Development and Nutritional Evaluation of Wheat and Barley Composite Flour Cookies using Response Surface Methodology

THESIS

Submitted to

Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur

In partial fulfilment of the requirement for the degree of

MASTER OF SCEINCE

In

AGRICULTURE

(FOOD TECHNOLOGY)

By

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2022

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All the assistance and help received during the course of investigation has been duly acknowledged by him.

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Place: Jabalpur

Date: **Ramcharan Patel**

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LIST OF ABBREVIATION

Symbol	Stand for
@	At the rate of
>	More than
<	Less than
±	Plus or minus
%	Percentage
°C	Degree Celsius
CD	Critical difference
Cm	Centimeter
mg	milligram
Ha	Hectare
Hr	Hour
Kg	Kilogram
L	Liter
M	Meter
G	Gram
Max.	Maximum
Min.	Minimum
NS	Non-significant
RH	Relative humidity
SEm	Standard error of mean
Temp.	Temperature
EC	Emulsifiable concentration
et al.	(And other or co-worker)
Fig.	Figure
H.B.F.	Hulless Barley flour
R.W.F.	Refined wheat flour
R.S.M.	Responses surface methodology

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INTRODUCTION

Once considered as sick man's diet, bakery products now have become essential food items of mass consumption popularity with rapid growth and changing eating habits of people. It still remains the cheapest of the processed ready to eat products in the country.

Biscuits and bread are considered to be the major bakery product and they account for 82 per cent of all bakery production. Biscuits/cookies are estimated to enjoy around 37 per cent share by volume and 75 per cent by share by value of the bakery industry. Cookies are very popular among all age groups, especially with children, as it holds a significant place in the baking industry due to variety in taste, texture and aroma. They are cereal based food products that generally contain three major ingredients; fat, flour, sugar; while some ingredients are aerating agents, flavouring agent, salt, and milk (Wade, 1988). Cookies have become one of the popular snack in the present time due to their low manufacturing cost, convenience, long shelf life, good eating quality also its ability to serve as a carrier for important nutrients (Hooda and Jood, 2005).

The word cookie is derived from the Dutch word "koekje" or (informal) "koekie" which means little cake, and arrived in the English language through the Dutch in North America, Cookies are made in a wide variety of styles using an array of ingredients including sugars, spices, chocolate, butter, peanut butter, nuts or dried fruits. The softness of the cookie may depend on how long it is baked (Washeed *et al.*, 2010).

Nowadays people are more concern about high fat – food products and obtain texture and flavour characteristics from the shortening used in the preparation of cookies (Florence *et al*., 2014).

Refined wheat flour which is a key ingredient for preparing cookies is a product of refining that contains higher proportion of starch, low dietary fibre and minerals. It is simply left over from wheat flour which is nutritionally deprived, containing only carbohydrates that provide calories. Growing awareness among the consumers regarding the constituents that affect health both positively and negatively (obesity, diabetes and cardiac

problems) concerns over physical appearance, changing life style and also increasing costs of health care have all contributed to the healthier bakery products. The number of such health conscious consumers is fast increasing and so is the health food industry. Value addition to existing foods with high value ingredients is a simple and feasible way of enhancing nutritional values To mitigate such issue enhancement of the nutritional value of cookies both quantitatively and qualitatively are being done using several nutritious food ingredients with exceptional nutritional qualities because of their nutraceutical and /or nutritional components, such as other cereals, pulses, millets, oil seeds, condiments and novel ingredients. Globally Wheat is cultivated in an area about 220 million hectares with a record production of 763.06 million tonnes of grain. Maximum area under wheat is in India 14%, followed by Russia 12.43%, China 11.14% and USA 6.90% which altogether accounts for about 45% of global area. While total area of wheat was 31,125 thousand hectare, production was 1,09,590 thousand metric tons and yield was 3.5 metric tons per hectare (according the year 2021-22).

Barley (*Hordeum vulgare L.*) is one such cereal which has greater nutrition value. It has both winter and spring, hulled and hulless, and two-row and six-row varieties. It contains starch (65-68%), proteins (10-17%), β-glucan (4-9%), fats (2-3%) and minerals (1.5-2.5%) (Wang *et al.,* 2015). Barley is grown in about 70 million hectares in the world. Global production is 160 million tons. Developing countries account for above 18% (26 million tons) of total barley production and 25% (18.5 million hectares) of the total harvested area in the world. In India total area of barley was 593 thousand hectares, production was 1666 thousand metric tons and productivity 2.8 metric tons per hectare (according the year 2021-22). Hulless barley *(Hordeum vulgare L.var nudum Hook. f.)* forms had a higher content of β-glucan, as well as a higher content of soluble dietary fibres than hulled forms (Fastnaught *et al.,* 1996). Therefore, need arises for replacing part of refined wheat flour with flour of hulless barley to encourage trends in consumption of bakery products by population of lower and middle income groups.

Hence present study “Development and Nutritional Evaluation of Wheat and Barley Composite Flour Cookies using Response Surface Methodology” is proposed with following objectives:

OBJECTIVES:

1. To optimize level of different ingredients of cookies, using response surface methodology (RSM) technique.
2. To study physical properties and sensory characteristics of developed cookies, using different levels of Refined Wheat flour, Hulless Barley Flour, Guar gum powder and Ammonium bicarbonate as per the formulation.
3. To develop the models for various significant physical and sensory characteristics of cookies.

REVIEW OF LITERATURE

Barley flour has several medicinal properties some of which are preventing dietary and constipation problem that are well documented. Barley flour fortified food products can be considered as a functional and healthful food. As barley flour compares quite favourably and nutritionally with wheat flour thus, in present investigation, attempts have been made to explore the possibility of utilizing it in developing cookies, as a partial substitute to wheat flour. Literature pertinent to the present study has been reviewed under the following heads and sub-heads

2.1 Physico-chemical properties of Wheat-Barley composite flour

2.2 Development of cookies:

2.3 Physical properties of hulless barley flour cookies

2.3.1 Diameter

2.3.2 Thickness

2.3.3 Spread Ratio (D/T)

2.3.4 Weight

2.4 Sensory characteristics of developed cookies

2.5 Proximate composition of hulless barley flour cookies

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2.5.2 Protein

2.5.3 Fat

2.5.4 Ash

2.5.5 Fiber

2.5.6 Carbohydrate

2.5.7 Energy

2.5.8 Sugar content

2.6 Hunter colour values of hulless barley flour cookies

2.1 Physico-chemical properties of Wheat-Barley composite flour

According to Holtekjolen *et al.,* (2008) the addition of barley to breads boosted the antioxidant qualities of the breads when compared to the control bread. During the baking process, the amount of free phenolics (TPC-S) reduced while the amount of bound phenolics grew (TPC-IS). The researchers discovered that using barley in breads offers health benefits. This, however, will be highly dependent on the barley variety.

Inglett *et al.,* (2013) found that under heat and shear, the barley-flaxseed composites were more structurally stable. Barley-flaxseed composites offer better water holding capabilities, texture, and beneficial pasting and viscoelastic characteristics, in addition to their nutritional benefits.

Hruskova *et al.,* (2015) Reported that Barley flour supplementation modified the wheat SRC profile and rheological behaviour in accordance with addition levels, as expected, and significantly improved its cookie forming capacity.

Svec *et al.,* (2016) investigated the behaviour of starch in wheat-barley composite flours and discovered that barley flour increased amylograph viscosity in a wheat-barley flour premix (790 units in wheat-barley mixture vs. 680 units for control). The specific volume of composite bread was dramatically lowered when barley flour and chia whole meal were used.

According to Ahmad *et al.,* (2018) after bread fortification, higher moisture content and lesser hardness were noted, with the influence being more pronounced with the defatted cake than with seed powder.

Aly *et al.,* (2021) reported that blending with whole barley flour (WBF) resulted in an increase in protein, ash, and crude fibre content, even at a low inclusion ratio (20%). Water absorption, dough formation, and arrival time all increased as the WBF ratio climbed. The dough's stability was improved by using a lower percentage of WBF (20%). The dough energy, expansion, and expansibility rheology were all reduced as the WBF ratio was increased. WBF-wheat biscuits received a high acceptance rating up to a replacement

ratio of 40%, but the higher level (40%) resulted in lower surface colour and attractiveness scores.

2.2 Development of cookies:

According to Olewnik and Kulp (1984) Cookies dough is composed of four main components, 1. flour, 2. fat, 3. sugar and 4. water changing the amounts of these ingredients can result in a variety of shapes and textures 2.5.1 Ingredients used in preparation of cookies.

Akinwande *et al*., (2008) developed cookies with the major ingredients are flour, fat, sugar, salt and water. These are mixed together with other minor ingredients (baking powder, skimmed milk, emulsifier and sodium meta-bisulphite) to form dough containing a gluten network.

Narwal *et al.,* (2017) made first effort to utilize a hulless barley genotype (BHS 352) for mixing with the wheat flour (C 306 & HS 490) and making mixed chapatti and cookies.

2.3 Physical properties of hulless barley flour cookies

2.3.1 Diameter

Gernah *et al.,* (2010) reported that the amount of fat added to the flour blends during production. An increasing trend for the diameter (38.90–40.20 mm) of cookies made from wheat brewers spent grain flour blends.

Okpala *et al.,* (2012) the cookies diameters ranged from 5 to 5.53 cm. A circle's diameter is defined as the circumference of a circle going through its centre and touching both of its edges.

Abdul *et al.,* (2015) reported a decrease in diameter for cookies with increasing substitution level of oat bran.

2.3.2 Thickness

Hussain *et al.,* (2006) supplemented flaxseed flour from 5 to 30% which significantly affected the physical parameter of the cookies. The Physical properties viz., thickness and diameter of cookies increased (from 4.43 to 6.10 cm and 26.03 to 29.10 cm, respectively) while spread factor decreased (from 58.73 to 47.71) with flaxseed supplementation. The

increased incorporation adversely affected colour and crispness, but flavour and texture were affected very less. Cookies developed with 20 per cent flaxseeds were highly acceptable.

It is reported by Abdul *et al.,* (2015) Increase in thickness could be due to the high adsorption of moisture of the dough with increase in malted barley bran level, owing to the presence of water binding components. Moreover, it could also be attributed to the inconsistent rolling thickness of the dough which was exhibited as a result of the addition of high fat content.

2.3.3 Spread Ratio (D/T)

Sindhuja *et al.,* (2005) reported that incorporation of amaranth millet flour in cookies from 0 to 30% significantly altered the cookie qualities. It reduced the spread ratio and breaking strength from 7.82 to 6.50, and 4.94 to 3.39 kg respectively while increased the thickness from 10.9 to 11.5 mm. However addition of lecithin (0.25%) and glycerol monostereate (0.25%) resulted in significantly increased the cookies spread (8.49) and decreased the breaking strength (3.81 kg). Incorporation of amaranth millet flour was reported to yield golden brown cookies which were malty and sweet flavoured.

Giwa and Abiodun, (2010) observed the addition of MBB caused a significant ($p < 0.05$) increase in the spread ratio of the cookies with increasing level of substitution from 0 to 50%. They also reported that the spread ratio of cookie samples increased with increasing substitution level with quality protein maize.

Chugh *et al.,* (2013) used carbohydrate-based fat replacers in their trials to make low-fat soft dough biscuits (maltodextrin and guar gum). When the amount of sugar was increased, the diameter (P 0.01) and stress-strain ratio (P 0.05) both reduced significantly. At high water levels, the spread ratio decreased significantly (P 0.01). The interactions of ammonium bicarbonate with sugar (P 0.05) and fat (P 0.1) had a substantial impact on hardness.

Abdul *et al.,* (2015) reported decreased spread ratios for cookies with increasing oat bran incorporation

2.3.4 Weight

Ayo *et al.,* (2007) found the significant reduction in the weight of cookies produced from soya bean supplemented with wheat flour.

2.4 Sensory Characteristics of developed cookies

Inglett *et al.,* (1994) investigated the sensory features of cookies and sweets when oat rim is substituted for fat. Shortening was replaced with oat rim gel at 50, 75, and 100 percent in oatmeal raisin cookies. A sensory panel of 20 people assessed the cookies. The flavour and texture attributes of the 50 percent substitution cookie were not substantially different (P > 0.05) from the control cookie, although variations were noticed at 75 and 100 percent substitution levels. At the 50% level, substituting oat rim gel for whipped cream in reduced-fat truffle centres resulted in no significant changes in flavour intensities compared to the control. When compared to the control, there was a substantial (P0.05) drop in the creamy buttery flavour at a 100 percent level of substitution.

Tsuji *et al.,* (2001) observed that darker colour of cookies may be due to the non-enzymatic reaction (Maillard reaction) between reducing sugar molecules and lysine protein. Also Sudha *et al.,* (2007**)** stated that darker colours are generally associated with enriched high fibre biscuits.

Hussain *et al.,* (2006) conducted to prepare the cookies from the composite flours with supplemented full fat flaxseed flour with wheat flour by 5, 10, 15, 20, 25 and 30%. Cookies prepared without flaxseed flour were kept as control. The mean quality score of the cookies decreased with the increase in the level of the flaxseed flour supplementation. Colour and crispiness of the cookies showed a declining trend as compared to flavour and texture of cookies. Cookies containing 20% and lower level of the full fat flaxseed flour were acceptable in relation to their overall acceptability. Significant reduction in the spread factor of the cookies was observed. Addition of the flaxseed flour restricted the spread of the cookies.

Shukla *et al.*, (2012) received a sensory score of 6.25 to 8.70 for colour, 6.23 to 8.70 for taste, and 6.25 to 8.70 for appearance. Sucralose and baking materials exhibited a substantial linear and quadratic effect on

biscuit and cake reactions. The taste and OAA reaction of the biscuit and cake were also affected by ingredient interactions. Sucralose 2.5 g, fat 14 g, baking powder 0.65 g, and water 12-13 ml were shown to be the best combinations. Only 25% of sugar can be replaced with sucralose in eggless cake compositions among the varied levels of sucralose (0, 12, 25, 50, 75, and 100%).

Vaijapurkar *et al.,* (2013) investigated when bajra flour was added, the texture of the biscuits changed significantly, according to the analysis of variance. The texture of the biscuits received a lower quality score as the amount of bajra flour used increased.

2.5 Proximate composition of barley flour cookies

2.5.1 Moisture

Ayo *et al.,* (2007) reported that the moisture content of the cookies was low enough (<10%) to reduce the chances of spoilage by micro-organisms and consequently guarantee good storage stability.

Gernah *et al.,* (2010) reported higher moisture content (5.20–9.30%) for cookies made from wheat-brewers spent grain flour blends.

According to Adebowale *et al.,* (2012) baked foods cake, cookies and bread with high moisture content encourages bacterial, yeast and mould growth that could lead to spoilage. However, cookies should therefore have low moisture for safe storage and inhibition of microbial growth that could affect their quality.

Thongram *et al.,* (2016) reported that moisture content of the cookies made from flour blends ranged from 6.2-10.6%. The results of the moisture content showed that there was a significant difference ($p < 0.05$) between cookies made from legume flour blends and wheat flour. High moisture content can signify short shelf life of the cookies where microbial spoilage can occur due to the presence of moisture.

2.5.2 Protein

Olaoye *et al.,* (2006) also observed an increase in the protein content with corresponding increase in the proportion of soy flour supplementation in bread produced from composite flour of wheat, plantain and soybean.

The findings conformed with the report of Omeire and Ohambele, (2010) for the increasing trend of protein content (8.54–17.72%) in cookies produced from wheat-defatted cashew nut flour blends, but lower than the protein content (10.62–28.12%) of cookies made from wheat-brewers spent grain (Gernah *et al.,* 2010).

Satinder *et al.,* (2011) observed increase could be attributed to the significant quantity of protein (12.5%) in barley bran.

The findings agreed with Adebowale *et al.,* (2012) report who observed an increased trend in the protein content (7.06–11.84%) of cookies made from sorghum-wheat flour blends.

2.5.3 Fat

Ihekoronye and Ngoddy, (1985) researched that the presence of high fat content in the cookies means high calorific value and also serves as a lubricating agent that improves the quality of the product, in terms of flavour and texture. In addition, fat is a rich source of energy and is essential as carriers of fat soluble vitamins; A, D, E and K. However, high levels of fat in food products should be < 25%, since this could lead to rancidity in foods and development of unpleasant and odorous compounds.

Omeire *et al.,* (2010) on their reports for the increasing trend in the fat content of the cookies produced from wheat-defatted cashew nut and wheat-brewers spent grain (2.52–4.80%) flour blends respectively.

2.5.4 Ash

Sanni *et al.,* (2008) added high ash content indicates high levels of minerals in the composite cookie samples. This suggests that cookies from the composite flour blends will provide more minerals to the consumers than the reference sample.

Omeire and Ohambele, (2010) observed a trend of increasing ash content (1.65–2.20%) in cookies produced from wheat defatted cashew nut flours.

Gernah *et al.,* (2010) also reported that cookies produced from wheat-brewers spent grain flour blends had high ash content (1.85–2.89%).

Thongram *et al.,* (2016) reported that the ash content of the cookies made from flour blends ranged from 1.16 - 3.66%. The results of ash content showed that there was a significant difference between cookies made from flour blends and wheat flour. The ash content is the amount of inorganic minerals present in a particular food or sample.

2.5.5 Fiber

Gernah *et al.*, (2010) observed for the increasing trend in the crude fiber (1.32–10.82%) contents of cookies made from wheat-brewers spent grain flour blends.

Omeire and Ohambele, (2010) reported In contrast, the result was higher than the crude fiber (1.05– 1.65%) of cookies produced from wheat defatted cashew nut flour blends.

Satinder *et al.,* (2011) reported that the presence of high fiber in food products is essential owing to its ability to facilitate bowel movement (peristalsis), bulk addition to food and prevention of many gastrointestinal diseases in man. Also found the increasing trend in the crude fibre content of the cookies upon substitution with malted barley bran flour could be a reflection of its composition that is reported to be 13.9%.

2.5.6 Carbohydrate

Gernah *et al.,* (2010) and Joel *et al., (*2014) reported a decreasing trend in the carbohydrate contents (73.46– 46.20%) and (70.45–23.71%) of cookies made from wheat-brewers spent grain flour blends and whole wheat- full fat soya flour blend.

Elleuch *et al.,* (2011) found that the low carbohydrate content and increased fibre content of the composite cookies have several health

benefits, as it aids digestion in the colon and reduces constipation often associated with products from refined grain flour.

2.5.7 Energy

Giwa and Ikujenlola, (2010) found a decreasing trend in the energy value (443.89–431.95 kcal) for cookies made from wheat and quality protein maize. The mixture's protein, fat, and carbohydrate components each added to the energy content of the cookies. Both young and old devour cookies, a stimulating item, primarily between meals. Malted barley bran could be added to cookies to increase their protein and fiber content.

Changmei and Dorothy, (2014) studied about cookies and biscuits prepared from foxtail millet and pearl millet. They reported that fiber content was found to be higher in biscuit and energy content was increased with the addition of every 10g of pearl millet in biscuit. In case of foxtail millet biscuits and cookies protein, CHO and iron content was increased with the addition of every 20g and 30g of foxtail millet.

2.5.8 Sugar content

Yamazaki, (1971) discovered that cookie dough are frequently blended by distributing fat through the flour and sugar to form a cohesive mass.

Sahanot, (1981) reported that Sucrose functions as a hardening agent, crystallising as the cookies cool and resulting in a crisp product. However, water retention necessitates a moderate amount of sugar.

Abboud and Hoseney, (1984) found when granular sucrose is used in cookie dough, part of it dissolves during the mixing process and the remaining dissolves during the baking process.

Abboud *et al.,* (1985) reported that except at the coarsest size (> 35 mesh), sugar particle size had no effect on cookie spread.

2.6 Hunter Colour Values of Hulless Barley Flour Cookies

Onishi M (2011) studied surface colour is one of the important characteristics of baked products and is considered as a critical index for judging baking quality. Baked products develop colour in the later stages of baking, simultaneously with crust formation and occur through chemical processes including the Maillard reaction and sugar caramelization.

Malik *et al.,* (2015) reported that the colour analysis showed certain change in L*, a* and b* values. More the fibre content was introduced in the samples, more the brown colour appeared. Multigrain breads were developed by replacing wheat flour by 5.10, 15, 20 and 30% of oat, barley, maize and rice flours while 1% flax seeds were added in bread to increase its pharmaceutical value.

MATERIALS AND METHODS

This chapter includes a variety of experimental procedures, materials, and approaches for **"Development and Nutritional Evaluation of Wheat and Barley Composite Flour Cookies using Response Surface Methodology".** During the years 2021-2022, the experiment has been done in the Department of Food Science and Technology, College of Agriculture, Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur. The raw materials acquired for the product development and methodologies for analyzing raw materials, preparing cookies, and evaluating their quality are listed under the headings below.

3.1 Experimental Material

3.1.1 Procurement of raw materials

Hulless barley was purchased from market nimadganj mandi, near kamaniya gate, Jabalpur, Madhya Pradesh, whereas, refined wheat flour, sugar and other ingredients was purchased from local market of Jabalpur, Madhya Pradesh. Analytical grade chemicals were purchased online from Amazon shopping app. The materials like Vanaspati/ghee, was procured from bakery unit, Dept of Food Science and Technology, JNKVV, Jabalpur and were used for preparation of cookies. The potable water in the department was used to mix several mixes of wheat-barley flour and other materials for cookies development. The prepared cookies were packaged in High Density Polyethylene bags. These were purchased from M/s Satyam plastics, Jabalpur. All the chemicals used in present investigation were of standard analytical grades from BDH (India), E-Merck and Sarabhai, M. Company. The glassware's used in the present investigation were from Qualigens and Borosil Company.

3.1.2 Equipment and machineries

The Department of Food Science and Technology JNKVV Jabalpur (MP) had all of the necessary equipment and machinery for product preparation and analysis. The following are the tools and machines that were utilised to conduct the experiment:

Table 3.1: Following machines and equipments were used in the research work

S. No.	Name of equipments/ machine	Purpose	Source of Supply
1.	Electronic Weighing Balance	To measure the accurate quantity of raw materials, baking ingredients, chemicals and developed cookies.	M/S Supreti Traders Shop No 6 Methodist Center,Opp. Kartik Hotel Napier Town,Jabalpur (MP)
2.	Spiral Dough Mixer	To mix all the ingredients uniformly to form cohesive dough mass.	M/S Tajshree Bakery Machinery, Durga Nagar, Manewada Road, Nagpur
3.	Cookies Dropping Machine	For development of cookies.	F-4,5 & O-1, U.P.S.I.D.C. Industrial Area, Begrajpur, Muzaffarnagar-251203, UP, India
4.	Rotary Baking Oven	For baking of the cookies.	M/s HCS Enterprises Plot No 273, HSIIDC RAI Industrial Estate Sonipat, Haryana
5.	Hot air oven	For determination of moisture content of the samples	M/S J.K. Sales & Promoters Gole Bazaar, Write Town, Jabalpur (M.P.)
6.	Muffle furnace	For the determination of ash content of flour, and cookies.	M/S J.K. Sales & Promoters Gole Bazaar, Write Town, Jabalpur (M.P.)
7.	Continuous band packaging machine	For storage study the packaging of HDPE, aluminium silver pouches of developed cookies.	M/S Supreti Traders Shop No 6 Methodist Center, OppKartik Hotel Napier Town, Jabalpur
8.	Micro-Kjeldahl Unit	For the determination of protein content of samples viz. flour and cookies..	M/s Pelican Equipments, 2ndFloor, 38 Burket T Nagar, Chennai
9.	Socs Plus, Fat Analyzer	For the determination of fat content of samples viz. flour and cookies.	M/s Pelican Equipments, 2ndFloor, 38 Burket T Nagar, Chennai
10.	Fiber Plus	For the determination of crude fiber content of samples viz. flour and cookies.	M/s Pelican Equipments, 2ndFloor, 38 Burket T Nagar, Chennai
11.	Hunter Colour Lab (colour flex)	Used for the determination the colour of cookies.	I R Technology Services Pvt Ltd B 8 Commerce Center 78 Tardeo road Mumbai

3.2 Experimental site, geographical situation and climatic condition

The experiment was carried out in the Department of Food Science and Technology, JNKVV, Jabalpur's Cereal Science lab (Processing hall-2), Crop Quality Lab, and Sensory Evaluation lab (MP). At a height of 411.78 meters above mean sea level. Jabalpur is located at 23' 90" N longitude and 79' 58"E longitude; It experiences subtropical climatic conditions, with hot, dry summers and chilly, dry winters. The area's 10-year mean annual rainfall is 1284 mm, with roughly 90 percent of the total annual rainfall falling between the end of June and the end of September. Within a year, the maximum and minimum temperatures range from 24°C to 45°C and 4°C to 32°C, respectively. In certain years, maximum temperatures exceed 45°C in May or June, while minimum temperatures drop to a minimum of 4°C in late December or early January. The relative humidity fluctuated from season to season. Throughout the rainy season, it varies from 80 to 90 percent, but during the winter and summer seasons, it drops to 60 to 70 and 30 to 40 percent, respectively.

3.3 Methodology

3.3.1 Preparation of Cookie (Sabeeha Yaqoob *et al.,* 2017)

(Recipe for making of Cookies from refined wheat flour (control sample)

The cookies were prepared using following ingredients as per the traditional creaming process outlined in Table given below:

Table 3.2: The cookies were prepared using following ingredients and its quantity

S.No.	Ingredients	Quantity
1.	Refined Wheat flour (g)	100
2.	Sugar (g)	50
3.	Shortening (g)	40
4.	Ammonium bicarbonate (g)	1
5.	Guar gum powder (g)	3
6.	Water (ml)	20

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Preparation of Ingredients (Weighing and Recipe calculation)

↓

Hydrogenated vegetable fat and powdered sugar mixed thoroughly in Mixture (5-8 min)

↓

Wheat flour + Hulless Barley flour (Mixed both the blends)

↓

Add Guar gum powder + ammonium bicarbonate
Mix Properly

↓

Dough forming with the addition of water and salt

↓

Put the dough in cookies dropper machine

↓

Developed cookies in tray

↓

Baking at 175ºC for 20 minute

↓

Cooling and Packaging

↓

Storage

Flow chart for preparation of hulless barley flour cookies

3.4 Experimental Design

The prime objective of study was to replace wheat flour with barley flour. There was also need of varying the proportion of other ingredients included in The ranges of variables were selected taking into consideration the maximum and minimum values used for control samples of preparation. Responses surface methodology (Mayer's, 1976) was used to reduce the number of experiments, without affecting the accuracy of result. The experiment was planned in central composite rotatable the formulation for getting optimum quality of product. Thus, based on information available in the literature, four variables viz., wheat flour, hulless barley flour, sugar, guar gum powder and ammonium bicarbonate were selected for development of the formulation. Design with half replicate which consisted of 30 experiments. First 16 experiments in first order part, 8 experiments in second order part and next 6 experiments were at central point or replication (Table 3.3 and 3.4).

Table 3.3 Experimental variables their coded and un-coded (actual) values for production of wheat and barley composite flour cookies

S. No.	Variables	Unit	Code	Coded Levels				
				-2	-1	0	+1	+2
1.	RWF:HBF	g	A	15	30	45	60	75
2.	Sugar	g	B	25	30	35	40	45
3.	Guar Gum	g	C	1.5	2.5	3.5	4.5	5.5
4.	Ammonium bicarbonate	g	D	2.5	3.0	3.5	4.0	4.5

a: ±values, b: centre point, RWF – Refined Wheat flour, HBF – Hulless Barley flour

Table 3.4 Experimental design matrix for production of Wheat-Barley composite flour cookies

Coded Form					Un-Coded Form			
Expt. No.	A	B	C	D	RBF:HBF (g) A	Sugar (g) B	Guar gum (g) C	Ammonium bicarbonate (g) D
First Order Interaction								
1.	-1	-1	-1	-1	30	30	2.5	3
2.	1	-1	-1	-1	60	30	2.5	3
3.	-1	1	-1	-1	30	40	2.5	3
4.	1	1	-1	-1	60	40	2.5	3
5.	-1	-1	1	-1	30	30	4.5	3
6.	1	-1	1	-1	60	30	4.5	3
7.	-1	1	1	-1	30	40	4.5	3
8.	1	1	1	-1	60	40	4.5	3
9.	-1	-1	-1	1	30	30	2.5	4
10.	1	-1	-1	1	60	30	2.5	4
11.	-1	1	-1	1	30	40	2.5	4
12.	1	1	-1	1	60	40	2.5	4
13.	-1	-1	1	1	30	30	4.5	4
14.	1	-1	1	1	60	30	4.5	4
15.	-1	1	1	1	30	40	4.5	4
16.	1	1	1	1	60	40	4.5	4

Coded Form					Un-Coded Form			
Expt. No.	A	B	C	D	RBF:HBF (g) A	Sugar (g) B	Guar gum (g) C	Ammonium bicarbonate (g) D
Second Order Interaction								
17.	-2	0	0	0	15	35	3.5	3.5
18.	2	0	0	0	75	35	3.5	3.5
19.	0	-2	0	0	45	25	3.5	3.5
20.	0	2	0	0	45	45	3.5	3.5
21.	0	0	-2	0	45	35	1.5	3.5
22.	0	0	2	0	45	35	5.5	3.5
23.	0	0	0	-2	45	35	3.5	2.5
24.	0	0	0	2	45	35	3.5	4.5
Centre Point								
25.	0	0	0	0	45	35	3.5	3.5
26.	0	0	0	0	45	35	3.5	3.5
27.	0	0	0	0	45	35	3.5	3.5
28.	0	0	0	0	45	35	3.5	3.5
29.	0	0	0	0	45	35	3.5	3.5
30.	0	0	0	0	45	35	3.5	3.5

3.5 Physical properties of developed cookies

Physical parameters such as weight, diameter, thickness and spread ratio were determined using A.A.C.C. (2000). All parameters were determined in five replications.

3.5.1 Diameter

Measured by vernier caliper and expressed in mm or diameter of cookies was measured by laying six cookies edge to edge with the help of a scale rotating them 90° and again measuring the diameter of six cookies (mm) and then taking average value.

3.5.2 Thickness

Measured by screw gauge and expressed in mm or thickness was measured by stacking six cookies on top of each other and taking average thickness (mm).

3.5.3 Spread ratio (D/T)

Spread ratio was calculated by dividing the average value of diameter by average value of thickness of cookies.

3.5.4 Weight

Weight of cookies was determined by using weighing balance and expressed in g. as average.

3.6 Sensory evaluation of developed cookies

3.6.1 Measurement of colour and appearance

The colour scanning machine (Model: Colour Flex EZ) was used for measurement of colour of crust and crumb of cookies. The colour was measured by using CIELAB (1976/D65) scale at 10 observers at D65 illuminate. The instrument was calibrated before placing the sample by placing black tile and white tile provided with the instrument. Once the instrument was standardized, it was ready to measure the colour of crust and crumb of cookies. It can also be crosschecked by placing the white tile which was provided for the L*, a*, b*, C* and H*values. The cookie was placed in sample cup. The deviation of the colour of the sample to standard was also observed and recorded in the computer interface. It provides readings in terms of L*, a*, b*, C* and H* where, L* indicate darker, a* indicate green, b* indicate yellow, C* indicate brighter and H* indicate hue.

3.6.2 Textural analysis of cookies

The cookies were analyzed for its penetration and cutting force using Texture analyzer (INSTRON). Penetration and cutting force max of the cookies were measured by triple beam 40 snap setup (Gaines, 1985). Load cell of 5 kg, 3 mm/s test speed and 5 mm travel distance were used. The sample was placed on two supporting beams a parted by 3 cm distance. The probe, TA-9 was programmed to travel a distance of 5 mm with a speed of 2 mm/sec with a normal cycle. Another beam connected to moving part was brought down to break down the cookies. Five samples from each type of cookies, fresh and stored were analyzed at 30 days interval (for 90 days). Mean value of three determinations was reported.

3.6.3 Taste of developed cookies

A semi trained panel of 10 members was given samples of barley flour Cookies to evaluate the following sensory quality attributes viz., colour, taste, flavour, texture and overall acceptability score. A 9-point Hedonic scale (Appendix-I) was used as described in AACC (1967). The data were statistically analyzed by standard procedure as described by Meilgaard *et al.,* (2007).

3.7 Chemical properties of refined wheat flour and hulless barley flour cookies.

3.7.1 Moisture

The moisture content in the sample was estimated according to the method of AOAC (1998). The sample (5g) was taken in pre-weighed moisture box, dried at 105ºC for 24hr in hot air oven, cooled in desiccators and weighed. The difference in weight of moisture box represents the moisture content of the sample.

Calculation

$$\text{Moisture \%} = \frac{\text{Difference in weight}}{\text{Weight of sample}} \times 100$$

3.7.2 Protein

The protein content in sample was determined by using conventional micro-Kjeldahl digestion and distillation procedure as given in AOAC (1998).

Reagents:

1. Catalyst mixture- A mixture of 100g K_2SO_4, 20g of $CuSO_4$ and 2.5g of SiO_2.
2. Sodium hydroxide solution: 40% (w/v).
3. Boric acid solution: 2% (w/v).
4. Concentrated sulphuric acid AR (sp. gr. 1.81)
5. Mixed indicator: 2 parts of 0.2% (w/v) methyl red and 1 part of 0.2% (w/v) methyl blue in absolute alcohol
6. Standard Hydrochloric Acid (0.1N).

Procedure

The sample (2g) was weighed accurately and transferred to a Kjeldahl flask taking care to see that the material did not stick to the neck of the flask. The catalyst mixture of about 2 g and concentrated sulphuric acid (10ml) were added. Then the flask was heated in an inclined position in digestion chamber for about 4-6 hr. till the liquid became clear (green blue colour).

Distillation

The content in the flask were allowed to cool and the digested material was transferred quantitatively to a vacuum jacketed flask of micro Kjeldahl distillation apparatus and the ammonia liberated by the addition of 25ml of 40%NaOH on heating was absorbed in 25ml of boric acid containing 2-3 drops of mixed indicator in 100 ml conical flask. The distilled off ammonia was titrated against 0.1N sulphuric acid. The blank was also run in a similar way.

Calculation

$$\text{Nitrogen (\%)} = \frac{\text{N of } H_2SO_4 \text{x Vol. of 0.1N } H_2SO_4 \text{ x 14}}{\text{Weight of sample x 1000}} \text{ x 100}$$

Crude Protein (%) = N % x 6.25/5.83

3.7.3 Fat

The fat content of the sample was determined by the procedure as described in AOAC (1998). The sample (5g) was weighed accurately, placed in thimble and plugged with cotton. The extractor-containing thimble was placed over a pre-weighed extraction flask (A). Fat content was determined by extracting the sample with solvent petroleum ether (AR grade 60-80°C) for 8hr using Soxhlet's extraction procedure. After extraction the excess of solvent was distilled off and the residual solvent was removed by heating at 80ºC in oven for 4-6 hr. the flask was weighted (B) and the fat content was determined as below:

Calculation

$$\text{Crude fat (\%)} = \frac{\text{Wt. of flask (B) – Wt. of flask (A)}}{\text{Weight of sample}} \text{ x 100}$$

3.7.4 Ash

The ash content in the sample was determined by procedure as describe in AOAC (1998). The sample (5g) was placed in pre-weighed crucible. It was burned on gas flame until it was completely charred. The samples were then placed in muffle furnace for combustion at 520°C for 5hr; thereafter samples were cooled in desiccators and weighed. The heating in muffle furnace was repeated until constant weight was obtained. The ash content was calculated as under.

Calculation

$$\text{Ash (\%)} = \frac{\text{(Initial wt of empty crucible and sample)} - \text{(Final wt of crucible with ash)}}{\text{Weight of sample}} \times 100$$

3.7.5 Crude fibre

The crude fibre was determined by the method as described in AOAC (1998).

Reagents

1. Sulphuric acid 0.255 N
2. Sodium hydroxide 0.313N

Procedure

Dry defatted sample (2g) was transferred in to 500ml conical flask to which 200ml of 0.255 N boiling sulphuric acid was added, and then it was boiled for 30 min., kept the volume constant by the addition of water at frequent intervals. The mixture was cooled and filtered through a muslin cloth and the residue was washed with hot water till it was free from acid. The material was then transferred to the same beaker and 200ml of boiling 0.313 N NaOH was added. After boiling for 30 min. the mixture was cooled and again filtered through muslin cloth. The residue was washed with water till it get free from alkali, followed by washing with absolute alcohol and ether to remove the moisture and residue fat. It was then transferred to a weighed crucible and kept in oven at 100°C for 4-6 hr. The crucible was cooled and

weighed. The difference in weight represents the crude fibre content in samples.

$$\text{Crude Fibre (\%)} = \frac{\text{Diff. in wt. of crucible}}{\text{Weight of sample}} \times 100$$

3.7.6 Carbohydrates

The content of carbohydrate in the selected samples were obtained by subtracting from 100, the sum of values of moisture, protein, fat and ash content per 100 g of the sample (Raghuramulu *et al.,* 1993).

Carbohydrate = 100 - (Moisture + Protein + Fat + Ash).

3.7.7 Energy

Food energy value (kcal/100 g) was determined according to the method of Marero *et al.*, (1998) using the factor (4 × %Protein) + (4 × %Carbohydrate) + (9 × %Fat).

3.7.8 Reducing sugar and Total sugar

Reducing sugar and Total sugar was estimate by Shaffer – Somogyi micro method as described in Rangana (1986).

Reagents

a. Copper sulphate solution: 100g ($CuSO_4 + 5H_2O$)

b. 0.1N Potassium iodate solution: 3.567g of (KIO_3)

c. Shaffer-Somogyi carbonate reagent: 25g anhydrous sodium carbonate (Na_2CO_3), Rochelle salt (potassium sodium tartrate), add with stirring 75ml of copper sulphate solution and 20g sodium bicarbonate. 250ml of 0.1N KIO_3 solution. Iodide – potassium oxalate solution: 2.5g potassium iodide (KI) and potassium oxalate ($K_2C_2O_4$).

d. Thiosulphate standard solution

e. 2 N Sulphuric acid solution

Preparation of sample

Weigh 2.5 – 5.0 g of sample, transfer to a 250ml beaker. Add about 50 ml of water, heat to boil, cool and transfer to a 250 ml volumetric flask. Add lead acetate solution, shake and let stand for 10 min. precipitate the excess of lead using necessary amount of potassium oxalate solution (22% in water). Make up to volume with water and filter.

Procedure

Reducing sugar: Pipette 5ml solution containing 0.5 – 5.5 mg dextrose into 25 × 200 mm test tube. Add 5ml of the Shaffer – Somogyi reagent and mix well by swirling. Prepare the blank using 5ml of water and 5ml of Shaffer – Smoggy reagent. Place the tubes, capped with funnels, in a boiling water bath for 15 min. Remove the tubes carefully without disturbing and cool in running water for 4 min. Remove the funnel and add down the side of each tube, 2ml of iodide-oxalate solution and then 3ml 2N H_2SO_4. Do not agitate the solution. Mix thoroughly to ensure that all cuprous oxide is dissolved and let these stand in cold water bath for 2 min mixing twice during that time. Titrate with 0.005 N thiosulphate solution using starch as indicator.

Total sugar: To 25 ml of the filtrate in a 50 ml volumetric flask, add 5.0 ml of HCL (1+1). Allow to stand for 24 hr at room temperature. Neutralize exactly with sodium hydroxide and make up to volume with water. Take an aliquot and determine the total invert, sugar as in reducing sugar.

Calculation

$$\text{Reducing Sugar \%} = \frac{\text{mg of dextrose x vol. made up x 100}}{\text{5 x Wt. of sample taken x 1000}}$$

Statistical analysis

The data obtained from each experiment were processed on Dell i3 processor Laptop using Design Expert 11 statistical software. Response surface graphs of selected response were developed to study the effect of independent variables and to optimize the levels of ingredients. The findings of experiments are presented in subsequent chapter.

RESULT

The present investigation entitled “Development and Nutritional Evaluation of Wheat and Barley Composite Flour Cookies using Response Surface Methodology” was carried out in the Department of Food Science and Technology JNKVV, Jabalpur, (M.P.). During present research work, physic-chemical properties and proximate composition of hull-less barley were investigated. The result looks into the potential of combinations using refined wheat flour and hull-less barley flour in the production of cookies. This chapter summarises the results of the conducting experiments.

Response Surface Methodology (RSM) was used to determine the effect of independent variables on certain prominent responses, such as physical qualities, proximate composition and sensory characteristics of developed hull-less barley cookies. The central composite design of response surface methodology was used in this work to design a statistical model and to determine the optimal level of components for developing cookies. The impacts of the ingredients such as composite flour, shortening, sugar, guar-gum powder and ammonium bi-carbonate were studied individually and combinations. According to the RSM, the best appropriate model was a two-factor interaction (2FI) model. The data from several studies such as physical and chemical qualities, sensory quality and a mineral composition of developed products are briefly addressed in this section and the data is shown in tables. Outlines of this chapter enlisted below:

4.1 Chemical composition of refined wheat flour and hulless barley flour

The chemical composition of the hulless barley flour and refined wheat flour have been shown in table no. 4.1 which revealed that moisture, protein, fat, fiber, carbohydrate and ash content of the refined wheat and hulless barley flour found to be 12.3, 10.1, 1.3, 1.2, 75.52, 0.78 percent and 10.01, 11.5, 2.2, 1.5, 73.9, 0.89 percent respectively. Also, the total sugar, reducing sugar and non-reducing sugar content of the refined wheat flour and hulless barley flour was found to be 14.44 mg, 3.03 mg, 11.41 mg and 10.57 mg, 3.57 mg, 7.00 mg respectively.

Table 4.1: Chemical composition of refined wheat flour and hulless barley flour

S.No.	Parameters	RWF*	HBF**
1.	Moisture (%)	12.3	10.01
2.	Protein (%)	10.1	11.5
3.	Fat (%)	1.3	2.2
4.	Fiber (%)	1.2	1.5
5.	Carbohydrate (%)	75.52	73.9
6.	Ash (%)	0.78	0.89
7.	Total Sugar (mg/100gm)	14.44	10.57
8	Reducing sugar	03.03	3.57
9.	Non-Reducing sugar	11.41	7.00

RWF* - Refined Wheat Flour; HBF*** - Hulless Barley Flour

4.2 Development of Hulless Barley flour cookies:

The aim of this study was to optimize the level of hulless barley flour for the production of hulless barley flour cookies and to study the effect of partial replacement of refined wheat flour with barley flour on developed cookies quality. Thirty treatments of cookies dough were prepared using different ratio of sugar, guar gum and varied ammonium bi carbonate. Wheat flour was partially replaced using hull-less barley flour at five levels (15, 30, 45, 60 and 75 g/100g), sugar were used at five levels i.e. (25, 30, 35, 40 and 45 g/100g) and guar gum added at five level (1.5, 2.5, 3.5, 4.5 and 5.5 g/100g) while the ammonium bicarbonate varied at five levels (2.5, 3.0, 3.5, and 4.5 g/100g. Physical parameters (diameter, thickness, spread ratio and weight), Sensory characteristics (colour, appearance, taste, texture) and proximate analysis (moisture, ash, fat, protein, carbohydrate, energy and sugar) of the developed product were evaluated. The obtained results revealed that replacing wheat flour partially with hulless barley flour at different proportions affected the cookies quality. Best quality, acceptable

and optimized cookies could be produced by replacing up to 30% hulless barley flour under investigated conditions. In addition, sugar, and guar gum gave best results when incorporated at levels 31.46g/100g and 3.25 g/100g whereas the ammonium bicarbonate for the same was 3.60g/100g.

4.3 Physical properties of hulless barley flour cookies

4.3.1 Diameter

Table 4.4 revealed that the diameter of the hulless barley cookies was maximum (46.23mm) in experiment 17 and minimum (42.69mm) in experiment 18. These experiments represented the combination of ingredients as 85:15, 35g, 3.5g, 3.5g and 75:25, 35g, 3.5g, 3.5g of RWF: HBF, sugar, guar gum, and ammonium bicarbonate respectively.

The Model (Table 4.4) of F-ratio 0.24 is less than the table value 2.38. P-values less than 0.0500 indicate model terms are significant. The Lack of Fit F-value of 2.19 implies the Lack of Fit is not significant relative to the pure error. The R^2 value of model is 11.30 percent. Thus, finding indicates that the model is non-significant and could explain only 11.30 percent variability in the experiments.

4.3.2 Thickness

A quick glance through table 4.4 shows that the thickness of the hulless barley cookies was maximum (12.12mm) in experiment 18 and minimum (10.8mm) in experiment 17. These experiments represented the combination of ingredients as 75:25, 35g, 3.5g, 3.5g and 85:15, 35g, 3.5g, 3.5g of RWF: HBF, sugar, guar gum, and ammonium bicarbonate respectively.

The Model F-ratio of 25.60 is higher than the table value 2.38 that intimate the model is significant. The R^2 value of model is 93.09 percent. Thus, finding indicates that the model is significant and could explain only 93.09 percent variability in the experiments.

The coefficients of regression model presented in table 4.3 described that levels of barley flour had positive linear significant effect on specific

thickness of cookies at 5% level of significance. Rests all other terms of model were non-significant even at 10% level of significance.

4.3.3 Spread Ratio (D/T)

The spread ratio of the hulless barley flour cookies was maximum (4.28) in experiment 17 and minimum (3.52) in experiment 18 (Table 4.2). These experiments had the combination of ingredients as 85:15, 35g, 3.5g, 3.5g and 75:25, 35g, 3.5g, 3.5g of RWF: HBF, sugar, guar gum, and ammonium bicarbonate respectively.

The Model F-value of 0.79 is lower than the table value i.e., 2.38 which denote the model is not significant. The R^2 value of model is 29.42 percent. It is indicated by the findings that the model is non-significant and could explain only 29.42 percent variability in the experiments.

4.3.4 Weight

Table 4.2 shows that the weight of the hulless barley flour cookies was highest (14.25g) in experiment 18 and lowest (11.42g) in experiment 17, which represented the combination of ingredients as 75:25, 35g, 3.5g, 3.5g and 85:15, 35g, 3.5g, 3.5g of RWF: HBF, sugar, guar gum and ammonium bicarbonate respectively.

The Model (ANOVA Table 4.4) indicates F-ratio of 30.66 is more than the table value i.e., 2.38. Also the R^2 value of model is 94.16 percent. The findings indicated that the model is significant and 94.16 percent per cent variability in the experiments could be explained by the model.

The coefficients of regression model presented in table 4.3 described that barley flour levels had positive linear significant effect on weight of cookies at 5% level of significance. Rest all other terms of model was non-significant even at 10% level of significance.

Table 4.2: Physical properties of hulless barley flour cookies

Experiment	Diameter (mm)	Thickness (mm)	Spread Ratio (D/T)	Weight (g)
1	46.02	11.51	3.99	11.83
2	45.18	12.1	3.95	13.87
3	45.7	11.56	3.98	11.83
4	45.82	11.98	4.10	13.87
5	45.28	11.5	3.93	12.24
6	45.59	12.12	4.01	13.46
7	45.62	11.45	3.98	12.24
8	45.45	12.18	3.95	13.46
9	45.39	11.55	3.93	12.24
10	44.93	12.1	3.98	13.46
11	45.3	11.6	3.91	11.83
12	45.75	12.2	3.95	13.46
13	45.9	11.56	3.94	11.83
14	45.92	12.15	4.00	13.46
15	46.22	11.57	4.03	11.83
16	44.85	12.2	3.83	13.46
17	**46.23**	**11.2**	**4.28**	**11.42**
18	**42.69**	**12.3**	**3.52**	**14.28**
19	43.72	11.8	3.62	12.65
20	43.36	11.92	3.61	12.65
21	42.19	11.89	3.56	13.06
22	44.26	11.9	3.67	12.65
23	44.15	11.82	3.76	13.06
24	42.68	11.97	3.71	13.06
25	44.01	11.82	3.68	13.06
26	45.12	11.96	3.74	12.65
27	43.06	11.95	3.61	12.65
28	42.63	11.95	3.61	13.06
29	44.24	11.89	3.67	12.65
30	42.28	12.1	3.60	13.06

Table 4.3: Regression coefficient of two factor interaction model and significant terms for physical properties of developed hulless barley cookies

Coefficient	Diameter (mm)	Thickness (mm)	Spread Ratio (D/T)	Weight (g)
Intercept	6.68	3.44	1.94	3.58
Linear				
β1 A	-0.0281	**0.0420***	-0.0148	**0.1070***
β2 B	-0.0007	0.0024	-0.0008	-0.0025
β3 C	0.0154	0.0009	-0.0088	-0.0069
β4 D	0.0106	0.0050	0.0098	-0.0071
Interactive				
β 1.2 AB	3.587E-06	0.0003	0.0057	0.0037
β 1.3 AC	-0.0022	0.0037	0.0084	-0.0106
β 1.4 AD	-0.0036	0.0000	-0.0100	-0.0032
β2.3 BC	-0.0074	-0.0001	0.0008	0.0037
β2.4 BD	-0.0025	0.0024	-0.0100	-0.0037
β 3.4 CD	0.0106	-0.0006	0.0056	-0.0041

**Significant at 1%; *Significant at 5%; A- Hulless Barley flour; B -Sugar; C-Guar gum; D-Ammonium bicarbonate

Table 4.4: ANOVA of two factor interaction model for Physical properties of developed hulless barley cookies

Source	Diameter (mm)	Thickness (mm)	Spread Ratio (D/T)	Weight (g)
Model SS	0.0304	0.0435	0.0258	0.2800
Model MS	0.0030	0.0043	0.0026	0.0280
Model DF	10	10	10	10
Error SS	0.0335	0.0009	0.009	0.0049
Error MS	0.0067	0.0002	0.0018	0.0010
Error DF	5	5	5	5
F ratio	0.2421	25.60	0.7922	30.66
F table	2.38	2.38	2.38	2.38
R Square	0.1130	0.9309	0.2942	0.9416
Std dev.	0.1121	0.0130	0.0571	0.0302
Mean	6.68	3.44	2.51	3.58
C.V.	1.68	0.3783	2.28	0.8446

MS: Mean square; SS: Sum of squares; DF: Degree of freedom; Std dev.: Standard deviation

4.4 Sensory Characteristics of developed cookies

The results of the sensory assessment of cookies developed from refined wheat flour and hulless barley flour blends are presented in Table 4.5. Sensory evaluation of developed cookies was conducted on a nine-point hedonic rating scale ranging from "Extremely like" on point 9 to "Extremely dislike" on point. Colour & Appearance, Taste, Texture, and Overall Acceptability were the sensory evaluation characteristics evaluated. Each sample was judged independently by the panel members.

The least scores were obtained for cookies containing maximum levels of barley (i.e., 45%) for all the 5 sensory attributes. Increasing the level of hulless barley flour in the cookies showed a decreasing trend in all the 5 sensory characteristics.

4.4.1 Colour and Appearance

Colour and appearance score presented in table 4.5 showed significantly increased score from 6.25 to 8.75 and 5.5 to 8.5 with decrease in hulless barley replacement in refined wheat flour. In general, cookies with 85 percentage refined wheat flour blended with 15 percentage barley flour gave maximum score (8.75 & 8.5) while cookies with 25 percentage wheat flour blended with 75 percentage barley flour showed minimum score (6.25 & 5.5). These experiments represented the combination of ingredients as 85:15, 35g,3.5g, 3.5g and 75:25, 35g, 3.5g, 3.5g of composite flour (RWF: HBF), sugar, guar gum and ammonium bicarbonate respectively.

The ANOVA Table 4.7 indicates that the F-ratio (3.11 and 4.67) is higher as compared to Table value of 2.76. The R^2 value of model is 33.21 and 42.78 per cent which indicates that model was significant and could explain 33.21 and 42.78 per cent variability in these experiments.

Table 4.6 indicates that levels of hulless barley flour had positive linear significant effect on colour and appearance of cookies at 5% level of significance. Rest all other terms of model were found to be non-significant even at 10% level of confidence.

4.4.2 Texture score

Texture score as represented by table 4.5 showed significantly increased score from (6.75) in experiment 18 to (8.25) in experiment 17 with decrease in hulless barley flour ratio in subsequent refined wheat flour. These experiments represented the combination of ingredients as 75:25, 35g, 3.5g, 3.5g and 85:15, 35g, 3.5g, 3.5g of RWF: HBF, sugar, guar gum, and ammonium bicarbonate respectively.

The ANOVA Table 4.7 indicates that the F-ratio (7.74) is higher as compared to Table value of 2.76. The R^2 value of model is 55.32 per cent, which indicates that the model was significant and 55.32 per cent per cent variability in the experiments could be explained by the model. Table 4.6 describes that hulless barley flour levels had positive linear significant effect on texture of cookies at 5% level of significance. Rest all other terms of model were found to be non-significant even at 10 per cent level of confidence.

4.4.3 Taste score

Taste score represented by table 4.5 showed significantly increased score from (6.15) in experiment 18 to (8.5) in experiment 17 with decrease in hulless barley flour levels in the developed cookies. The combination of ingredients in these experiments was 75:25, 35g, 3.5g, 3.5g and 85:15, 35g, 3.5g, 3.5g of RWF: HBF, sugar, guar gum, and ammonium bicarbonate respectively.

The ANOVA Table 4.7 indicated that the F-ratio (4.08) was higher as compared to Table value of 2.76. The R^2 value of model is 39.48 per cent. The finding indicates that model was significant and could explain 39.48 per cent variability in the experiments. The Table 4.6 indicates that levels of hulless barley flour had positive linear significant effect on taste of cookies at 5% level of significance. Rest all other terms of model were found to be non-significant even at 10 per cent level of confidence.

4.4.4 Overall Acceptability

Table 4.5 provides the overall Acceptability score of the developed cookies which significantly increased from 5.95 in experiment 18 to 8.4 in experiment 17. These experiments represented the combination of ingredients as 75:25, 35g, 3.5g, 3.5g and 85:15, 35g, 3.5g, 3.5g of RWF: HBF, sugar, guar gum, and ammonium bicarbonate respectively.

The ANOVA Table 4.7 showed that the F-ratio (7.59) was higher as compared to Table value of 2.76. The R^2 value of model was 54.85 per cent. The findings indicated that the model was significant and 54.85 per cent variability in the experiments could be explained by the model. The Table 4.6 indicates that levels of barley flour had positive linear significant effect on taste of cookies at 5% level of significance. Rest all other terms of model was found to be non-significant even at 10 per cent level of confidence.

Table 4.5: Sensory characteristics of developed cookies using hedonic rating scale

Exp. No.	Colour	Appearance	Texture	Taste	Overall Acceptability
1	7.75	8.25	8.25	8	8
2	7.25	7.45	7.25	7.5	7.45
3	7.6	8	7.75	7.75	7.7
4	7.75	7.75	7	7.5	7.45
5	7.75	8.25	7.75	7.75	7.85
6	7	7.25	7.75	6.75	7.15
7	7.75	7.25	7.75	7.75	7.65
8	7.25	7.75	7	7.75	7.4
9	7.75	8.25	7.75	7.25	7.65
10	7.75	7.75	7.25	7	7.4
11	8	7.25	7.75	7.75	7.7
12	8	7.25	7.75	7	7.4
13	8	7.75	7.75	7.75	7.7
14	7.75	7.5	7.25	7.5	7.45
15	7.25	8	7.25	8	7.65
16	7	7	7	7.75	7.2
17	**8.75**	**8.5**	**8.5**	**8.25**	**8.4**
18	**6.25**	**5.5**	**6.15**	**6.75**	**5.95**
19	7.5	7.75	7	8	7.5
20	7.95	8.25	7.5	8	8.25
21	7.25	7.75	7.75	7	7.4
22	7.75	7	7.25	7	7.25
23	8	7.75	7.25	7.5	7.65
24	8	7.75	7.5	7.75	7.65
25	7	8	7	7.75	7.45
26	7	8	7.25	7.75	7.5
27	7.75	7.5	7.25	8	7.7
28	7	7.25	7.25	7.5	7.3
29	8	7.25	7	7.25	7.25
30	7.75	7.5	7.5	7.4	7.55

Table 4.6: Regression coefficient of linear model and significant terms for sensory characteristics of developed hulless barley cookies

Coefficient	Colour	Appearance	Texture	Taste	Overall Acceptability
Intercept	2.75	2.76	2.72	2.75	2.74
Linear					
β1 A	**-0.0542***	**-0.0722***	**-0.0649***	**-0.0477***	**-0.0610***
β2 B	0.0037	-0.0092	-0.0056	0.0134	0.0074
β3 C	-0.0084	0.0206	-0.0170	0.0095	-0.0077
β4 D	0.0105	-0.0091	-0.0017	-0.0019	-0.0037

**Significant at 1%; *Significant at 5%; A- Hulless Barley flour; B -Sugar; C-Guar gum; D-Ammonium bicarbonate

Table 4.7: ANOVA of linear model for sensory characteristics of hulless barley cookies

Source	Colour	Appearance	Texture	Taste	Overall Acceptability
Model SS	0.0752	0.1392	0.1087	0.0611	0.0924
Model MS	0.0188	0.0348	0.0272	0.0153	0.0893
Model DF	4	4	4	4	4
Error SS	0.0364	0.0191	0.0061	0.0124	0.0046
Error MS	0.0073	0.0038	0.0012	0.0025	0.0009
Error DF	5	5	5	5	5
F ratio	3.11	4.67	7.74	4.08	7.59
F table	2.76	2.76	2.76	2.76	2.76
R Square	0.3321	0.4278	0.5532	0.3948	0.5485
Std dev.	0.0778	0.0863	0.0593	0.0612	0.0551
Mean	2.75	2.76	2.72	2.75	2.74
C.V. %	2.83	3.13	2.18	2.23	2.01

MS: Mean square; SS: Sum of squares; DF: Degree of freedom; Std dev.: Standard deviation

4.5 Proximate composition of hulless barley flour cookies

4.5.1 Moisture

The effect of different ingredients and their combination on moisture content of cookies is presented in (Table 4.7). It ranged from 2.4 to 5.25 percent. The minimum and maximum moisture content in developed cookies was recorded at experiment 17 and 18 respectively. These experiments represented the combination of ingredients as 85:15, 35, 3.5, 3.5 g and 25:75, 35, 3.5, 3.5 g of RWF: HBF, sugar, guar gum, ammonium bicarbonate respectively.

The ANOVA table (Table 4.9) indicated that the F-ratio (2.17) is lower as compared to table value of 2.38. The R^2 value of the model is 53.30 per cent, which indicates that model is not significant and could explain only 53.30 per cent variability in the experiments. Hence the model was not found adequate for further analysis.

The probability value of regression model (Table 4.8) shows that levels of barley flour had positive linear significant effect at 5 % level of confidence on moisture content. Rest all other terms of model were found non-significant even at 10 per cent level of confidence.

4.5.2 Protein

The protein content in hulless barley flour cookies varied from 11.19-14.05 per cent (Table 4.8). The minimum and maximum protein of cookies was obtained at Expt. 17 and 18 respectively. The combination of ingredients in these experiments was 85:15, 35, 3.5, 3.5 g and 25:75, 35, 3.5, 3.5 g of RWF: HBF, sugar, guar gum, and ammonium bicarbonate respectively.

The analysis of variance table for two factor interaction model (Table 4.10) indicates that the F-ratio of the model (30.65) was higher as compared with the table value of 2.38 at 5 per cent level of significance. The R^2 value of model was 94.16 per cent. It indicates that model explained 94.16 per cent, variability in the experiments. The model is considered adequate; therefore, further analysis has been carried out.

The analysis of regression model (Table 4.9) shows that levels of barley flour had positive linear significant effect at 5 % level of confidence on protein content. Rest all other terms of model terms were found not significant even at 10 per cent level of confidence.

4.5.3 Fat

The Fat content of cookies varied from 22.39-25.25 per cent (Table 4.8). The minimum and maximum fat content in cookies was at Expt. 17 and 18 respectively. These experiments had the combination of ingredients as 85:15, 35, 3.5, 3.5 g and 25:75, 35, 3.5, 3.5 g of RWF: HBF, sugar, guar gum, ammonium bicarbonate respectively.

The analysis of variance table for two factor interaction model (Table 4.10) indicates that the F-ratio of the model (30.95) was higher as compared with the Table value of 2.38 at 5 per cent level of significance. The R^2 value of model was 94.22 per cent, which indicates that the model explained 94.22 per cent variability in the experiments. The model is considered adequate; therefore, further analysis has been done.

The probability value of regression model (Table 4.9) shows that levels of barley flour had positive linear significant effect at 5 % level of confidence on fat content. Rest of all other terms of the model were found non-significant even at 10 per cent level of confidence.

Table 4.8: Chemical composition of developed hulless barley flour and refined wheat flour cookies

Exp. Unit	Moisture %	Protein %	Fat %	Ash %	Fiber %	Carbohydrate %	Energy (K Cal)
1	3.12	11.6	22.8	0.99	2.32	59.17	488.28
2	3.76	13.64	24.84	1.11	2.96	53.69	492.88
3	3.2	11.6	22.8	0.95	2.4	59.05	487.8
4	3.65	13.64	24.84	1.09	2.85	53.93	**493.84**
5	3.02	12.01	23.21	0.92	2.22	58.62	491.41
6	3.88	13.23	24.43	1.07	3.08	54.31	490.03
7	3.21	12.01	23.21	1	2.41	58.16	489.57
8	3.92	13.23	24.43	1.13	3.12	54.17	489.47
9	2.98	12.01	23.21	0.89	2.18	58.73	491.85
10	3.84	13.23	24.43	1.21	3.04	54.25	489.79
11	3.32	11.6	22.8	0.91	2.52	58.85	487
12	3.92	13.23	24.43	1.23	3.12	54.07	489.07
13	3.22	11.6	22.8	0.91	2.42	59.05	487.8
14	4.01	13.23	24.43	1.08	3.21	54.04	488.95
15	2.87	11.6	22.8	1.09	2.07	59.57	489.88
16	4.12	13.23	24.43	1.13	3.32	53.77	487.87
17	**2.4**	**11.19**	**22.39**	**0.83**	**1.6**	**61.59**	492.63
18	**5.25**	**14.05**	**25.25**	**1.61**	**4.45**	**49.39**	481.01
19	4.24	12.42	23.62	1.23	3.44	55.05	482.46
20	4.41	12.42	23.62	1.45	3.61	54.49	480.22
21	4.66	12.83	24.03	1.11	3.86	53.51	481.63
22	4.14	12.42	23.62	1.29	3.34	55.19	483.02
23	4.03	12.83	24.03	1.41	3.23	54.47	485.47
24	4.21	12.83	24.03	1.32	3.41	54.2	484.39
25	4.2	12.83	24.03	1.21	3.4	54.33	484.91
26	3.98	12.42	23.62	1.15	3.18	55.65	484.86
27	4.54	12.42	23.62	1.49	3.74	54.19	**479.02**
28	4.71	12.83	24.03	1.37	3.91	53.15	480.19
29	3.94	12.42	23.62	1.51	3.14	55.37	483.74
30	4.42	12.83	24.03	1.3	3.62	53.8	482.79

Table 4.9: Regression coefficient of two factor interaction model and significant term for proximate composition of hulless barley cookies

Coefficient	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate
Intercept	1.95	3.55	4.88	1.08	1.73	7.45
Linear						
β1 A	0.1306	**0.1079***	**0.0784***	0.0582	0.1487	**-0.1764***
β2 B	0.0076	-0.0025	-0.0018	0.0151	0.0086	-0.0040
β3 C	-0.0059	-0.0070	-0.0052	0.0061	-0.0066	0.0094
β4 D	0.0089	-0.0071	-0.0052	0.0002	0.0098	0.0018
Interactive						
β 1.2 AB	-0.0027	0.0037	0.0027	-0.0043	-0.0031	-0.0017
β 1.3 AC	0.0174	-0.0107	-0.0078	-0.0123	0.0198	0.0031
β 1.4 AD	0.0138	-0.0033	-0.0025	0.0094	0.0156	-0.0048
β2.3 BC	-0.0074	0.0037	0.0027	0.0121	-0.0088	-0.0018
β2.4 BD	-0.0009	-0.0037	-0.0027	0.0059	-0.0013	0.0026
β 3.4 CD	-0.0026	-0.0042	-0.0029	0.0003	-0.0030	0.0043

**Significant at 1%, *Significant at 5%, β1-Hulless Barley flour, β2-Sugar, β3-Guar gum, β4-Ammonium bicarbonate.

Table 4.10: ANOVA of two factor interaction model for proximate composition of hulless barley cookies

Source	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate
Model SS	0.4223	0.2852	0.1506	0.0948	0.5478	0.7504
Model MS	0.0422	0.0285	0.0151	0.0095	0.0548	0.0750
Model DF	10	10	10	10	10	10
Error SS	0.0280	0.0050	0.0026	0.0201	0.0345	0.0205
Error MS	0.0056	0.0010	0.0005	0.0040	0.0069	0.0041
Error DF	5	5	5	5	5	5
F Ratio	2.17	30.65	30.95	1.14	2.21	8.63
F Table	2.38	2.38	2.38	2.38	2.38	2.38
R Square	0.5330	0.9416	0.9422	0.3750	0.5374	0.8196
Std dev.	0.1395	0.0305	0.0221	0.0912	0.1575	0.0932
Mean	1.95	3.55	4.88	1.08	1.73	7.45
C.V.	7.15	0.8603	0.4524	8.48	9.09	1.25

MS: Mean square; SS: Sum of squares; DF: Degree of freedom; Std. dev.: Standard deviation

4.5.4 Ash

The ash content of cookies ranged from 0.83 to 1.61 percent (Table 4.8). The minimum and maximum ash content of cookies was found at experiment 17 and 18 respectively. These experiments represented the combination of ingredients as 85:15, 35, 3.5, 3.5 g and 25:75, 35, 3.5, 3.5 g of RWF: HBF, sugar, guar gum, ammonium bicarbonate respectively.

The analysis of variance table for full second order regression model (Table 4.10) indicated that the F-ratio of the model (1.14) was lower as compared with the table value of 2.38 at 5 per cent level. The R^2 value of model was 37.50 percent. It indicates that model explained 37.50 percent, variability in the experiments.

4.5.5 Fibre

The developed cookies had the fiber content in the range of 1.6 to 4.45 per cent (Table 4.8). The minimum and maximum fiber of cookies was found at experiment 17 and 18 respectively. These experiments represented the combination of ingredients as 85:15, 35, 3.5, 3.5 g and 25:75, 35, 3.5, 3.5 g of RWF: HBF, sugar, guar gum, ammonium bicarbonate respectively.

The analysis of variance table for full second order regression model (Table 4.10) indicates that the F-ratio of the model (2.21) was lower as compared with the table value of 2.38 at 5 per cent level of significance. The R^2 value of model was 53.74 percent. It indicates that model explained 53.74 percent variability in the experiments.

4.5.6 Carbohydrate

The different combinations of ingredients and their effect on carbohydrate content of developed cookies are given in (Table 4.8). It ranged from 49.39 to 61.59 per cent. The minimum and maximum carbohydrate content of cookies was found at Expt. 18 and 17 respectively. These experiments represented the combination of ingredients as 25:75, 35, 3.5, 3.5 g and 85:15, 35, 3.5, 3.5 g of RWF: HBF, sugar, guar gum, ammonium bicarbonate respectively.

The Analysis of variance (table 4.10) indicates that the F-ratio (8.63) is lower as compared to Table value of 2.38. The R^2 value of perdition model is 81.96 per cent, which indicates that model is non-significant and could explain 81.96 per cent variability in the experiments.

The levels of barley flour had positive linear significant effect at 5 % level of confidence on carbohydrate content, which is shown by the analysis of regression model (Table 4.9). Rest all other terms of model were found non-significant even at 10 per cent level of confidence.

4.5.7 Energy

The energy value of cookies was in the range of 479.02 to 493.84 kcal (Table 4.8). Experiment 27 and 4 represented the minimum and maximum energy values of the cookies. These experiments represented the combination of ingredients as 55:45, 35, 3.5, 3.5 g and 40:60, 40, 2.5, 3 g of RWF: HBF, sugar, guar gum, ammonium bicarbonate respectively.

4.5.8 Total sugar

The effect of different ingredient and their combination on total sugar of barley flour cookies given in (Table 4.11). The Total sugar content of cookies varied from 16.72 and 17.69 mg/100g. The minimum and maximum total sugar of cookies was at experiment 19 and 20 respectively. These experiments represented the combination of ingredients as 55:45, 25, 3.5, 3.5 g and 55:45, 45, 3.5, 3.5 g of RWF: HBF, sugar, guar gum, ammonium bicarbonate respectively.

The ANOVA Table (Table 4.13) indicates that the F-ratio (66.05) is higher as compared to Table value of 2.38. The R^2 value of perdition model is 97.20 per cent. The finding indicates that model is significant and could explain 97.20 per cent variability in the experiments.

The levels of barley flour had positive linear significant effect at 5 % level of confidence on total sugar content of cookies, which is shown by the analysis of regression model (Table 4.12). Rest of all other terms of model were found non- significant even at 10 per cent level of confidence.

4.5.9 Reducing sugar

The effect of different ingredient and their combination on reducing sugar of cookies is given in (Table 4.11). The reducing sugar content of cookies varied from 3.5 and 4.6 mg/100g. The highest and lowest value of reducing sugar of developed cookies was found at Expt. 19 and 20 respectively. These experiments represented the combination of ingredients as 55:45, 25, 3.5, 3.5 g and 55:45, 45, 3.5, 3.5 g of RWF: HBF sugar, guar gum, ammonium bicarbonate respectively.

The ANOVA Table (Table 4.13) indicated that the F-ratio (24.65) is higher as compared to Table value of 2.38. The R^2 value of perdition model is 92.84 per cent. The finding indicates that model is significant and could explain 92.84 per cent variability in the experiments.

The analysis of regression model (Table 4.12) shows that levels of barley had positive linear significant effect at 5 % level of confidence on reducing sugar content of cookies. Rest of all other terms of model were found non- significant even at 10 per cent level of confidence.

4.5.10 Non-Reducing Sugar

As revealed by table 4.10, the non-reducing sugar content was maximum (14.19 mg/100g) in experiment 19 and minimum (12.12 mg/100g) in experiment 20. These experiments represented the combination of ingredients as 55:45, 25g, 3.5g, 3.5g and 55:45, 45g, 3.5g, 3.5g of composite flour (RWF: HBF), sugar, guar gum and ammonium bicarbonate respectively.

The ANOVA Table (Table 4.13) indicates that the F-ratio (91.99) is higher as compared to Table value of 2.38. The R^2 value of perdition model is 97.98 per cent. The finding indicates that model is significant and could explain 97.98 per cent variability in the experiments.

The analysis of regression model (Table 4.12) shows that levels of improver had positive quadratic significant effect at 5 % level of confidence on reducing sugar content of cookies. Rest all other terms of model were found non- significant even at 10 per cent level of confidence

Table 4.11: Proximate composition (sugar) of hulless barley flour and refined wheat flour cookies

Experiment	Total Sugar (mg/100g)	Reducing Sugar (mg/100g)	Non reducing Sugar (mg/100g)
1	17.3	3.81	13.49
2	17.09	4.14	12.95
3	17.31	3.86	13.45
4	16.92	4.28	12.64
5	17.4	3.8	13.6
6	16.92	4.42	12.5
7	17.45	3.75	13.7
8	17	4.48	12.52
9	17.38	3.85	13.53
10	17.04	4.4	12.64
11	17.3	3.9	13.4
12	16.92	4.5	12.42
13	17.33	3.86	13.47
14	16.89	4.45	12.44
15	17.48	3.87	13.61
16	16.98	4.5	12.48
17	17.1	4.1	13
18	17.16	4.22	12.94
19	**17.69**	**3.5**	**14.19**
20	**16.72**	**4.6**	**12.12**
21	17.2	4.19	13.01
22	17.19	4.2	12.99
23	17.18	4.12	13.06
24	17.21	4.27	12.94
25	17.17	4.12	13.05
26	17.22	4.26	12.96
27	17.19	4.25	12.94
28	17.17	4.25	12.92
29	17.22	4.19	13.03
30	17.21	4.4	12.81

Table 4.12: Regression coefficient of two factor interaction model and significant term for proximate composition (sugar) of hulless barley cookies

Coefficient	Total Sugar	Reducing sugar	Non reducing Sugar
Constant	4.14	2.04	3.61
Linear			
β_1 A	**-0.0267***	**0.0713***	**-0.0706***
β_2 B	0.0016	0.0040	-0.0004
β_3 C	0.0018	0.0014	0.0011
β_4 D	0.0009	0.0085	-0.0037
Interactive			
$\beta_{1.2}$ AB	-0.0004	0.0004	-0.0008
$\beta_{1.3}$ AC	-0.0027	0.0063	-0.0066
$\beta_{1.4}$ AD	0.0005	-0.0001	0.0004
$\beta_{2.3}$ BC	0.0041	-0.0003	0.0047
$\beta_{2.4}$ BD	-0.0009	0.0041	-0.0034
$\beta_{3.4}$ CD	-0.0023	-0.0009	-0.0020

**Significant at 1%; *Significant at 5%; A- Hulless Barley flour; B -Sugar; C-Guar gum; D-Ammonium bicarbonate

Table 4.13: ANOVA of two factor interaction model for proximate composition (sugar) of hulless barley cookies

Source	Total Sugar	Reducing Sugar	Non reducing Sugar
Model SS	0.0178	0.1251	0.1214
Model MS	0.0018	0.0125	0.0121
Model DF	10	10	10
Error SS	0.0000	0.0025	0.0007
Error MS	7.948	0.0005	0.0001
Error DF	5	5	5
F Ratio	66.05	24.65	91.99
F Table	2.38	2.38	2.38
R Square	0.9720	0.9284	0.9798
Std dev.	0.0052	0.0225	0.0115
Mean	4.14	2.04	3.61
C.V.	0.1253	1.11	0.3185

MS: Mean square; SS: Sum of squares; DF: Degree of freedom; Std. dev.: Standard deviation

4.6 Hunter colour Value of hulless barley flour cookies

4.6.1 L* (Darkness)

The effect of different ingredient and their combination on L* (Darkness) colour values of cookies are given in (Table 4.13). The minimum (34.58) and maximum (55.65) values were recorded in Expt. 18 and 17 respectively, which represented the combination of ingredients to be 25:75 g, 35 g, 3.5 g, 3.5 g and 85:15 g, 35 g, 3.5 g, 3.5 g of refined wheat flour and hulless barley flour, sugar, guar gum and ammonium bicarbonate respectively.

4.6.2 a* (Green)

Table 4.13 comprises the results of effect of different ingredient and their combination on a* (Green) colour values of cookies. The minimum and maximum a* (Green) values were 12.95 and 14.97 recorded in Expt. 18 and 12 respectively, which represented the combination of ingredients as 25:75 g, 35 g, 3.5 g, 3.5 g and 60:40 g, 40 g, 2.5 g, 4 g of refined wheat flour: hulless barley flour, sugar, guar gum and ammonium bicarbonate respectively.

4.6.3 b* (Yellow)

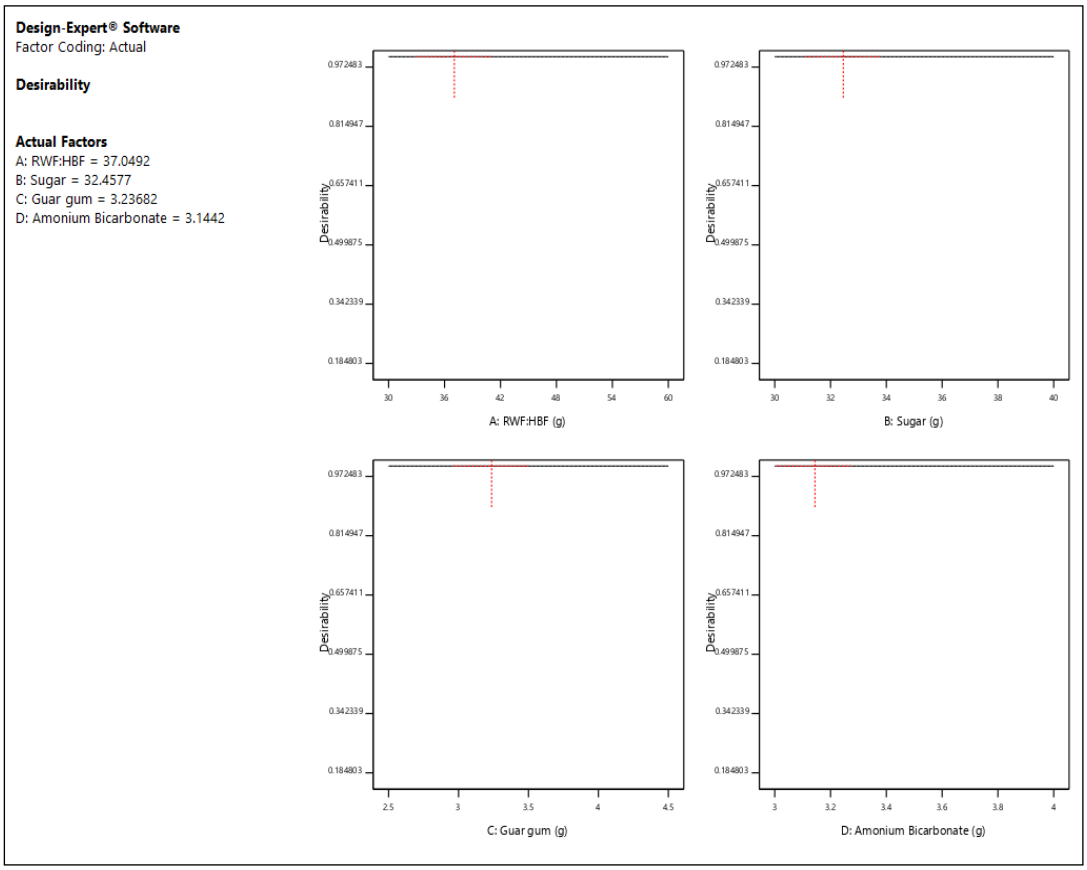
The findings presented in Table 4.13 reveals the results of effect of different ingredient and their combination on b* (Yellow) colour values of cookies. It varied from 12.02 to 30.20 in Expt. 14 and 1 respectively. The Expt. 14 and 1 represented the combination of ingredients to be 60:40 g, 30 g, 4.5 g, 4 g, and 70:30 g, 30 g, 2.5 g, 3 g, of refined wheat flour and hulless barley flour, sugar, guar gum and ammonium bicarbonate respectively.

Table 4.14: Hunter Colour Value of hulless barley flour cookies

Experiment	Hunter Colour Value		
	L*	a*	b*
1	48.40	12.32	**30.20**
2	39.86	11.31	16.96
3	48.43	13.03	23.36
4	39.53	13.76	16.32
5	47.28	13.80	23.65
6	44.13	13.27	19.57
7	45.62	12.83	26.64
8	44.98	12.24	19.59
9	46.44	12.42	26.57
10	39.86	12.12	16.62
11	46.46	13.67	26.54
12	37.86	**13.88**	18.69
13	45.45	12.60	25.07
14	37.58	11.85	**12.02**
15	49.54	12.05	26.74
16	36.74	12.88	17.67
17	**55.65**	12.32	29.51
18	**34.58**	**9.86**	17.50
19	43.75	13.63	19.56
20	41.55	13.39	18.78
21	40.40	12.84	18.18
22	39.82	13.96	19.25
23	38.69	13.38	18.27
24	41.37	13.39	18.10
25	43.25	11.33	16.69
26	41.35	12.41	17.87
27	41.83	11.55	18.85
28	36.27	11.74	15.32
29	39.56	12.44	18.93
30	42.43	11.49	19.47

4.7 Optimized Values

The RSM approach was used to optimize ingredients in the cookies production using four factors as responses. A: RWF: HBF - 37.04, B: Sugar - 32.45, C: Guar gum - 3.23 and D: Ammonium bi-carbonate - 3.14 g/100g. The results obtained desirability in the present investigation actual factors indicated that better quality cookies. The efforts were also made to develop the technology for utilization of hulless barley as a novel ingredient in formulation of cookies.



DISCUSSION

Due to consumer awareness of nutrition, the use of barley flour and other components in food products is currently of interest. Since hulless barley flour contains non-glutenous protein, carbohydrates, and soluble fibre, it can enhance the nutritional content of dishes, especially baked goods like cookies. Due to its capacity to bind two molecules of cholesterol, the B-glucans molecule found in barley wheat aids in lowering blood cholesterol levels. Thusly created hull-free barley flour cookies can be successfully employed as a disease-delaying diet for treating diabetics and cardiovascular disorders in individuals. In this chapter, experimental results on optimising the proportions of baking ingredients for the manufacturing of cookies using hullless barley flour and refined wheat flour are justified. The reported values of various parameters provided by various studies have been used to explain the results, and they are discussed as follows.

5.1 Physical properties of hulless barley flour cookies

5.1.1 Diameter

The diameter followed of hulless barley flour cookies, which significantly ($p < 0.05$) increased from 42.69 to 46.23 mm for the cookie sample 18 and 17 respectively. This could be attributed to the amount of fat added to the flour blends during production. Similarly, an increasing trend for the diameter (38.90–40.20 mm) of cookies made from wheat barley grain flour blends was reported by Gernah *et al.,* (2010). However, the findings disagree with the observation of Abdul *et al.* (2015) who reported a decrease in diameter for cookies with increasing substitution level of oat bran.

5.1.2 Thickness

The effect of different ingredient and their combination on diameter of cookies varied from 11.2 – 12.3. The graded levels of hulless barley flour have positive linear significant effect on thickness of cookies. A similar finding of change in thickness of cookies during baking was also reported by Sharma and Chauhan, (2002), Hooda and Jood, (2005) and Sudha *et al.,* (2007).

5.1.3 Spread Ratio (D/T)

The spread ratio of the cookies ranged between 3.52 and 4.28; cookie experiment 17 had the highest spread ratio value, while the experiment 18 had the least. A similar finding was observed by Giwa and Abiodun (2010).

5.1.4 Weight

The weight of the cookies ranged from 11.42 to 14.28 g; cookie sample 18 were heaviest and bulkiest among the samples, while the sample 17 had the least weight. Addition of hulless barley flour caused a significant at 5% in the weight of cookies. The findings were in contrary to the observation of some researchers who reported significant reduction in the weight of cookies produced from soya bean supplemented with wheat flour (Ayo *et al.,* 2007).

5.2 Sensory Characteristics of developed cookies

The colour score of hulless barley flour cookies varied from 5.5 - 8.75. The levels of hulless barley flour had positive linear significant colour of cookies at 5% level of significance. The colour, appearance, texture, Taste and overall acceptability sensory score of hulless barley flour cookies varied from 6.25-8.5, 5.5-8.5, 6.15-8.5, 6.75-8.25, and 5.95-8.4 respectively. The results of regression model for above sensory attributes were found significant. The findings suggest that levels of barley flour had a positive linear significant effect on colour, appearance, texture, Taste and overall acceptability sensory score of barley flour cookies. The effect of sugar and improver levels was also observed significant in linear term for colour score of barley flour cookies.

The results are in accordance with the findings of Tsuji, Kimoto, and Natori (2001) who observed that darker colour of cookies may be due to the non-enzymatic reaction (Maillard reaction) between reducing sugar molecules and lysine protein. Also, Sudha, Baskaran, and Leela-Vathi (2006) stated that darker colours are generally associated with enriched high fibre biscuits.

5.3 Proximate composition of hulless barley flour cookies

5.3.1 Moisture

The moisture content (%) of the cookies ranged between 2.4 and 5.5. The cookie sample 17 had the least value while cookie sample 18 had the highest value. However, increased substitution level with barley flour caused significant at 5% level reduction in the moisture content values. The moisture content of the cookies was low enough (<10%) to reduce the chances of spoilage by micro-organisms and consequently guarantee good storage stability (Ayo *et al.,* 2007).

5.3.2 Protein

The protein content of the cookies ranged from 11.19 to 14.05%; cookie sample 18 had the highest protein content (15.64%) while the cookie sample had the lowest (11.21%). Addition of hulless barley flour caused significant ($p < 0.05$) increase in the protein content of the cookies. The observed increase could be attributed to the significant quantity of protein (12.5%) in barley bran (Satinder, Sativa, & Nagi, 2011). The findings conform to the report of Omeire and Ohambele (2010) for the increasing trend of protein content (8.54–17.72%) in cookies produced from wheat-defatted cashew nut flour blends.

5.3.3 Fat

The fat content (%) of the cookies ranged between 22.39 and 25.25%. Cookie sample 18 had the highest fat content while the sample 17 had the least value. The fat content of the cookies increased significantly ($p < 0.05$) as the substitution level increased from 15 to 75% with hulless barley flour. The finding agrees with Omeire and Ohambele (2010) and Gernah *et al.,* (2010) on their reports.

5.3.4 Ash

Ash content of the cookies ranged from 0.83 to 1.61% for the cookie sample 17 and cookie sample 18 respectively. The addition of HBF significantly ($p < 0.05$) increased the ash content of the cookies progressively.

Gernah *et al.,* (2010) also reported similar findings that cookies produced from wheat-brewers spent grain flour blends had high ash content (1.85–2.89%).

5.3.5 Fibre

The crude fibre content of cookies produced from RWF-HBF flour blends ranged from 1.6 to 4.45%; cookie sample 18 had the highest value while the cookie sample 17 had the lowest value. Hulless barley flour has relatively higher crude fibre content than wheat and this justify the results obtained for the cookie samples.

The finding conforms to the observation of Gernah *et al.,* (2010) for the increasing trend in the crude fibre (1.32–10.82%) contents of cookies made from wheat-brewers spent grain flour blends.

5.3.6 Carbohydrate

Carbohydrate content of the cookies ranged between 49.39 and 61.59%. Cookie sample 17 had the highest carbohydrate content while the cookie sample 18 had the highest value. The increase in proportion of hulless barley flour brought about decrease in the carbohydrate content of the cookies.

Similarly, a decreasing trend in the carbohydrate contents (73.46 – 46.20%) and (70.45–23.71%) of cookies made from wheat-brewers spent grain flour blends and whole wheat- full fat soya flour blends was reported by Gernah *et al.,* (2010) and Joel, Fatima, and Stephen (2014) respectively.

5.3.7 Energy

The energy value of the cookie samples ranged between 479.02 and 493.84 kcal/100 g; cookie sample 27 had the lowest energy value, while the cookie sample 4 had the highest value. Similarly, a decreasing trend in the energy value (443.89–431.95 kcal) for cookies made from wheat and quality protein maize was reported by Giwa and Ikujenlola (2010).

5.3.8 Sugar content

The total sugar content of the developed cookies ranged from 16.72 mg/100g to 17.69 mg/100g. Also, barley has large amount of bran and fiber which can be attributed to decreased amounts of sugar in the developed

cookies with respect to increasing hulless barley content. Abboud *et al.,* (1985) reported that except at the coarsest size (> 35 mesh), sugar particle size had no effect on cookie spread.

5.4 Hunter colour values of hulless barley flour cookies

The hunter L*(Darkness), a*(Green) b*(Yellow) values of hulless barley flour cookies for colour of product varies from 34.58-55.69, 9.86-13.88, 12.02-30.20 respectively. Frost DJ, Adhikari K, Lewis DS (2011) reported similar results in barley cookies with increase proportions of barley flour cookies.

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

Once considered as sick man’s diet, bakery products now have become essential food items of mass consumption popularity with rapid growth and changing eating habits of people. It still remains the cheapest of the processed ready to eat products in the country.

According to estimates, the bakery industry's share of biscuits and cookies is about 37% by volume and 75% by value. Due to the range of flavours, textures, and aromas, cookies are incredibly popular among people of all ages, but especially with children. Cookies also hold a key position in the baking sector. 82 percent of total bakery production is made up of bread and biscuits, which are regarded as the main bakery products. They are cereal-based foods that often include the three elements fat, flour, and sugar. Aerating agents, flavouring agents, salt, and milk are all common ingredients (Wade, 1988). Cookies have gained popularity as a snack due to its inexpensive cost of production, convenience, long shelf life, good eating quality, and capacity to transport essential nutrients. Therefore, in such conditions, it would be beneficial to produce cookies using hulless barley flour. The current study, "Development and Nutritional Evaluation of Wheat and Barley Composite Flour Cookies Using Response Surface Methodology," has been planned in view of the above information. The results of the experiments are detailed below.

1. The moisture, fat, protein, fiber, carbohydrate and ash content were found to be 12.3, 1.3, 10.1, 1.2, 75.52, 0.78 percent in refined wheat flour and 10.01, 2.2, 11.5, 1.5, 73.9, 0.89 percent in hulless barley flour respectively.
2. The physical properties of the developed cookies i.e., diameter, thickness, spread ratio and weight ranged from 42.69 to 46.23 mm, 10.8 to 12.12 mm, 3.52 to 4.28 and 11.42 to 14.28 g respectively.
3. The results of regression model for above physical attributes were found non-significant.

4. The sensory scores of the cookies for colour, appearance, texture, taste, and overall acceptability varied from 6.25 - 8.75, 5.5 - 8.5, 6.15 - 8.5, 6.75 - 8.25 and 5.95 - 8.4 respectively.
5. The regression model's results for the above sensory qualities were found significant at 5%. The data suggested that the level of barley flour incorporation in the cookies had a positive linear significant effect on the sensory attributes.
6. The moisture, fat, protein, carbohydrates, ash, fiber and energy in the cookies varied from 2.4 - 5.25, 22.39 - 25.25, 11.19 - 14.05, 49.39 - 61.59, 0.83 - 1.61, 1.6 - 4.45 percent and 480.22 - 493.84 Kcal respectively.
7. The regression model's results for the above proximate composition were found significant at 5%. The data suggested that the level of barley flour incorporation in the cookies had a positive linear significant effect on the proximate composition.
8. The Total sugar, reducing and non-reducing sugar in developed barley fortified cookies ranged from 16.72 to 17.69, 3.5 to 4.6 and 12.12 to 14.19 respectively.
9. The regression model's results for the above sugar contents were found significant at 5%. The data suggested that the level of barley flour incorporation in the cookies had a positive linear significant effect on the sugar content of the developed barley fortified cookies.
10. The Hunter colour values of developed barley fortified cookies i.e., L*, a* and b* values ranged from 34.58 to 55.65, 9.86 to 12.02 and 13.88 to 30.2 respectively.

6.2 Conclusion

The results clearly demonstrated that the models developed are appropriate and can be used to describe the effect of ingredients like hulless barley, sugar, guar gum and ammonium bicarbonate. The model also explains the effect of ingredients on cookie characteristics. It was determined that best quality, acceptable and optimized cookies could be produced by replacing up to 37.04% refined wheat flour by hull-less barley

flour under investigated conditions when combined with other baking components such as sugar, guar gum and ammonium bicarbonate at levels 32.45, 3.23 and 3.14g/100g respectively. While treatment 17 showed superior sensory score in respect of quality over other treatments. It combined with refined wheat flour and hulless barley flour (75:15%), sugar (35%), guar gum (3.5%) and ammonium bi carbonate (3.5%).

6.3 Suggestion for further work

1. To study the large scale consumer acceptance trial for hulless barley flour cookies.
2. Evaluation of β-glucan and other bioactive principal compounds in hulless barley flour cookies.
3. Development of value added product with incorporation of hulless barley.

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APPENDIX-I

The format of sensory score card

S. No.	Hedonic scale	Hedonic rating
1.	Like extremely	9
2.	Like very much	8
3.	Like moderately	7
4	Like slightly	6
5.	Neither like nor dislike	5
6.	Dislike slightly	4
7.	Dislike moderately	3
8.	Dislike very much	2
9.	Dislike extremely	1

Preparation of Raw Material

Fig. 3.1 Hulless barley

Fig.3.2: Hulless barley flour

Fig. 3.3: Weighing of ingredient (Shortening)

Fig.3.4: Weighing of ingredient (Hulless barley)

Cookies Making Process

Fig 3.5: Mixing ingredients in spiral mixer

Fig 3.6: Developed cookies by cookies dropper machine

Fig. 3.7: Pre baking cookies

Fig. 3.8: Baking of cookies in rotary oven

Fig. 3.9 Baked cookies

Fig. 3.10: Packaging of cookies

85:15:25:1.5:2.5

70:30:30:2.5:3

55:45:35:3.5:3.5

40:60:40:4.5:4

25:75:45:5.5:4.5

Fig. 3.11: Prepared cookies in different ratio of refined wheat flour, hulless barley four, sugar, guar gum and ammonium bicarbonate