Overall Acceptability score**
Intercept	7.16	6.94	7.48	7.02	7.09
F_0 (A)	-0.26**	0.099	0.055	-2.776E-003	-0.010
Nisin (B)	-0.099	4.850E-004	0.020	-0.038	-0.012
A^2	0.10	7.210E-003	0.066	0.091**	0.081**
B^2	0.063	0.043	-0.080	0.11**	0.054**
AB	0.041	0.33	-0.12	0.045	0.088**
R Squared	0.85	0.53	0.43	0.85	0.93
Adequate Precision	8.553	4.928	3.555	6.495	10.224
PRESS	0.55	2.67	1.03	0.14	0.048

**Significant at 1% level *Significant at 5% level

Colour score=+7.16 – 0.26 * F_0 – o.099 + 0.10 * F_0 ^{2} + 0.063 * nisin^2 + 0.041 * 0.041 F_0 * nisin.

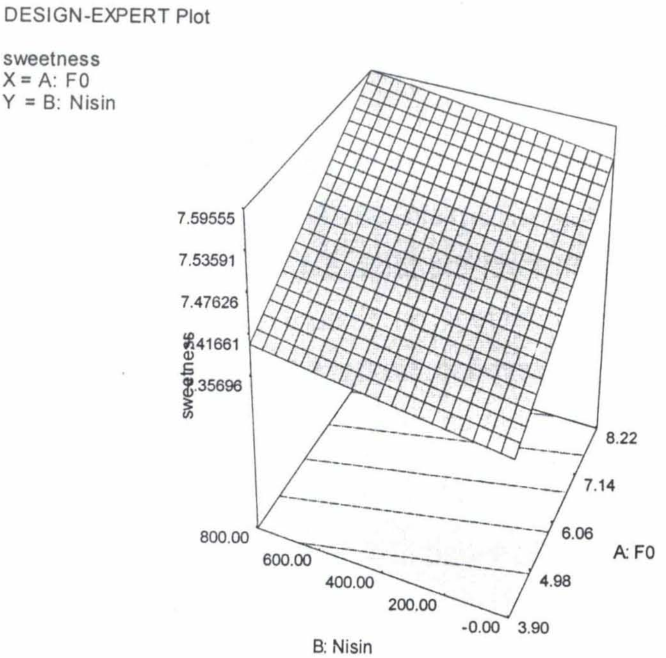
Texture score: The texture score of retort process *dalia* dessert ranged from 6.41 (F_0 * 4.73 nisin, 682.84 IU/g)) to 7.41 ($F_{0\,,}$4.70; nisin, 117.16 IU/g) as can be seen from the table 5.4. However, there was no predictable impact of these two factors on texture score. (Table 5.5). As could be expected the data displayed in the fig. 5.2 showed a saddle response surface relating to the texture score as influenced by F_0 and nisin levels

Sweetness Score: Table 5.3 shows that the the sweetness score of *dalia* dessert was in the ranged of 7.16 (Exp.No.1) to 7.78 (Exp. No.13). Here again none of the two factors had any significant effect nor did their interaction (Table 5.5). The response surface for sweetness as depicted in Fig. 5.3 also corroborated the lack of significance of F_0 and nisin level with regard to sweetness perception.

Flavour score: It can be seen from Table 5.4 shows that the hedonic score for flavour of the retort processed *dalia* dessert ranged from 6.95 (F_0 5.97; nisin, 400 IU/g) to 7.33 (F_{0-}4.7 and nisin, 117.16 IU/g). The quadratic function was highly significant (P<0.01) as can be seen from Table 5.5. There was no direct correlation of either factor nor was the interaction between the two factors significant.

It is evident from response surface plot for flavour score. It can be seen from Fig. 5.4 that either low or high values of both the factors or a low value of one and high of the other resulted in a high flavour score, whereas intermediate values of the two variables caused the flavour score to fall. The prominent flavour attribute of retort-processed *dalia* dessert was staleness, which varied in intensity with F_0, but there was direct relationship between the latter two indicating complexities of the chemical reactions leading to stale flavour development during sterilization. The representative equation could be written as:

Flavour score = +7.02 – 2.776E- 0.03 * F_0 – 0.038 *nisin + 0.091 * F_0 ^{2} + 0.11 * nisin^2 + 0.045 * F_0 * nisin



5.3 Response surface relating sweetness as influenced by level of F_0 and nisin in long life dalia dessert

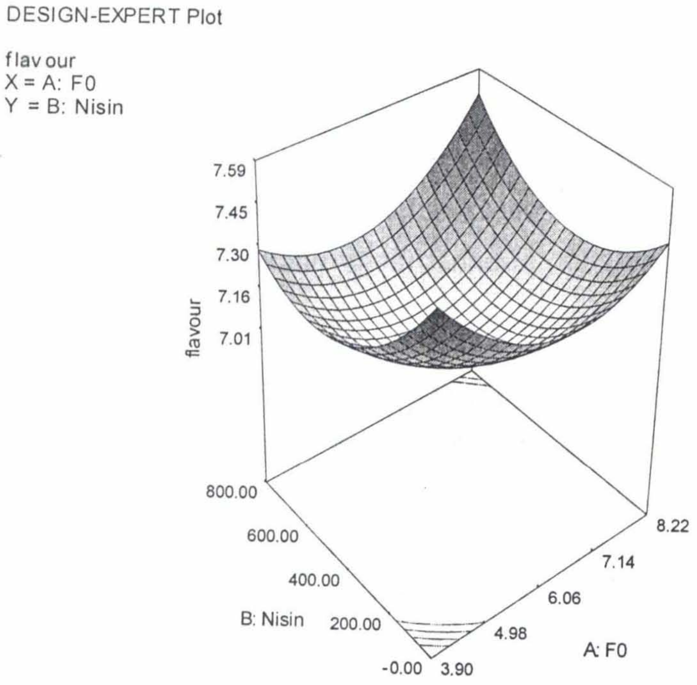


Fig 5.4 Response surface relating flavour as influenced by level of F_0 and nisin in long life dalia dessert

For this regression, the coefficient of determination was 0.85, high enough for the model to be reliable (Henika, 1982), it being able to predict 85 % of variance in the flavour score. The value for adequate precision at 6.495 for this quadratic model was appreciably higher than the minimum desired value of 4.00. This, coupled with low PRESS value (0.14) suggested that the model fit was highly desirable.

Overall Acceptability score: The overall acceptability score was found to ranged between 7.06 **(**$F_{0,}$ 6.01; nisin, 400 IU/g) to 7.34 ($F_{0,}$ 4.70; nisin, 117.161 IU/g) (Table 5.4)

The regression coefficient estimates (Table 5.5) showed the quadratic terms of F_0 and nisin to be significant (P< 0.01) as also the interaction between the two (P< 0.01). The calculated adequate precision was 10.22, which is more than the table value of the minimum desired 4.00. Fitness of model was also supported by a low PRESS value viz. 0.048. The coefficient of determination (R^2) for the overall acceptability score was 0.93, which was appreciably higher than the suggested minimum desirable value indicating that the model developed was satisfactory, and can be used to navigate the design. As is depicted in Fig. 5.5 the overall acceptability score was a quadratic function of F_0 and nisin with the interaction between the two factors being significant (P<0.01). Thus, low values of both the factors yielded a high overall acceptability score as also the high values, whereas a low value of one factor and high of the other resulted in low overall acceptability rating which was also the case for intermediate values of both variables. The relevant regression equation for overall acceptability can be given as:

$$\text{Overall acceptability score} = +7.09 - 0.010 * F_0 - 0.012 * \text{nisin} + 0.081 * F_0^2 + 0.054 * \text{nisin}^2 + 0.088 * F_0 * \text{nisin}.$$

Apparently, the overall acceptability response was largely a reflection of the flavour response with some added contribution of the colour response.

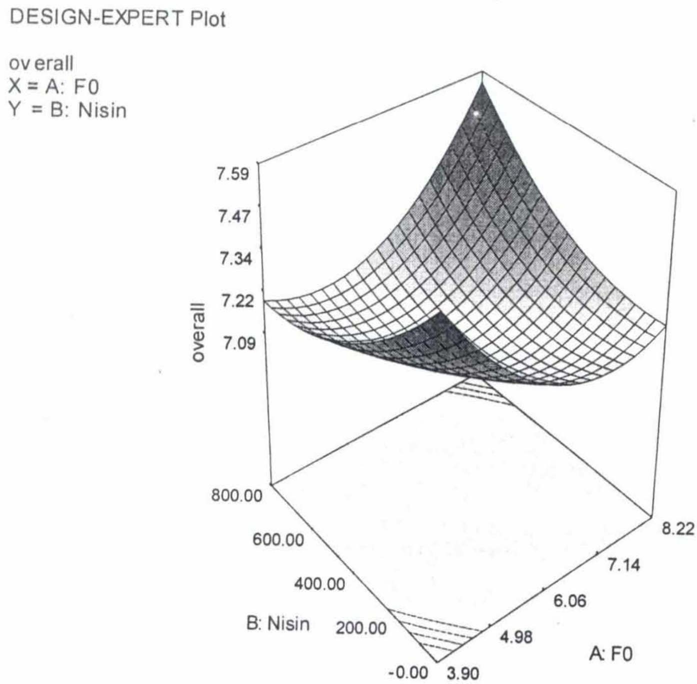


Fig 5.5 Response surface relating overall acceptability as influenced by level of F_0 and nisin in long life dalia dessert

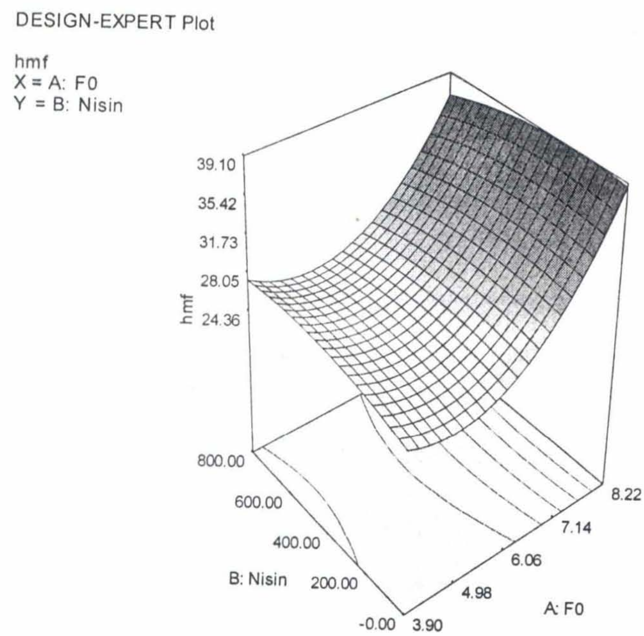


Fig 5.6 Response surface relating HMF as influenced by level of F_0 and nisin in long life dalia dessert

5.3.3.2 *Physico-chemical Properties of freshly prepared dalia dessert as influenced by F_0 and Nisin levels*

The effect of F_0 and nisin as independent variables on physico-chemical properties presumed to have some bearing on the sensory attributes of long-life *dalia* dessert were examined in the present investigation and are discussed here under.

HMF content: Brown discolouration owing to Maillard reaction is one of the major chemical changes taking place during thermal processing of milk and milk products (Patton, 1952). 5-hydroxy-methyl furfural (HMF) is one of the products arising due to the intermediate (or second) stage of the chain of Maillard reactions (Narinder, 1988) and is often used as an index of the degree of browning. The HMF content of the *dalia* dessert samples varied from 23.20 to 39.17 micromole/kg (Table 5.6). The coefficients determination (R^2) was 0.94 which was higher than the minimum value specified by Henika (1982). Thus the relevant regression curve predict 94% if variance in HMF. The adequate precision level was also greater than the 4 (15.44) which denote that the mode is satisfactory. PRESS value was 82.99, which is higher indicating non-suitability of the model for the prediction of HMF on the basis of F_0 and nisin levels. Coefficients of regression equation shown in Table 5.7 indicate that linear terms of F_0 and quadratic term of F_0 were having significant (P<0.01) positive effect on the HMF content, while other quadratic term and interactions were showing negative effect but not significant.

The regression of HMF on F_0 and nisin values could be expressed as follows:

$$HMF = +27.28+3.52 * F_0 +0.038 * nisin +2.47 * F_0^2 -0.56 * nisin^2 -0.46* F_0 * nisin$$

The Response surface plot (Fig. 5.6) depicting the above relationship shows that the HMF value did not change with nisin level, but increased exponentially with increasing F_0 value at all levels of nisin.

TBA value: The TBA (thiobarbituric acid) value is a measure or oxidative change in a fat containing product. In retort processed *dalia* dessert,

Table 5.6 Physico-chemical properties of freshly processed long-life *dalia* dessert as influenced by levels of F_0 and nisin

Expt. No	Level		Physico-chemical parameter					
	F_0	Nisin (IU/g)	HMF	TBA	pH	colour		
						L*	a*	b*
1	4.70	117.16	23.20	0.096	6.47	81.20	1.93	17.00
2	7.45	117.16	32.47	0.086	6.44	78.96	3.70	19.83
3	4.73	682.84	24.64	0.085	6.47	80.76	2.36	17.30
4	7.63	682.84	33.32	0.093	6.42	79.80	2.63	18.03
5	3.90	400.00	29.00	0.095	6.47	82.00	1.66	16.16
6	8.22	400.00	39.17	0.091	6.39	78.63	3.46	18.86
7	6.02	0.00	27.70	0.092	6.48	80.40	2.90	18.13
8	5.95	800.00	26.81	0.086	6.43	80.26	2.90	18.03
9	5.98	400.00	27.56	0.090	6.44	79.26	3.40	19.10
10	5.95	400.00	26.75	0.092	6.42	79.46	2.50	17.46
11	5.97	400.00	27.14	0.092	6.43	80.00	3.10	18.83
12	6.01	400.00	27.76	0.093	6.50	79.66	3.16	18.76
13	6.24	400.00	28.08	0.093	6.48	78.83	3.36	19.50

Table 5.7 Coefficients of Full Second Order Polynomial Model for physico-chemical responses to F_0 and nisin in freshly produced *dalia* dessert

Factor	Physico-chemical parameter					
	HMF	TBA	pH@	Colour		
				L*	a*	b*
Intercept	27.28	0.092	6.45	79.46	3.09	18.72
A- F_0 (A)	3.52**	-1.011E-003	-0.022*	-1.03**	0.59**	0.98**
B- Nisin	0.038	-1.739E-003**	-0.011	0.011	-0.063	-0.18
A^2	2.47	2.615E-004		0.39*	-0.27*	-0.51*
B^2	-0.56	-1.709-003**		0.43*	-0.13	-0.29
AB	-0.46	4.524E-003**		0.33	-0.38*	-0.52
R Squared	0.9412	0.9233	0.46	0.93	0.88	0.83
Adequate Precision	15.441	13.79	5.75	13.52	11.18	8.89
PRESS	82.99	4.257E-005	9.006E-003	2.35	1.33	4.76

@ Linear model *Significant at 5% level **Significant at 1% level it ranged from 0.085 to 0.096. Minimum level was found in the product with F_0 4.73 and nisin 682.84 IU/g, and maximum in the dessert with F_0 4.70 and nisin 117.16 IU/g. It thus appeared that increase in the nisin level results in decreased TBA value (Table 5.6)

As shown in Table 5.7, the regression coefficients for the quadratic model indicate that the nisin level had highly significant negative effect in both linear and quadratic terms. The F_0 value and nisin were also having significant interactive effect ($p<0.01$).

The response surface graphs for TBA (Fig. 5.7) shows negative effect of nisin ($P<0.01$) but no effect of F_0 value. As the level of nisin increased the TBA value rapidly decreased at F_0 values but the trend was reversed at high F_0 values, the interaction having significant ($P<0.01$).

By the following response surface equation the TBA content for any level of factor combination can be calculated:

$$TBA = 0.092-1.011E\text{-}003 * F_0 - 1.739E\text{-}003 * nisin+2.615E\text{–}004 * F_0^2 - 1.079E\text{-}003 * nisin^2+4.524E\text{-}003 * F_0 * nisin$$

The model summary statistics shows the coefficient of determination (R^2) for TBA to be 0.92, which is highly desirable. The PRESS value 4.257E-005 was low enough to prevent the use of factor for the prediction of TBA. Also, the high value for adequate precision value, 13.79 indicates a desirable signal to noise ratio (Table 5.7).

pH: The range of the pH of the retort processed *dalia* dessert was from 6.39 (F_0 8.22 and nisin 400 IU/g) to 6.50 (F_0 6.01 and nisin 400 IU/g) (Table 5.6). The model summary statistics show that the pH declined with increasing F_0 value, the relationship fitting a Linear model, and the coefficient of determination (R^2) being 0.46. The PRESS value of 9.066E-003 was very low which can be considered highly desirable for the model. The adequate precision value of , 5.75 indicated a desirable signal to noise ratio (Table 5.7).

The response surface graph for pH (Fig. 5.8) also shows that the pH decreased as a function of F_0, ($P< 0.01$). As the level of F_0 increased, the pH was observed to decrease where as nisin showed non-significant, negative

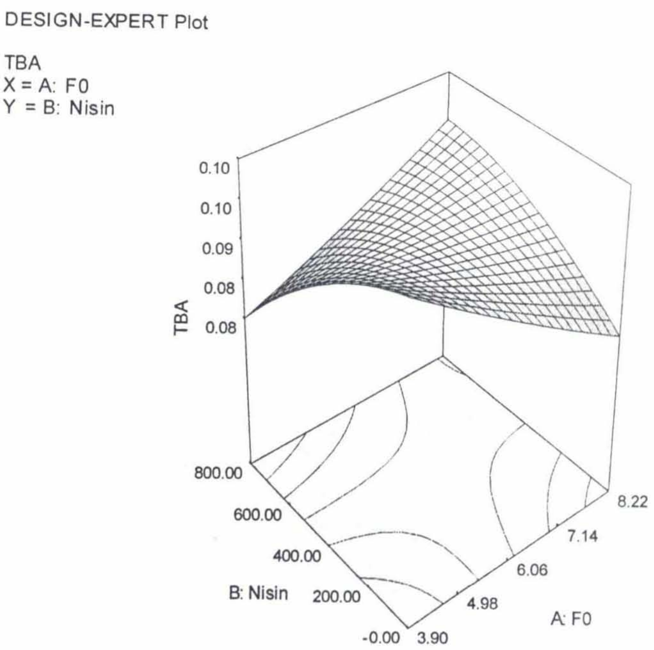


Fig 5.7 Response surface relating TBA as influenced by level of F_0 and nisin in long life dalia dessert

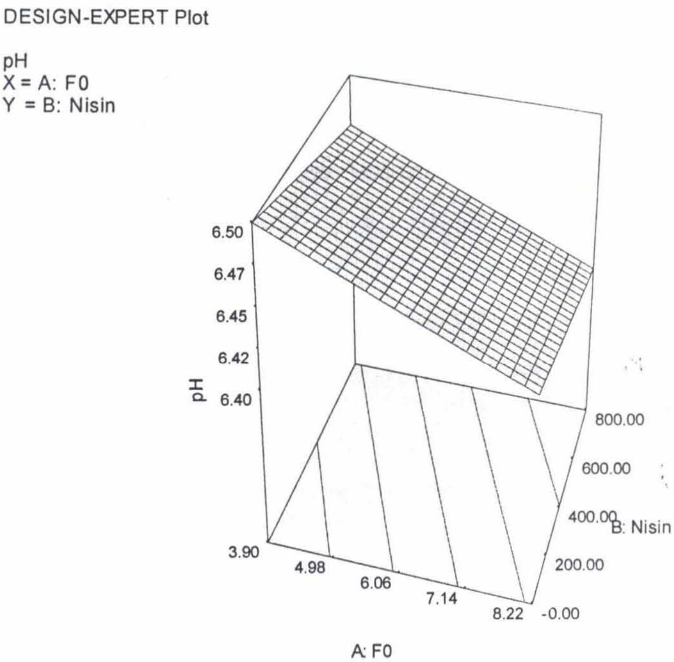


Fig 5.8 Response surface relating pH as influenced by level of F_0 and nisin in long life dalia dessert

relationship. Progressive drop in pH in milk products and other foods undergoing Maillard browning is widely recognized (Parry, 1974). Jha (2000) noted the pH of retort processed rice kheer to decrease appreciably upon retort process of in-pouch rice kheer.

By the following response surface equation for pH expressed the relationship between pH and the two process variables in *dalia* dessert:

$$pH = +6.56113 - 0.015876 * F_0 - 3.93100E\text{-}004 * nisin$$

Colour Indices L*, a* and b*: The colour of the retort processed *dalia* dessert measured in terms of CIELAB parameters L* (whiteness or brightness), a* (redness or greenness) and b* (yellowness or blueness) indicated that the colour of the freshly made product could be profiled in terms of whiteness (L*), Greenness (+a*) and yellowness (+b*). The average value ranged from 78.83 (F_0 value 6.24 and nisin 400 Iu/g) to 82.00 (F_0 3.90 and nisin 400 Iu/g) (Table 5.6).

The negative co-efficient of regression L* value on F_0 (Table 5.7) was F_0 significant in both linear ($P<0.01$)and quadratic terms ($P<0.05$). As the F_0 value increased, the L* value decreased. As indicated by model summary statistics, the R^2 for L* (brightness) was 0.93, higher than the suggested minimum desirable value (Table 5.7). The adequate precision value was found to be 13.52, higher than table value of 4.00 is required for a satisfactory model. Moreover, the PRESS value was also sufficiently small i.e., 2.35, and hence the model could be considered reliable.

The response surface for L* vs. F_0 and nisin level. (Fig. 5.9) confirmed the above observations. It could be described by the following equation:

$$L^* = 79.46 - 1.03^* F_0 + 0.011^* nisin + 0.39^* F_0^2 + 0.43^* nisin^2 + 0.33^* F_0{}^* nisin.$$

The average values of a* intensity of the green hue and b* intensity of the yellow hue ranged from 1.66 and 16.16 (F_0 3.90 and nisin 400 IU/g) to 3.70 and 19.83 (F_0 7.45 and nisin 117.16 IU/g) (Table 5.6). The co-efficient of determination (R^2) was 0.88 and 0.83, which was higher than the minimum

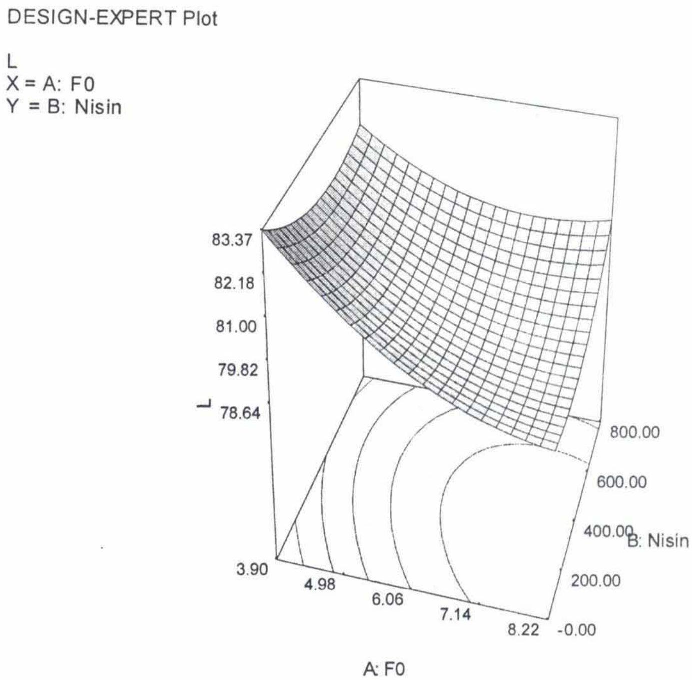


Fig 5.9 Response surface relating L* (Lightness) as influenced by level of F_0 and nisin in long life dalia dessert

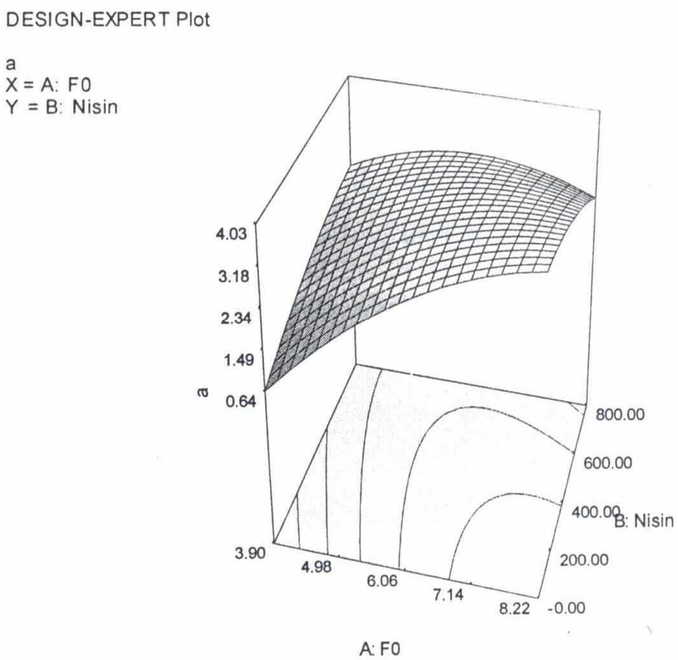


Fig 5.10 Response surface relating a* (redness) as influenced by level of F_0 and nisin in long life dalia dessert

value specified by Henika (1982) (Table 5.7). Adequate precision level was also greater than 4.00 (i.e., 11.18 and 8.89) which denote that the model was satisfactory. PRESS value was 1.33 and 4.76 which was small indicating suitability of data. Coefficients of regression equation showed that the linear terms of a* and b* were highly significant ($P<0.01$) for a* and b* as well as the quadratic term of b* with regard to F_0. The interaction between F_0 and nisin a* was also significant ($P<0.05$) effect. Thus the F_0 showed a positive effect on the a* and b* i.e., as F_0 increased the values of a* and b* also increased. Response surfaces presented in Fig. 5.10 and 5.11 also reflect this trend.

The two response surfaces could be express in terms of the following quadratic equations:

$$a^* = 3.09 + 0.59^* F_0 - 0.063^* \text{nisin} - 0.27^* F_0^2 - 0.13^* \text{nisin}^2 - 0.38^* F_0 * \text{nisin}$$

$$b^* = 18.72 + 0.98^* F_0 - 0.18^* \text{nisin} - 0.51^* F_0^2 - 0.29^* \text{nisin}^2 - 0.52^* F_0 * \text{nisin}$$

5.3.3.3 *Physico-chemical changes during storage of retort processed dalia dessert*

The effect of F_0 and nisin on the reaction rate constants of the physico-chemical changes during storage had been also examined.

HMF value of stored *dalia* dessert: The HMF content of retort-processed *dalia* dessert increased during storage at 37°C, the rate constant for this linear change ranging from 0.011 (F_0-8.22 and nisin, 400.00 IU/g) to 0.040 (F_0-4.7 and nisin, 117.16 IU/g) (Table 5.8). As indicated by model summary statistics, the R^2 for reaction rate constant k of HMF was 0.91, higher than the suggested value (Table 5.9). The adequate precision value was found to be 14.49, higher than table value of 4.00 as desired for a satisfactory model. Moreover, the low PRESS value viz. 2.244E-004 also indicated a high fitness of the model data. The coefficients of regression and analysis of variance for the reaction rate constant of HMF increase (Table 5.9) show that the F_0 was negatively correlated ($P<0.01$) as also nisin

Table 5.8 Effect of the level of F_0 and nisin on the reaction rate constant of different physico-chemical characteristics of *dalia* dessert during storage at 37°C

Expt. No	Level		Reaction Rate					
	Fo	Nisin (IU/g)	HMF	TBA	pH	Colour		
						L*	a*	b*
1	4.70	117.16	0.040	0.0347	0.0009	0.0018	0.0266	0.0068
2	7.45	117.16	0.021	0.0514	0.0006	0.0009	0.0138	0.0077
3	4.73	682.84	0.025	0.0398	0.0005	0.0012	0.0149	0.0046
4	7.63	682.84	0.017	0.0531	0.0011	0.0005	0.0099	0.0048
5	3.90	400.00	0.028	0.0311	0.0008	0.0016	0.0241	0.0055
6	8.22	400.00	0.011	0.0593	0.0007	0.0006	0.0113	0.0064
7	6.02	0.00	0.030	0.0455	0.0008	0.0013	0.0228	0.0073
8	5.95	800.00	0.026	0.046	0.0008	0.0008	0.0147	0.0042
9	5.98	400.00	0.024	0.0415	0.0009	0.0015	0.0152	0.0055
10	5.95	400.00	0.026	0.0403	0.0008	0.0013	0.0158	0.0061
11	5.97	400.00	0.025	0.0422	0.0008	0.0012	0.0157	0.0054
12	6.01	400.00	0.030	0.0468	0.0008	0.0011	0.014	0.0063
13	6.24	400.00	0.025	0.0393	0.0008	0.0013	0.016	0.0059

Table 5.9 Coefficients of Full Second Order Polynomial Model for physico-chemical responses (reaction rate constant) to different levels of F_0 and nisin in stored *dalia* dessert

Factor	Reaction rate constant (k) for					
	HMF	**TBA**	**pH**	**L***	**a***	**b***
Intercept	0.026	0.042	8.17E-004	1.291E-003	0.015	5.839E-003
F_0 (A)	-5.935E-003**	8.239E-003**	1.738E-005	-3.516E-004**	-4.451E-003**	2.811E-004*
Nisin (B)	-3.098E-003*	8.714E-004	4.182E-006	-2.103E-004**	-3.437E-003**	-1.183E-003**
A^2	-2.506E-003*	1.062E-003	-3.114E-005	-6.965E-005	7.580E-004	6.444E-005
B^2	1.403E-003	1.704E-003	-1.003E-005	-1.111E-004	1.282E-003*	-1.356E-005
AB	3.053E-003	-1.151E-003	2.283E-004**	6.215E005	1.909E-003*	-1.935E-004
R Squared	0.91	0.92	0.87	0.94	0.96	.95
Adequate Precision	14.49	13.53	10.78	13.66	18.91	16.16
PRESS	2.244E-004	1.529E-004	2.033E-007	2.847E-007	6.144E-005	1.551E-006

**Significant at 1% level *Significant at 5% level

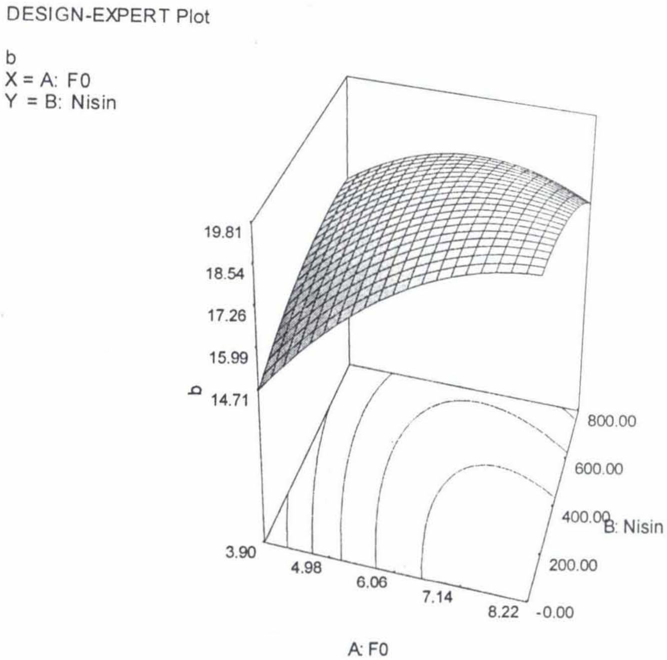


Fig 5.11 Response surface relating b* (yellowness) as influenced by level of F_0 and nisin in long life dalia dessert

(P<0.05); the quadratic term of F_0 was also significant (P<0.05) for HMF rate constant. It was thus evident that an increase in F_0 decreased the rate of rise in HMF with the result that the difference in the initial HMF content between a low F_0 formulation and a high F_0 formulation. Further, a higher level of added nisin would cause HMF to increase slowly than would a lower level of the fresh product would not change appreciably during storage. The response surface plot (Fig. 5.12) clearly reflected the trends. The regression equation representing this response surface can be given as follows:

$$k(HMF) = 0.026 - 5.935E{-}003 * F_0 - 3.098E{-}003 * nisin - 2.506E{-}003 * F_0^2 + 1.403E{-}003 * nisin^2 + 3.053E{-}003 * F_0 * nisin.$$

TBA value of stored *dalia* dessert: The TBA value increased during storage of the *dalia* dessert at 37^0C. The rate of increase expressed for a linear change was a function of the F_0 value of the process used to produce the dessert and it ranged from 0.0311 (F_0 - 3.90 and nisin, 400 IU/g) to 0.0593 (F_0 -8.22 and nisin, 400IU/g) (Table 5.8). It was directly correlated (P<0.01) to $F_{0\ as}$ can seen from the positive coefficient of regression (Table 5.9). As F_0 increased, the reaction rate constant also increased. The response surface plot (Fig. 5.13) clearly depicted this trend. The coefficient of determination (R^2) 0.92, was higher than the minimum value of 0.85desired for a good model. The adequate precision value (13.53) was appreciably greater than 4.00 which denotes that the model was satisfactory. The PRESS value was 1.529E-004, which is very small indicating the suitability of the model for prediction purposes.

The following response surface equation adequately expressed the relationship between the reaction rate constant of TBA during storage and F_0 and nisin level.

$$k\ (TBA) = 0.042 + 8.239E{-}003 * F_0 + 8.714E{-}004 * nisin + 1.062E{-}003 * F_0^2 + 1.704E{-}003 * nisin^2 - 1.151E{-}003 * F_0 * nisin.$$

pH of stored *dalia* dessert: The pH of retort-processed *dalia* dessert decreased during storage and rate of decrease at 37°C ranged from 0.005 (F_0-4.73 and nisin, 682.84, IU/g) to 0.011 (F_0-7.63 and nisin, 682.84 IU/g) (Table 5.8). The coefficient of determination (R^2) was 0.87, which was higher

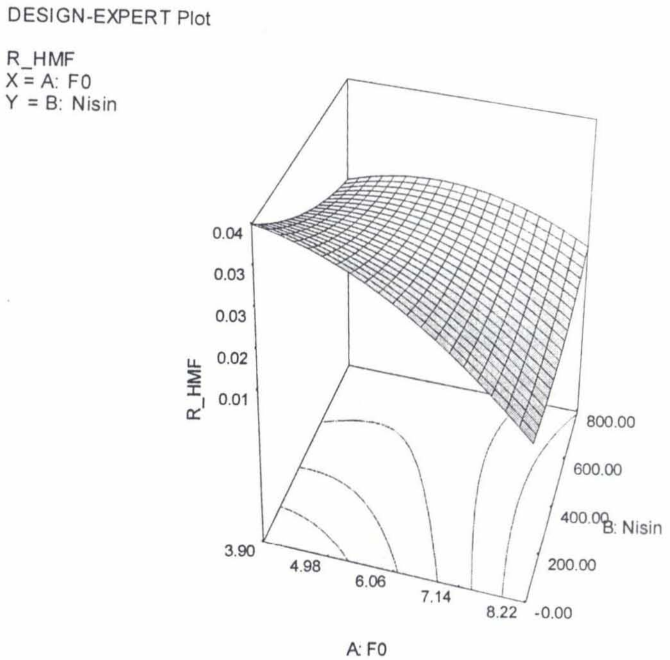


Fig 5.12 Response surface relating reaction rate constants of HMF as influenced by level of F_0 and nisin in long life dalia dessert

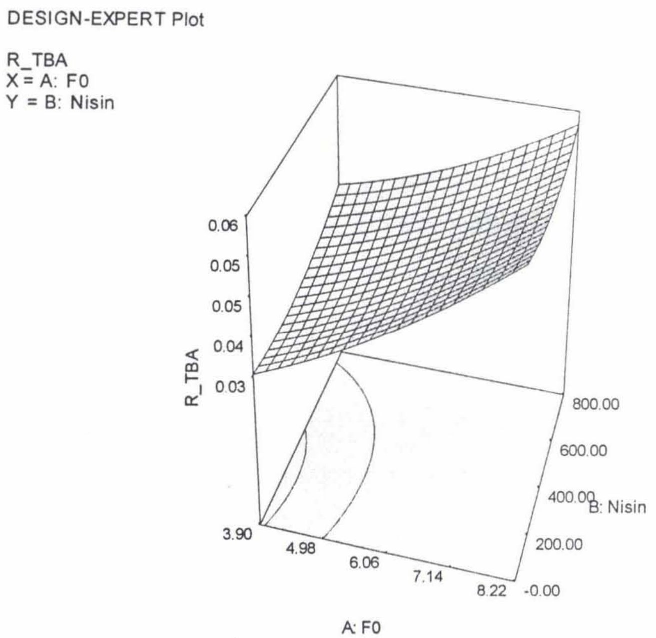


Fig 5.13 Response surface relating reaction rate constants of TBA as influenced by level of F_0 and nisin in long life dalia dessert

than the minimum value specified (Table 5.9). Adequate precision level was 10.78; higher than the table value 4.00, which denotes that the model is satisfactory. The PRESS value was 2.033E-007; i.e. very small indicating suitability of the model for the prediction of the data. Coefficients of regression equation show that the interaction between F_0 and nisin was highly significant ($P<0.01$) with regard to their effect on storage induced change in pH. The linear and quadratic terms were however not significant (Table 5.9).

The response surface plot Fig. 5.14 shows that either F_0 or nisin alone had no significant effect on pH decrease during storage, but their combined effect was highly significant ($P<0.001$)

By the following regression equation the response pH at any level of factor combination could be calculated.

$$k(pH) = 8.173E\text{-}004+1.738E\text{-}005* F_0+4.182E\text{-}006*nisin-3.114E\ 005* F_0^2+2.283E\text{-}\ 004* F_0*nisin$$

CIELAB parameters of stored *dalia* dessert: Browning of dalia dessert stored at 37°C was reflected in decreasing colour index L* (brightness or lightness), the rate of change for this parameter ranging from 0.0005 (F_0-7.63 and nisin, 682.84 IU/g) to 0.0018 (F_0-4.70 and nisin 117.16 IU/g) (Table 5.8). The rate constant was greatly influenced by F_0 and nisin levels, effects being negative ($P<0.01$) as can be seen from Table 5.9. The coefficient of determination (R^2) was 0.94, which was higher than the minimum value required (Table 5.9). Adequate precision level was 13.66, higher than the table value 4.00, which denote that the model is satisfactory. PRESS value was 2.847E-007, which was very small indicating suitability of the model for the prediction of the data. Coefficients regression show that as F_0 and nisin increased the rate of decrease of L* decreased. The quadratic terms and interaction term were not significant. It can be seen from Fig. 5.15 that as the F_0 and nisin level increased, the k (L*) decreased. All quadratic and interaction terms had a negative impact but were not significant.

By using the following regression equation 94 per cent variance in k(L*) could be explained:

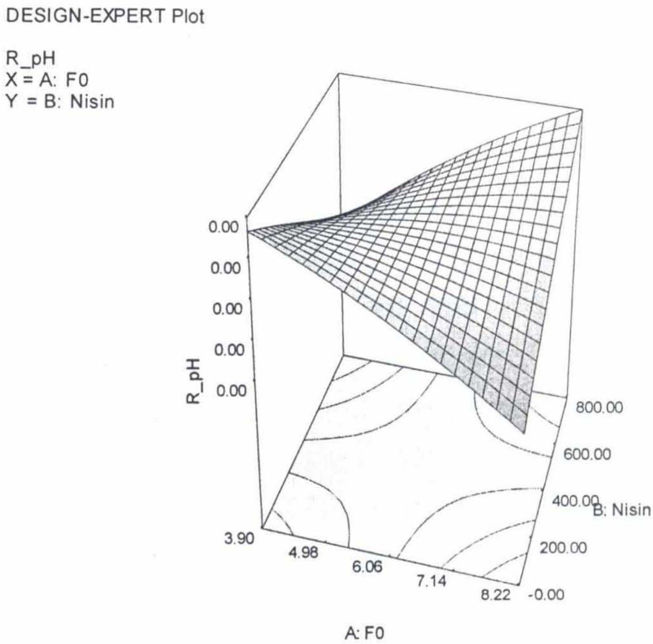


Fig 5.14 Response surface relating reaction rate constants of pH as influenced by level of F_0 and nisin in long life dalia dessert

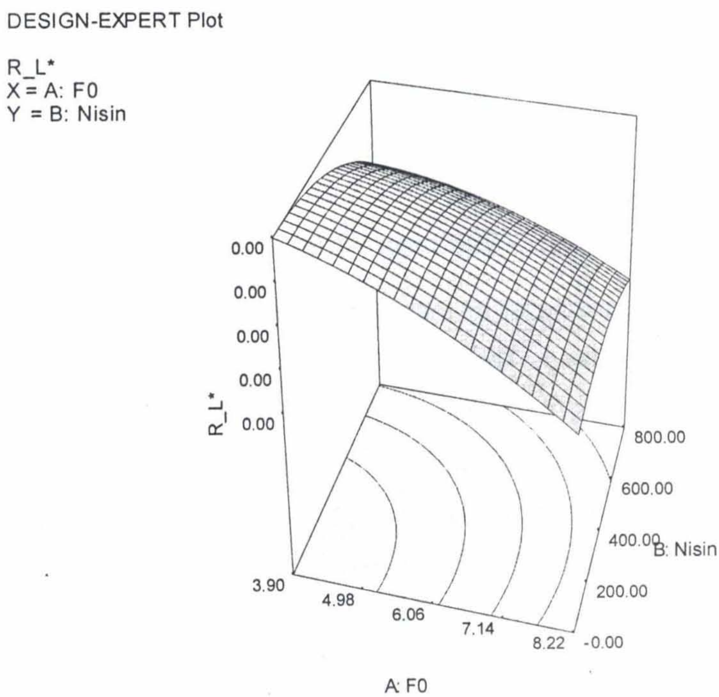


Fig 5.15 Response surface relating reaction rate constants of L* (lightness) as influenced by level of F_0 and nisin in long life dalia dessert

$$k(L^*) = 1.291E\text{-}003 - 3.516E\text{-}004 * F_0 - 2.103E\text{-}004 * nisin - 6.965E\text{-}005 * F_0^2 - 1.111E\text{-}004 * nisin^2 + 6.215E\text{-}005 * F_0 * nisin.$$

As the storage of retort-processed dalia dessert progressed, the colour parameter a* indicative of redness increase and rate of increase [k(a*)] ranged from 0.0099 (F_0, 7.63 and nisin, 682.84 IU/g) to 0.0266 (F_0 4.70 and nisin 117.16 IU/g) (Table 5.8). The rate of increase in the intensity of red hue was inversely related to both the F_0 and nisin level in the dessert (Table 5.9).The coefficient of determination R^2 was 0.96, which was higher than the minimum value required (Table 5.9). Adequate precision level was 18.91, higher than the table value 4.00; it denotes that the model was satisfactory. PRESS value was 6.144E-005m,, which could be considered very small indicating suitability of the model for response prediction. Coefficients of regression (Table 5.9) show that both the linear terms F_0 and nisin levels were highly significant (P<0.01), quadratic term for nisin and interaction between nisin and F_0 significant (P<0.05). It is evident from the Fig. 5.16 that the F_0 and nisin decreased the k(a*) employing that the rate of development redness of the product as part of the browning process was less when F_0 and nisin both were high. This phenomena could be described by the following equation:

$$k(a^*) = 0.015 - 4.451E\text{-}003 * F_0 - 3.437E\text{-}003 * nisin + 7.580E\text{-}004 * F_0^2 + 1.282E\text{-}003 * nisin^2 + 1.909E\text{-}003 * F_0 * nisin$$

The colour parameter b* increased in the stored product i.e. yellowness of the product increased. The range of rate of rise in this parameter [k(b*)] ranged from 0.042 (F_0, 5.95 and nisin, 800 IU/g) to 0.077 (F_0 7.45 and nisin 117.16 IU/g) (Table 5.8). The coefficient of determination (R^2) was 0.95, which was higher than the minimum value specified (Table 5.9). Adequate precision level was 16.16, greater than the table value 4.00; denoting that the model was satisfactory. The PRESS value was 1.551E-006, which was very small indicating suitability of the model for the prediction of the rate constant based on F_0 and nisin. Coefficients of regression show that linear the term for F_0 positive and significant (P<0.05) whereas linear term for nisin was negative (P<0.01). Other quadratic and interaction terms were not significant.

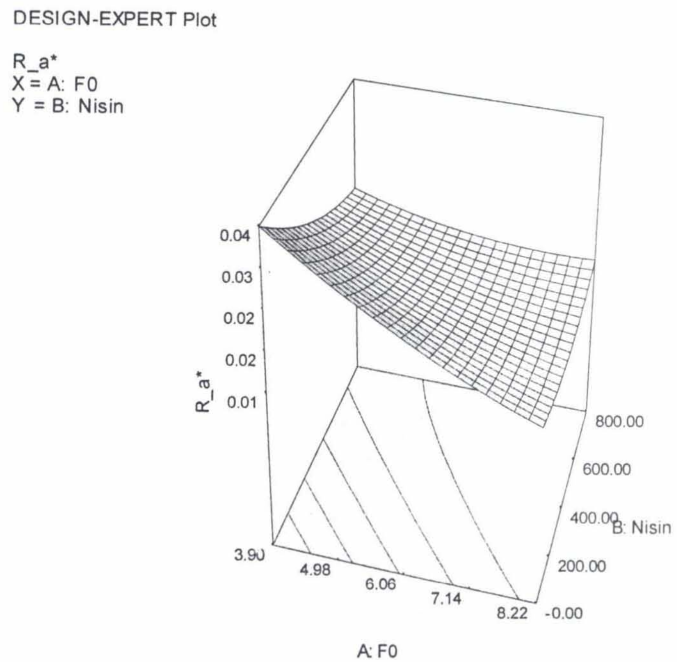


Fig 5.16 Response surface relating reaction rate constants of a* (redness) as influenced by level of F_0 and nisin in long life dalia dessert

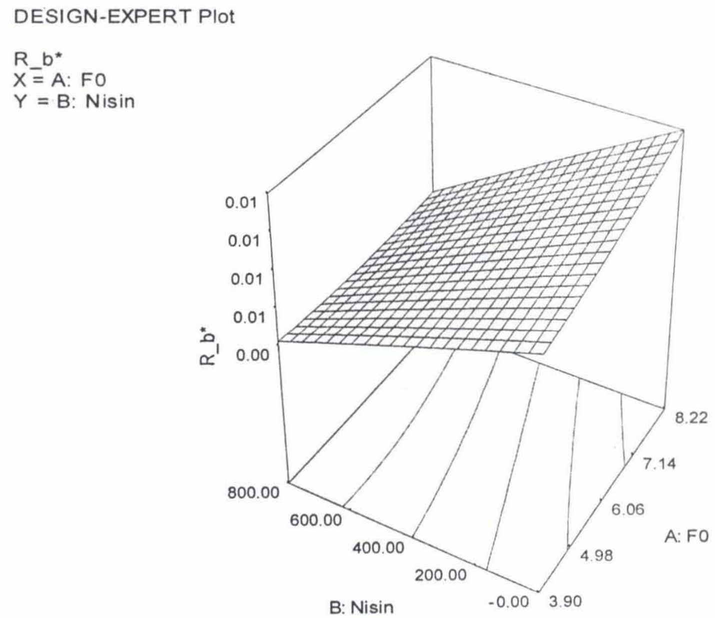


Fig 5.17 Response surface relating reaction rate constants of a* (redness) as influenced by level of F_0 and nisin in long life dalia dessert

The response surface plot (Fig. 5.17) shows that as F_0 increases, the k(b*) also increased, whereas, nisin exerted an opposite effect, i.e. as nisin increased reaction rate constant for b* decreased. The following regression equation adequately expressed the above relationship:

$$k(b^*) = 5.839E\text{-}003+2.811E\text{-}004*F_0-1.183E\text{-}003*nisin+6.444E\text{-}005*F_0^2+1.356E\text{-}005*nisin^2-1.935E\text{-}004*F_0*nisin$$

5.3.3.4 *Changes in sensory status of retort processed dalia dessert during storage at 37°C*

The physicochemical parameters of storage-induced changes in physicochemical properties discussed above appear to result in changes in corresponding sensory properties of the dessert. The sensory status of stored *dalia* dessert was examined in terms of hedonic rating for colour, texture, sweetness and flavour. Also, certain sensory profile parameters were monitored in terms of intensity of colour, textural descriptions and flavour. The data are presented in Appendix-II.

The hedonic colour score decreased as storage progressed primarily on account of brown discolouration and to some extent visual coagulation of milk. On an average colour score decline from initial 7.3 to 6.2 after 60 days of storage. Although, the score was generally higher for the product obtained ta a lower F_0 value, the trend was less evident at the end of storage than the beginning.

The texture score tended to show a slight increase during the first 15 days of storage but then decline gradually during the rest of the storage to a final average value of 6.3 from an initial value of 7.1. The early improvement in the score might be attributed to softening of the grains and later decrease in the score due to the hardening of the grains resulting in the coarseness.

The sweetness score of stored *dalia* dessert gradually declined from initial 7.2 to 6.3. Presumably because of the reduced perception of sweetness in the presence of increasing staleness in the product.

The flavour score also gradually declines declined as the storage period advanced, the initial average value of 7.136 decreased to 5.924 at the end of storage. The major change in flavour characteristic of the product was development of staleness which of is a common phenomenon in most high heat processed dairy products stored for a long time.

The scores of individual sensory attributes were converted into an overall acceptability rating by taking a weighted average, the weightage attached to different attributes being colour 0.2, texture 0.3, sweetness 0.2 and flavour 0.3. The overall rating thus determined decline during the storage from 7.2 for the fresh product to 6.4 in the product stored for 60 days at 37°C.

As noted for hedonic colour rating above, the intensity of brown discolouration tended to increase from initial 51.4 to final 57.0. Among textural descriptor visual consistency, relative amount of grains, hardness of grains and coarseness increase during storage whereas, stickiness or sliminess decrease (Appendix-II). The degree of sweetness showed a slight tendency to decrease during storage but remained close to the optimum level of 50.

The intensity of staleness exhibited a definite rise from initial moderate level (33.3) to definite level (65.7).

5.3.3.5 Determination of shelf-life of retort process dalia on the basis of sensory parameters

As discussed in foregoing section the sensory scores for the dalia dessert decreased during storage at 37°C. The decrease being significant in all attributes. Since sensory rating is most important criteria of the acceptability of a product, shelf-life was estimated by assigning a certain minimum value (6.75) on the 9-point hedonic scale for flavour and overall acceptability of marketable product. The shelf-life data thus obtained were subjected to response surface analysis as done earlier in respect of fresh product.

From the data od shelf-life on the basis of flavour score during storage having ranged from 27 (F_0 - 6.00 and nisin 600 IU/g) to 36 days (F_0 - 4.00 and nisin 400 IU/g). In this case quadratic model was fitted. From the regression equation, that F_0 had linear high significant ($P<0.01$) but it has inverse effect on the shelf-life. As F_0 increases, gradually there is a decrease in the shelf-life on the flavour basis. Indirectly this shows that if F_0 is higher there are more chances of stale flavour development. In the model, quadratic terms were also significant and the interaction effect of F_0 and nisin level had high significant ($P<0.01$) but also their effect is inverse. As both the level increased the flavour based shelf-life decreased.

From the model the coefficient of determination (R^2) was 0.90, which was higher than the minimum value required. Adequate precision level was 13.52 higher than the table value 4.0, denoted that the model is satisfactory. PRESS value 22.87, which indicated the suitability of the model for the prediction of the data. Response surface plot Fig. 5.18 shows that as F_0 increased the response initially decreased and then subsequently increased not too much. The figure shows quadratic effect on response by model equation for the shelf-life on the basis of flavour:

$$\text{Flavour-shelf} = 31.63-1.31* F_0 - 0.72*\text{nisin}+1.17* F_0 2 - 1.44*\text{nisin}2 - 2.00* F_0*\text{nisin}$$

The response in terms of shelf life based on overall acceptability of the product was significant for F_0 ($P<0.05$) and nisin level ($P<0.01$) when a cubical model (R2, 0.99) was considered for data fitting. The model was satisfactory as indicated by a high adequate precision value (14.01) Fig 5.19.

5.3.4 Process optimization based on fresh product characteristics and shelf life

5.3.4.1 *Fresh product quality-based optimization*

As discussed earlier (vide section 5.3.3.3) the fresh product quality in terms of sensory, flavour colour and overall acceptability scores exhibited significant dependence on processing conditions viz., F_0 -value and nisin level. The quadratic model for hedonic overall rating was used to work out the factors levels for a maximum score for a freshly prepared *dalia* dessert. As show in table 5.10, the output values of F_0 and nisin level were 7.39 and 785.2 IU/gm respectively, the desirability of the prediction being very high i.e. 1.00.

Combining the sensory flavour score with overall acceptability rating also yielded the values of 8.11 and 690.0 IU/g respectively for the two factors. However, such high values would yield distinctly more brown product which would turn even darker during ambient storage. Hence, this solution was considered unsatisfactory.

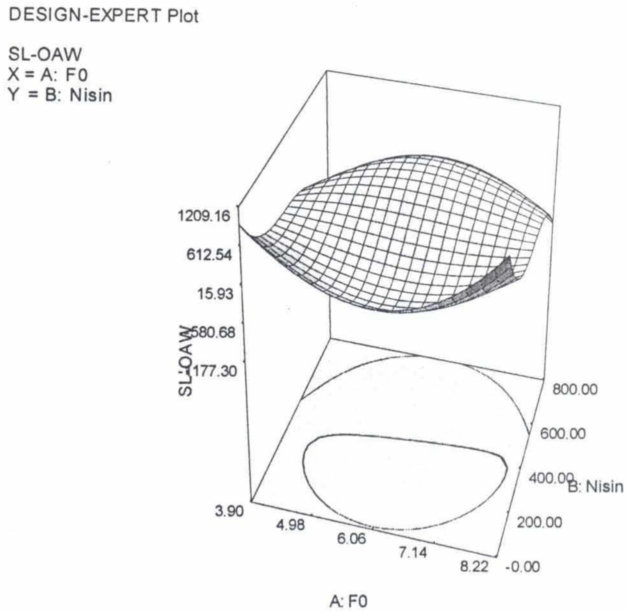


Fig 5.18 Response surface relating shelf life based on weighted overall acceptability as influenced by level of F_0 and nisin in long life dalia dessert

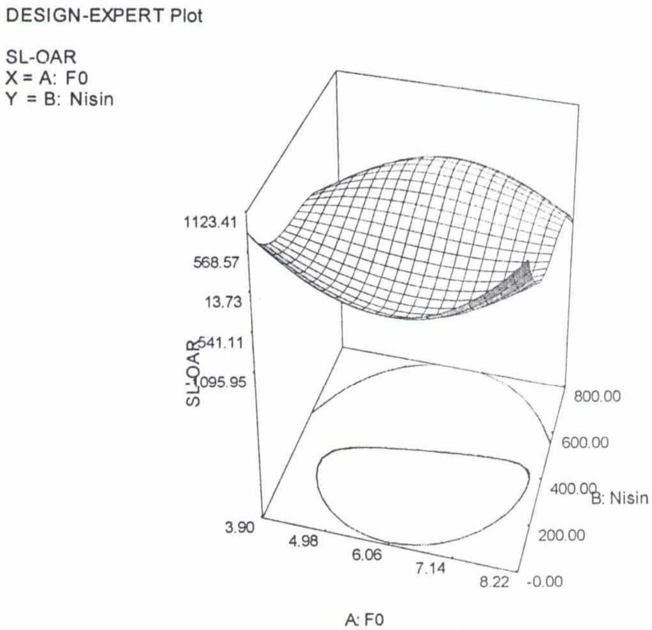


Fig 5.19 Response surface relating shelf life based on [redacted] overall acceptability as influenced by level of F_0 and nisin in long life dalia dessert

5.3.4.2 ***Shelf life-based factor optimization***.

Shelf life determined on the basis of overall acceptability rating was found to fit a cubical model. Prediction of F_0 and nisin levels using this model for a optimum shelf life yielded estimates of 4.15 and 325.7IU/g for the two factors, respectively (Table 5.10). The corresponding estimate of shelf life at 37° C was 65 days. The relatively low level of F_0 would also insure a comparatively high nutrient retention in the product even during storage.

5.3.4.3 ***Combined –basis optimization of F_0 and Nisin***

Taking into account the overall acceptability of freshly prepared product together with the shelf life based on overall acceptability rating could be expected to yield a more realistic estimate of process condition for optimum shelf life. As shown in Table 5.10, the F_0 value and nisin level thus predicted for a shelf life of 58 days were 7.74 and 647.0 IU/g respectively with desirability level of 0.98. Combining the overall acceptability score with flavour-based shelf life of the dessert yielded an optimum F_0 of 3.90 and nisin level of 302.4 IU/g, but the corresponding shelf life was just 35 days (Table 5.10). The predicted values of F_0 and nisin level in long life *dalia* dessert for overall acceptability-based shelf life and reaction rate constant for the colour parameter of L* as the constraints, were 7.76 and 641.5 IU/g with a corresponding shelf life of 58 days and desirability of 0.98.

It can be further seen from the table that adding the fresh-product overall rating as the third constraints did not appreciably alter the factor resulted values or the desirability level and the corresponding shelf life remained 58 days only. Thus, the factor prediction based on shelf life (overall acceptability) discussed above in section 5.3.6.2 would be most desirable for the low F_0 value and practically shelf life of 65 days at 37° C.

Since, the product was transported from the site of production to the place of storage study, it had been held at about 30^0C for approximately two weeks, when the samples were actually transferred to 37^0C this being taken as the beginning of storage (0 days). Accordingly, the product would actually have an extra shelf life of about one week and a total life of 72 days at 37^0C. A *dalia* dessert obtained using the optimized process conditions viz. F_0 4.15

and nisin 325.7 IU/g would keep much longer at the average ambient temperature of 30° C. It would, therefore, have an adequate useful life for commercial marketing of the product.

Table 5.10 Predicted values of flavour and overall acceptability scores, and shelf life based on these parameters

Sl. No.	Constraints	Goal	F0	Nisin	Score	Shelf life	Desirability
1	OA (fresh)	Max.	7.39	785.2	7.36	-	1.00
2	Flavour (fresh) +OA (fresh)	do do	8.11	690	7.36	-	1.00
3	Shelf life-OA	do	4.15	325.7	-	64.7	1.00
4	OA (fresh) Shelf life-OA	do do	7.74	647.0	7.33	58.0	0.98
5	OA (fresh) Shelf life-flavor	do do	3.90	302.4	7.34	35.2	0.96
6	Shelf life-OA R-L*	Max Min	7.76	641.5-	-	58.0	0.98
7	OA (fresh) Shelf life-OA R-L*	do do Min	7.75	645.6	7.33	58.0	0.97

Photo Plate No. 5.1 Long-Life dalia dessert

6. SUMMARY AND CONCLUSION

Dalia dessert obtained by cooking crack wheat (or wheat grits) in milk usually by boiling in an open pan thereby also partly concentrating the later and adding cane sugar is one of popular traditional dairy products exhibiting a considerable potential for commercial marketing through modern channels. However, lack of suitable technology coupled with very limited shelf life is the major stumbling block in the way of its organized production and marketing. In order to offer a technological option to the dairy industry for expanding its product range by manufacturing *dalia* dessert while the same time providing the consumer with the much needed quality, safety and convenience pact into the product, the present project was undertaken. The principle objective was to investigate the feasibility of producing a shelf stable *dalia* dessert by means of a cooking-cum-sterilization process employing the retort technology.

Relevant literature reviewed as presented in chapter 2 and the scope and plan of the proposed work elaborated in chapter 3. The materials and methods used in this investigation have been described in chapter 4. The results obtained in the present study as presented and discussed in forgoing chapter are summarized below.

6.1 SELECTION OF WHEAT VARIETY SUITABLE FOR *DALIA* MAKING

Keeping in view the variation in physico-chemical properties among different variety of wheat regard to its suitability for preparation of *dalia* dessert, an attempt was made to screen five different varieties including three durum (*Triticum durum*) varieties viz. PDW-233, WH-896 and PDW-274 and to non-durum (*Triticum aestivum*) viz. HD-2687 and PBW-343. the durum variety WH-896 yielded the most preferred dessert prepared by the traditional method, its hedonic rating for colour, texture and flavour being respectively 8.0, 8.1 and 8.1 on a 9-point scale. It was followed, by PBW-343 (scores 7.4, 73.5 and 7.4 respectively) which is distinctively better than the rest of the varieties. Accordingly, WH-896 *dalia* was used in for the studies.

6.2 PRELIMINARY STUDIES ON PRODUCT FORMULATION

Early attempts at retort processing of canned mixture of preconcentrated milk, *dalia* and sugar showed that lumping of grains and destabilization (coagulation) of milk were the major problems to be overcome. So, preliminary studies were conducted to have a formulation with the right levels of *dalia* grains and TS in milk that would not cause objectionable grain lumping or milk coagulation. These investigation revealed that a TS level of 15% (3.9% fat) obtained by adding whole milk powder to toned milk, and 7.4% *dalia* grains in the formulation would not have a serious problem of lump formation or milk coagulation upon retorting in a rotary system. The formulation was, therefore, need to conducts Response Surface (RSM) experiments (13 numbers) based on a two-factor Central Composite Rotatable Design (CCRD) comprising the two factors, levels of 4.0 – 8.0 for F_0 and 0 – 800 IU/g nisin as a thermal preservatives.

6.3 CHEMICAL COMPOSITION AND HEAT PENETRATION CHARACTERISTICS OF IN-CAN RETORT PROCESSED *DALIA* DESSERT

The average composition of retort sterilized *dalia* dessert was : 29.60 5 TS, 3.56 % protein, 0.84 % ash and 21.54 % total carbohydrates including 2.88 % amylose.

The product was characterized by a short lag period for the heating curve, J_h (0.40-0.85), small heating rate index, f_h (3.2-5.5min) and a short lag factor for the cooling curve, j_c (0.91 – 1.10) implying essentially convective heating in the retort. The process time, B, was 10.20-15.78 min for F_0 value of 3.90-8.22, whereas the cook value, c_g was 28.95-54.03 min. such a process would ensure adequate cooking and inactivation of anaerobic spore-forming food poisoning microorganisms.

6.4 EFFECTS OF F_0 AND NISIN LEVELS ON PROPERTIES OF RETORT PROCESSED *DALIA* DESSERT

Thirteen lots of *dalia* dessert obtained from the two–factor experiments were examine for sensory attributes (hedonic rating and profiling) as well as physico-chemical properties. The data were analyzed using design experiment software.

The colour, flavour and overall acceptability scores of the product were in the range of 7.00-7.71, 6.95-7.33 and 7.06-7.34, respectively, the two factors F0 and nisin (bearing negative correlations with these hedonic scores. Quadratic model fits of the data showed R^2 values of 0.85 or more, a high. Adequate precision (8.55, 6.50 and 10.22) and low press values (0.55, 0.14 and 0.05) indicating a good measure of reliability. The texture (6.41-7.41) and sweetness scores (7.16-7.78) did not show any definitive relationship with F_0 or nisin.

RSM design which showed quadratic fits to be highly desirable from model reliability point of view.

6.5 OPTIMIZTION OF F_0 AND NISIN LEVELS

The regression model for overall acceptability F_0 the product was used to estimate the optimum F_0 and nisin level for a maximum shelf life, the solutin being F_0 4.15 and nisin 375.7 IU/g and the corresponding shelf life of 65 days at 37^0C.considering the flavour based shelf life and overall acceptability of the fresh product yield the optimize levels of F_0 (3.90) and nisin (302.4 IU/g) while this model yield a much shorter predicted shelf life (35 days) than that from the model based on both the fresh products acceptability rating and acceptability-limited shelf life (58 days), the first solution would yield a maximum possible shelf life of 65 days with a high level of desirability. Since the product was prepared at CIFT, Cochin and brought to Karnal for storage studies, about two weeks had elapsed at 30°C (equivalent to about 7 days at 37°C) before storage commenced at 37°C. Thus the actual shelf life of *dalia* dessert produced by using F_0 at 4.15 and nisin at 376 IU/g would keep well for 72 days at 37°C and much longer at 30°C which is mean ambient temperature for most parts of the country.

In conclusion, an in-can retort processed *dalia* dessert could be produced with a good acceptability by using a rotary sterilizer and nisin as an adjunct preservative. An F_0 value of 4.15 and nisin 376 IU/g yield a product that is both safe and wholesome, and offer considerable consumer convenience in form of canned *dalia* dessert. This technology could be adapted by the user industry for more diversified production operations in the increasingly competitive market.

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Appendix-I

Score Card for Sensory Evaluation of Dalia

ATTRIBUTE RATING

Please indicate your assessment by making a small vertical line-mark along the linear scale by giving the corresponding sample number

COLOUR

Liquid phase	White	light brown	dark brown
Particulate Phase	Too light	optimally brown	dark brown

TEXTURE

Visual consistency	Too thin	Optimum	Too thick
Grain size	Too fine	Optimum	Too big
Lumpiness	Nil	Definite	Extreme
Relative amount of grain	Too low	Optimum	Too much
Hardness of grains	Too soft	Optimum	Too tough
Stickiness/ sliminess	Nil	Moderate	Extreme
Coarseness	Nil	Moderate	Extreme

FLAVOUR

Sweetness	Too low	Optimum	Extreme
Cooked/Stale flavour	Nil	Moderate	Extreme

Appendix-II

Sensory Evaluation of Dalia

Kindly examine the given samples for QUALITY ATTRIBUTES to the 9-point Hedonic scale, as below:

Like extremely	(9)
Like very much	(8)
Like moderately	(7)
Like slightly	(6)
Neither like nor dislike	(5)
Dislike slightly	(4)
Dislike moderately	(3)
Dislike very much	(2)
Dislike extremely	(1)

S.No.	Attributes	Sample No.		
		1	2	3
1	Colour			
2	Texture			
3	Sweetness			
4	Flavour			
5	Overall Acceptability			

Comments, if any:

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Date: _______________ **Signature:** ____________________

Name: ___________________

Sensory (hedonic) rating and attribute properties of stored *dalia* dessert

Hedonic colour score							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	7.00± 0.63	6.56± 0.68	6.83± 0.81	6.64± 0.69	6.14± 0.38
400	3.9	2	7.71± 0.49	7.50± 0.45	7.41± 0.66	7.10± 0.21	7.00± 0.79
682.84	7.63	3	7.19± 0.70	6.78± 0.81	7.10± 0.55	6.92± 0.80	6.04± 0.47
682.84	4.73	4	7.75± 0.69	7.31± 0.65	7.16± 0.68	7.21± 0.49	6.71± 0.64
0	6.02	5	7.50± 0.63	6.69± 0.65	6.75± 0.76	6.86± 0.55	6.54± 0.55
400	5.95	6	7.50± 0.46	6.86± 0.75	6.70± 0.83	6.66± 0.75	
117.16	4.7	7	7.67± 0.61	7.44± 0.68	7.43± 0.45		
400	8.22	8	7.00± 0.58	6.91± 0.73	6.58± 0.58	6.54± 0.46	5.60± 1.14
117.16	7.45	9	7.07± 0.45	6.91± 0.73	6.36± 0.47	5.75± 1.09	
400	5.98	10	7.06± 0.82	6.64± 0.85	6.90± 0.65	6.80± 0.76	
400	5.97	11	7.29± 0.57	6.71± 0.81	6.90± 0.65	6.00± 0.31	
400	6.24	12	7.07± 0.45	7.08± 0.66	6.25± 0.88	6.40± 0.82	5.50± 1.41
400	6.01	13	7.07± 0.45	7.08± 0.73	6.75± 0.43	5.80± 1.09	
Average			7.30	6.96	6.86	6.56	6.22

Hedonic texture score

Nisin	F_0	Run	Days				
			0	15	30	45	60
800	5.95	1	7.33± 0.88	6.81± 1.39	7.25± 0.76	6.61± 0.70	6.71± 1.07
400	3.9	2	6.78± 0.75	7.00± 0.83	7.33± 0.51	6.83± 0.68	6.80± 0.57
682.84	7.63	3	7.19± 0.70	7.50± 0.64	7.60± 0.65	6.67± 0.61	6.21± 2.00
682.84	4.73	4	6.42± 0.49	6.94± 0.82	7.00± 0.55	7.00± 0.58	6.57± 1.74
0	6.02	5	6.83± 0.68	7.00± 0.96	7.33± 0.41	7.07± 0.61	6.71± 1.55
400	5.95	6	6.81± 0.65	7.64± 0.69	7.20± 0.76	6.33± 1.33	
117.16	4.7	7	7.42± 0.92	7.13± 0.35	7.36± 0.48		
400	8.22	8	7.28± 0.39	7.50± 0.55	7.41± 0.58	6.75± 0.52	6.00± 1.41
117.16	7.45	9	7.78± 0.99	7.66± 0.60	6.14± 1.25	5.95± 0.11	
400	5.98	10	6.94± 0.56	7.43± 0.73	7.40± 0.65	6.50± 1.54	
400	5.97	11	7.00± 0.40	7.43± 0.73	7.50± 0.79	6.92± 0.66	
400	6.24	12	7.21± 0.70	7.66± 0.60	6.83± 0.81	6.80± 0.91	5.40± 1.34
400	6.01	13	6.71± 1.07	7.41± 0.80	6.71± 0.70	6.00± 0.35	
Average			7.05	7.32	7.16	6.62	6.34

Hedonic sweetness score

Nisin	F_0	Run	Days				
			0	15	30	45	60
800	5.95	1	7.50± 0.84	7.25± 0.75	7.50± 0.45	6.96± 0.09	7.43± 0.45
400	3.9	2	7.71± 0.49	7.58± 0.49	7.50± 0.55	7.50± 0.77	7.10± 0.74
682.84	7.63	3	7.38± 0.88	7.35± 0.75	7.60± 0.55	7.42± 0.49	7.29± 0.49
682.84	4.73	4	7.33± 0.82	7.50± 0.60	7.41± 0.49	7.39± 0.57	7.43± 0.53
0	6.02	5	7.33± 0.82	7.37± 0.79	7.50± 0.45	7.25± 0.52	7.36± 0.48
400	5.95	6	7.38± 0.88	7.43± 0.73	7.80± 0.57	7.25± 0.42	
117.16	4.7	7	7.17± 0.82	7.44± 0.62	7.36± 0.48		
400	8.22	8	7.71+ 0.49	7.66± 0.51	7.58± 0.49	7.41± 0.66	7.10± 0.55
117.16	7.45	9	7.64± 0.62	7.66+ 0.51	7.43± 0.53	7.05± 0.94	
400	5.98	10	7.44± 0.86	7.36± 0.75	7.70± 0.45	7.30± 0.45	
400	5.97	11	7.28± 0.90	7.43± 0.73	7.70± 0.45	7.42± 0.66	
400	6.24	12	7.78± 0.57	7.58± 0.49	7.58± 0.49	7.25± 1.03	6.80± 0.27
400	6.01	13	7.57± 0.53	7.66+ 0.51	7.50± 0.50	6.85± 0.78	
Average			7.48	7.48	7.55	7.25	7.22

Hedonic flavour score							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	7.25± 0.61	6.87± 1.02	6.83± 0.75	6.50± 0.64	6.00± 1.15
400	3.9	2	7.21± 0.57	7.08± 0.49	7.00± 0.31	6.83± 0.26	6.10± 0.65
682.84	7.63	3	7.19± 0.70	7.07± 0.53	7.20± 0.27	6.33± 1.25	5.86± 1.14
682.84	4.73	4	7.08± 0.80	7.37± 0.44	6.75± 0.61	6.93± 0.67	6.00± 1.44
0	6.02	5	7.25± 0.42	7.12± 0.87	6.58± 0.58	6.86± 0.75	6.21± 1.32
400	5.95	6	7.00± 0.89	7.07± 0.60	7.20± 0.76	6.00± 1.76	
117.16	4.7	7	7.33± 0.61	7.38± 0.44	6.79± 0.70		
400	8.22	8	7.28± 0.49	7.16± 0.98	6.91± 0.73	6.66± 0.41	5.90± 0.55
117.16	7.45	9	7.21± 0.63	7.08± 1.02	6.78± 0.70	6.55± 0.45	
400	5.98	10	7.06± 0.73	6.78± 0.63	7.00± 0.61	6.30± 1.99	
400	5.97	11	6.85± 0.63	7.00± 0.70	7.20± 0.57	6.08± 0.86	
400	6.24	12	7.00± 0.76	6.91± 1.36	6.00± 0.95	6.05± 0.11	5.40± 0.82
400	6.01	13	7.07± 0.67	6.91± 1.36	6.71± 0.57	5.75± 1.58	
Average			7.14	7.06	6.84	6.40	5.92

Overall acceptability score (weighted)							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	7.28± 0.55	7.87± 0.88	7.09± 0.53	6.65± 0.40	6.53± 0.62
400	3.9	2	7.28± 0.49	7.24± 0.48	7.28± 0.28	7.01± 0.40	6.69± 0.45
682.84	7.63	3	7.23± 0.60	7.20± 0.56	7.38± 0.35	6.77± 0.55	6.29± 0.87
682.84	4.73	4	7.07± 0.43	7.26± 0.46	7.04± 0.35	7.10± 0.36	6.60± 0.83
0	6.02	5	7.19± 0.48	7.05± 0.69	7.02± 0.33	7.00± 0.45	6.66± 0.82
400	5.95	6	7.12± 0.61	7.27± 0.57	7.22± 0.60	6.48± 0.10	
117.16	4.7	7	7.39± 0.60	7.33± 0.35	7.20± 0.46		
400	8.22	8	7.31± 0.30	7.31± 0.59	7.13± 0.45	6.81± 0.37	6.11± 0.75
117.16	7.45	9	7.06± 0.65	7.34± 0.65	6.63± 0.60	6.31± 0.19	
400	5.98	10	7.10± 0.56	7.06± 0.58	7.24± 0.47	6.66± 1.13	
400	5.97	11	7.07± 0.52	7.16± 0.61	7.33± 0.45	6.58± 0.26	
400	6.24	12	7.23± 0.46	7.31± 0.69	6.62± 0.58	6.58± 0.46	5.70± 0.71
400	6.01	13	7.14± 0.64	7.25± 0.76	6.88± 0.43	6.05± 0.68	
Average			7.19	7.28	7.08	6.67	6.39

LP (scale)							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	55.23	59.98	58.00	60.30	65.00
400	3.9	2	29.57	22.5	34.33	30.23	40.67
682.84	7.63	3	59.64	64.75	43.00	61.16	70.20
682.84	4.73	4	46.62	51.18	52.50	47.30	48.20
0	6.02	5	55.23	60.15	61.42	51.70	53.40
400	5.95	6	52.50	60.87	54.00	50.00	
117.16	4.7	7	45.99	46.70	37.25		
400	8.22	8	49.39	58.33	57.66	54.47	58.33
117.16	7.45	9	49.73	57.5	61.75	63.43	
400	5.98	10	64.05	64.62	55.50	46.53	
400	5.97	11	62.37	62.87	51.00	51.33	
400	6.24	12	46.87	53.66	65.00	60.13	63.33
400	6.01	13	50.9	55.66	50.00	54.66	
Average			51.39	55.29	52.42	52.60	57.02

Visual consistency rating							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	66.78	71.04	53.00	55.81	60.20
400	3.9	2	31.92	38.66	45.33	47.92	48.00
682.84	7.63	3	49.98	60.12	50.50	57.69	63.80
682.84	4.73	4	48.93	51.48	48.57	44.13	39.60
0	6.02	5	59.22	59.14	53.25	50.25	44.40
400	5.95	6	40.53	56.62	52.50	52.55	
117.16	4.7	7	43.05	48.08	45.75		
400	8.22	8	45.69	47.00	50.00	54.45	62.00
117.16	7.45	9	63.84	50.66	81.75	79.36	
400	5.98	10	54.81	59.00	47.00	48.03	
400	5.97	11	55.86	65.00	51.50	59.33	
400	6.24	12	55.44	57.33	62.33	61.66	65.00
400	6.01	13	67.03	60.66	74.25	75.66	
Average			52.54	55.75	55.068	57.24	54.71

Intensity of grain lumping							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	52.92	57.61	45.25	45.05	44.75
400	3.9	2	58.29	43.00	44.66	45.16	44.33
682.84	7.63	3	58.80	57.25	44.00	51.25	58.00
682.84	4.73	4	58.80	60.50	50.50	51.07	53.00
0	6.02	5	76.65	52.26	48.00	49.66	53.00
400	5.95	6	52.92	43.25	34.50	38.80	
117.16	4.7	7	10.50	27.83	13.50		
400	8.22	8	47.77	54.16	56.66	55.55	56.67
117.16	7.45	9	43.4	48.50	58.00	57.75	
400	5.98	10	49.56	53.12	44.00	46.66	
400	5.97	11	44.94	45.87	43.00	44.56	
400	6.24	12	45.08	45.66	52.00	56.43	62.67
400	6.01	13	43.4	58.50	52.00	59.05	
Average			49.46	49.80	45.08	50.08	53.20

Relative amount of grains							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	60.76	64.73	53.9	60.50	61.60
400	3.9	2	38.64	42.66	47.66	46.50	48.33
682.84	7.63	3	47.04	60.50	52.00	55.00	63.00
682.84	4.73	4	40.32	51.80	49.56	45.30	43.40
0	6.02	5	50.96	57.74	53.90	52.80	52.60
400	5.95	6	43.11	58.50	53.50	55.90	
117.16	4.7	7	33.88	48.40	46.00		
400	8.22	8	48.09	46.66	50.00	53.60	61.00
117.16	7.45	9	64.05	51.66	73.25	61.21	
400	5.98	10	48.44	56.33	50.00	58.00	
400	5.97	11	52.08	59.00	51.50	57.30	
400	6.24	12	59.43	53.66	54.33	59.80	66.33
400	6.01	13	65.52	57.00	65.00	63.23	
Average			50.18	54.51	53.89	55.76	56.61

Hardness of grain							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	41.58	32.59	46.65	43.66	50.20
400	3.9	2	54.43	46.00	52.00	53.75	46.00
682.84	7.63	3	46.62	44.00	41.50	42.75	50.80
682.84	4.73	4	46.41	37.17	46.75	46.41	50.00
0	6.02	5	42.21	36.95	44.65	45.16	50.00
400	5.95	6	52.08	48.33	43.00	47.00	
117.16	4.7	7	55.44	40.15	44.75	48.25	
400	8.22	8	50.23	45.00	51.00	49.52	42.67
117.16	7.45	9	43.51	45.00	43.75	45.09	
400	5.98	10	44.73	46.00	41.50	45.00	
400	5.97	11	55.65	51.50	41.50	51.05	
400	6.24	12	44.68	45.00	49.00	48.64	41.67
400	6.01	13	38.81	50.00	44.50	50.00	
Average			47.41	43.60	45.42	47.41	47.33

Intensity of stickiness / slimminess							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	36.54	19.99	20.62	21.16	24.60
400	3.9	2	24.57	27.33	22.33	18.88	13.33
682.84	7.63	3	25.62	34.50	12.00	22.25	26.40
682.84	4.73	4	26.88	17.64	18.62	18.87	20.40
0	6.02	5	32.97	17.86	19.87	20.43	21.00
400	5.95	6	27.93	29.62	12.00	21.43	
117.16	4.7	7	20.58	20.40	16.50		
400	8.22	8	25.41	26.33	23.33	23.83	16.67
117.16	7.45	9	32.13	29.66	22.25	21.00	
400	5.98	10	28.77	32.50	12.00	22.13	
400	5.97	11	24.15	33.12	12.00	17.75	
400	6.24	12	24.99	29.00	25.00	20.62	18.33
400	6.01	13	32.13	30.00	21.25	22.33	
Average			27.90	26.77	18.29	20.89	20.10

Coarseness intensity							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	21.42	37.59	31.40	25.66	29.20
400	3.9	2	28.72	31.33	24.33	31.33	32.50
682.84	7.63	3	32.97	37.00	27.50	31.50	32.20
682.84	4.73	4	23.31	35.67	28.17	26.43	30.80
0	6.02	5	22.05	36.74	28.10	28.44	29.40
400	5.95	6	28.35	40.16	23.00	28.13	
117.16	4.7	7	30.47	62.19	25.75		
400	8.22	8	19.48	27.00	25.66	27.50	33.50
117.16	7.45	9	22.34	26.33	34.50	35.67	
400	5.98	10	24.78	37.00	23.50	24.33	
400	5.97	11	39.69	39.00	22.00	25.05	
400	6.24	12	22.68	25.66	27.33	28.75	35.00
400	6.01	13	22.34	27.66	31.50	32.50	
Average			26.05	35.64	27.13	28.77	31.80

Sweetness intensity							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	50.68	46.6	47.00	50.00	55.6
400	3.9	2	42.84	47.33	47.33	48.13	48.00
682.84	7.63	3	52.08	52.37	47.5	48.33	55.6
682.84	4.73	4	48.44	49.14	47.00	48.50	49.4
0	6.02	5	49.00	48.58	47.00	48.00	49.6
400	5.95	6	52.08	52.37	49.00	50.00	
117.16	4.7	7	52.36	48.01	50.00		
400	8.22	8	48.08	48.66	48.33	48.33	46.00
117.16	7.45	9	47.04	50	50.00	50.00	
400	5.98	10	52.08	51.5	50.00	50.00	
400	5.97	11	52.08	51.5	49.00	49.00	
400	6.24	12	47.04	47.33	45.66	47.33	44.00
400	6.01	13	47.04	50	51.00	50.00	
Average			49.30	49.49	48.37	48.97	49.74

Intensity of staleness							
			Days				
Nisin	F_0	Run	0	15	30	45	60
800	5.95	1	32.97	51.64	58.62	60.23	60.25
400	3.9	2	26.37	38.00	46.66	55.30	60.00
682.84	7.63	3	35.70	54.00	46.50	61.66	62.50
682.84	4.73	4	25.83	38.04	54.15	60.44	62.50
0	6.02	5	32.13	42.95	62.50	61.25	60.75
400	5.95	6	43.68	47.25	53.50	74.88	
117.16	4.7	7	18.27	36.11	45.50		
400	8.22	8	25.20	51.00	56.00	68.13	74.00
117.16	7.45	9	30.40	55.66	57.50	74.50	
400	5.98	10	45.15	58.00	52.50	75.55	
400	5.97	11	47.88	54.5	50.00	70.05	
400	6.24	12	38.13	60.66	68.66	72.88	80.00
400	6.01	13	31.08	59.33	57.50	70.13	
Average			33.30	49.78	54.58	67.08	65.71