

DEVELOPMENT AND EVALUATION OF APPLE POMACE WAFFLE CONE

Thesis

by

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(H-2018-16-D)**

submitted to



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CERTIFICATE-I

This is to certify that the thesis titled “**Development and evaluation of apple pomace waffle cone**” submitted in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy Food Technology** in the discipline of **Food Science and Technology** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) - 173230, is a bonafide research work carried out by **Mr. Sanjay Patidar (H-2018-16-D)** son of Shri Bhagirath Patidar under my supervision and that no part of this thesis has been submitted for any other degree or diploma.


The assistance and help received during the course of this investigation have been fully acknowledged.

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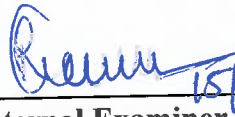
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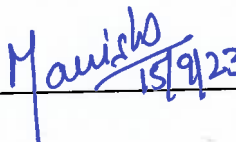
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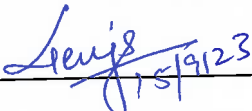
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ABBREVIATIONS USED

%	:	Per cent
°C	:	Degree Celsius
µg	:	Microgram
CD	:	Critical difference
CFU	:	Colony forming units
cm	:	Centimetre
CRD	:	Completely Randomized Design
<i>et al.</i>	:	And more
g	:	Gram
GAE	:	Gallic acid equivalent
<i>i.e.</i> ,	:	That is
Kg	:	Kilogram
LAB	:	Lactic acid bacteria
LDPE	:	Low density polyethylene
m	:	Meter
mg	:	Milligram
MH	:	Million hectare
min.	:	Minute
MMT	:	Million metric tonnes
MT	:	Metric tonnes
ppm	:	Parts per million
RBD	:	Randomized block design
SE	:	Standard error
<i>viz.</i>	:	Videlicet

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Chapter - 1

INTRODUCTION

Apple (*Malus × domestica* Borkh.) family Rosaceaceae is the most favoured and widely grown commercial fruit crop across the temperate regions of the world (Agrahari and Khurdiya, 2003). China is the leading producer of apple, producing about 46.85 per cent followed by the United States, Turkey, Poland and India (USDA, 2020). It is the fourth major consumed fruit crop in the world after oranges, bananas and grapes. In India, the commercial cultivation of apple is largely confined to the states of Jammu and Kashmir UT, Himachal Pradesh and Uttarakhand and the remaining is produced in Arunachal Pradesh, Sikkim, Nagaland and Meghalaya (Chadha and Awasthi, 2005). Apple production is the backbone of the rural economy of many North Western Himalyan regions of India with the production of 2437.37 MT from an area of 308.00 thousand hectares (NHB, 2022). Himachal Pradesh is known as the Apple Bowl of India and is the second largest producer accounting for 26.42 per cent apple production after Jammu and Kashmir UT. The major apple producing districts of Himachal Pradesh are Shimla, Kullu, Mandi, Chamba and Kinnaur (Sharma *et al.*, 2016).

Worldwide, apple processing generates a huge volume of waste, considering the annual processed tonnage up to 11.00 million tons (USDA, 2018). According to the tonnage processed, 3.30 million tons (MT) of waste is generated every year. In most apple processing industries, the waste generated can be categorized into two types, the first type is the fruit discarded during sorting process due to its partially bruised/spoiled nature and the second type is the apple pomace obtained after juice extraction. Apple pomace is the main by-product of apple juice processing industries accounting for about 25.00 per cent of the original fruit mass (eg. skin, stem, seeds and pulp). The solid waste represents 20.00 to 35.00 per cent of the fresh weight of the apples comprising 85.00 per cent (WB) moisture content (Rabetafika *et al.*, 2014). Apple pomace disposed in dump yards easily ferments, causing environmental problems (un-control fermentation 250.00-300.00 g/kg BOD) and health hazards (Kaushal *et al.*, 2002). This by-product is usually treated in traditional ways such as landfilling, incineration, composting and low-quality animal feed, beside causing serious environmental problems and losses for the industries due to the waste treatment and transportation costs for dumping into landfills (Macagnan *et al.*, 2015).

However, the pomace is also rich in nutritionally important compounds such as carbohydrates, protein, pectin, phenolic compounds, dietary fibre and minerals (Bhushan *et al.*, 2008). Apple pomace has a greater carbohydrate content than apple due to the inclusion of the sugar-containing seeds (Queji *et al.*, 2010). The main fibre constituent found in apple pomace is pectin that results in 94.30 per cent inhibition of pancreatic lipase. It also has a potential anti-obesity treatment because of its ability to inhibit fat absorption and, thus, reduce calories (Kumar and Chauhan, 2010). Consumers are also becoming more interested in phytochemicals that are present in fruits because of their antioxidant activity that greatly reduce the liver cancer incidences and colon cancer cells and other health promoting effects (Robards *et al.*, 1999; Boyer and Liu, 2004). Thus, it is of vital importance to reuse it as an industrial by-product to improve the process of economics and its sustainability. Recently, many researches have been done on the utilization of apple pomace for the development of new functional foods as the apple pomace is rich in many bioactive compounds and dietary fibre. The apple pomace is incorporated for the enhancement of bakery products (bread, cookies, cakes, muffins and crackers), meat products (nuggets, sausages and goshtaba), dairy products (curd and yogurt), extruded products, confectionary, and also used to manufacture alcoholic beverages (Lyu *et al.*, 2020).

Wheat (*Triticum aestivum*) belongs to family Poaceae which is an important cereal crop and staple food for most of the population of the world. Wheat is the second most produced cereal grain after maize, and the global trade of wheat is greater than all other crops combined. The total global production of wheat was 779.33 million metric tons from an area of 206.00 million hectares (Statista, 2022). China, India and Russia are the three largest individual wheat producers in the world, accounting for about 41.00 per cent of the world's total wheat production. India is the second largest producer of wheat in with an annual production of 106.00 MMT from an area of 30.50 MH (FAO, 2022). Chemically wheat flour consists of 7.00 per cent moisture, 13.90 per cent protein, 4.50 per cent fibre, 3.60 per cent fat and 69.50 per cent carbohydrate (Ndife *et al.*, 2011). It also contains β -carotenoids, polyphenol, antioxidant, choline, phytic acid, lignins, lignane and micronutrients such as vitamin E, folates, zinc, iron, selenium, copper, manganese, phosphorous, calcium, sodium, magnesium, potassium along with sulphur containing amino acids (Maldonado *et al.*, 2012). Whole wheat flour is used in the preparation products like bread, cookies, crackers, pasta, muffins, cake, noodles, pizza and tortillas *etc.*

Rice (*Oryza sativa* L.) the family Poaceae is a common cereal crop consumed by over half of the world's population as a staple food. It ranks third in the production next to sugarcane and maize (Maclean *et al.*, 2013; monks *et al.*, 2013). The world's rice production is reported to be 502.98 million tons from an area of 164.19 million hectares (Statista, 2022). India is the second largest producer of rice in the world next to China followed by Indonesia and Bangladesh accounting for 130.00 million tons from an area of 46.00 million hectares (FAO, 2022). However, in many rice cultivars pericarp and seed coat exhibits surface colour due to which it is classified as coloured rice such as red, blue, black and purple rice. Additionally, it is high in terms of nutrition as compared to white rice. Red rice varieties contain 9.28 to 13.12 per cent moisture content, 0.82 to 1.50 per cent total ash, 1.15 to 3.19 per cent fat content, 2.52 to 4.18 per cent dietary fibre, 7.16 to 10.36 per cent protein and 73.73 to 79.27 per cent carbohydrate content (Sompong *et al.*, 2011). Further, polyphenols, antioxidant, anthocyanin, vitamins and minerals like sodium, phosphorus, potassium, sulphur, magnesium, calcium, iron, copper, zinc and selenium are 2.00 to 3.00 times higher in red rice than that of white rice (Jing *et al.*, 2000). Many people are diagnosed with gluten intolerance, so the red rice flour is a suitable ingredient for developing gluten-free product such as noodles, pasta, cakes, breads and other fermented products. (Das and Bhattacharya, 2019).

The bakery industry is one of the fastest growing food industries. The majority of bakery products are made with refined wheat flour, but rising health concerns such as constipation, obesity and other chronic diseases necessitate the consumption of foods which are high in dietary fibre and protein in addition to the major carbohydrates. The fortified fibre enriched apple pomace powder in bakery products are gaining much popularity in market as compared to the traditional ones (Bijlwan *et al.*, 2019). The bakery products are typically made from large cereal crops like wheat flour but, apple pomace powder and red rice flour are increasingly being used in baked goods such as ice-cream cone which is a dry, cone-shaped flat waffle, enabling ice-cream to be held in hand and eaten. Ice-cream cones represent an essential element in manufacturing and marketing novelty frozen desserts because they are gluten-free and high in nutrients (Mhatre *et al.*, 2022). Similarly, the food industrial by-products are rich sources of functional ingredients such as fibre, minerals and phytochemicals among others (Jeddou *et al.*, 2017).

Nowadays, the consumers are looking for convenient, nutritive and minimally processed food with longer shelf life. Due to urbanization, the trend in consumption of

convenient food is increasing day by day as there is a large number of the working population, lack of time and scarcity of household workers in cities and towns. It is possible to utilize pomace as a food product directly or after minimal processing for the development of dietary fibre rich edible cutlery such as waffle cone and waffle bowls which will not only reduce the environment problem but also result in development of novel products. In view of the demand for healthy processed food products in the future, the present study was proposed with the following objectives.

Objectives:

The proposed study was taken with following objectives:

- i) To develop process protocol for apple pomace waffle cones.
- ii) To develop instant apple pomace waffle pre-mix.
- iii) To evaluate the quality of standardized products.

Chapter - 2

REVIEW OF LITERATURE

Apple (*Malus × domestica* Borkh.) is a fruit that millions of people prefer the most and is commonly cultivated in temperate climate worldwide. It ranks fourth in production next to banana, orange, and grapes in the world (Shalini and Gupta, 2010). The global apple production is reported to be 65688.79 MT (FAO, 2020). India ranks as the fifth largest producer of apples in the world after China, USA, Turkey and Poland. In India, the annual production of apple is 2437.37 MT from an area of 308.00 thousand hectares (NHB, 2022). Apple is largely grown in the Himalayan regions of India mostly in Jammu and Kashmir UT, Himachal Pradesh and Uttarakhand states (Dhyani *et al.*, 2015). Himachal Pradesh is the “Apple bowl of India” and is also the second-largest producer after Jammu and Kashmir UT. It is also known for the production of quality apples with an annual production of 643.88 MT (NHB, 2022). The districts of Shimla, Kullu, Mandi, Chamba and Kinnaur are the major apple-producing areas of Himachal Pradesh (Sharma *et al.*, 2016). Apple is an important fruit in most people's diets owing to its well-known medicinal properties. The chemical composition of apple is extremely complex as it is made up of a variety of organic and inorganic compounds e.g., sugars, acids, pectin, tannins, fibre, cellulose, vitamins, enzymes and phytohormones (Violeta *et al.*, 2010). The majority of the fruit produced is consumed fresh and only a small amount is processed into different products. A conventional process at a laboratory scale used for the extraction of juice is expected to extract 75.00 per cent of the fresh weight of an apple as juice and 25.00 per cent as pomace.

The solid biomass after extraction of juice from fresh apple is called 'Apple pomace' which represents about 25.00 to 35.00 per cent of the weight of the fresh fruit (Kolodziejczyk *et al.*, 2007; Gulhane *et al.*, 2015). Apple pomace is a by-product of the apple juice manufacturing industry that includes a wide range of nutritionally essential compounds including carbohydrates, phenolic compounds, dietary fibre and minerals. Approximate proportions of various morphological constituents of apple pomace include pulp (54.00 %), peel (34.00 %), seeds (7.00 %), seed core (4.00 %), and stalks (2.00 %) (Nawirska and Kwaśniewska, 2005). Being an excellent source of dietary fibre and other complex polysaccharides, apple pomace exhibited the potential to be used in the bakery industry to make high-fiber baked products (Rawal and Masih, 2014).

Wheat (*Triticum aestivum*) is the staple food for most of the population of the world and is widely adapted to a variety of tropical, subtropical and temperate environments (Hussain *et al.*, 2010). Wheat is the second most produced cereal grain after maize, and the global trade of wheat is greater than all other crops combined. The worldwide wheat crop production is reported to be 779.33 MTT from an area of 206.00 MH (Statista, 2022) which occupies 27.00 per cent of the total cereal production worldwide (Curtis *et al.*, 2002). China, India, and Russia are the three largest wheat-producing countries in the world, accounting for about 41 per cent of the world's wheat production. India is the second largest producer of wheat with an annual production of 106.00 MTT from an area of 30.50 MH where most of the production is concentrated in the state of Uttar Pradesh, Madhya Pradesh, Punjab, Haryana, Rajasthan and Bihar (FAO, 2022). Wheat is a major crop and an important component of the human diet, particularly in developing countries. It provides around 20.00 per cent of the daily energy requirement. As such wheat has no food value unless it is converted to flour which can then be used to prepare a large number of products for human consumption such as cookies, crackers, pasta, noodles, bread, and breakfast foods (Narwal *et al.*, 2017). The health benefits of wheat flour can be further enhanced by blending it with the flours of other nutritious grains. People have become more health conscious and now look for additional health benefits besides the basic nutrition from cereal-based food products. For this reason, more and more multigrain food products are available in the market and attracting more consumers (Otlles and Cagindi, 2006).

Rice (*Oryza sativa*. L.) is a major cereal crop and staple food for two third of the world's population with approximately 95.00 per cent of production in Asia (Bhattacharjee *et al.*, 2002). It ranks third in production next to sugarcane and maize (Maclean *et al.*, 2013). The world's rice production is reported to be 502.98 MTT from an area of 164.19 MH (Statista, 2022). The world's major rice-producing countries are China, India, Indonesia, Bangladesh, and Vietnam. Moreover, rice is used as a source of nourishment for more than half of the world's population, thus, making it as second most important cereal grain (Bhatia *et al.*, 2009; Prasad *et al.*, 2010). India ranks as the second-largest producer of rice in the world next to China followed by Indonesia and Bangladesh. The production of rice in India is about 130.00 MTT from an area of 46.00 MH which contributes about 689.00 and 780.00 Kcal/capita/day to the food supply in Asian countries (FAO, 2022). In addition, India is one of the largest countries in terms of agricultural energy consumption of which rice forms a

significant part (Kennedy *et al.*, 2019). Rice bran oil is generally considered to be one of the high-quality vegetable oils in terms of its cooking attribution, shelf life, fatty acid composition and stability at higher temperatures as it contains oleic, linoleic, and λ -linolenic acids as unsaturated fatty acid and palmitic and stearic acids as saturated fatty acids. Red rice has been used in ancient times for human consumption and the product developed from red rice due to its high nutritional and medicinal value could be beneficial for humans. Keeping in mind the nutritional value of the raw material *viz.*, apple pomace flour, whole wheat flour and red rice flour, the present study has been undertaken for the utilization of apple pomace flour, whole wheat flour and red rice flour for the development of processed products.

2.1 PHYSICO-CHEMICAL CHARACTERISTICS OF FLOURS

2.1.1 Moisture content

Moisture content is the amount of water in the material and plays a significant role in determining the shelf life of food products (Ebuehi and Oyewole, 2007). The moisture content of apple pomace depends on the drying phenomena and storage conditions (Jung *et al.*, 2015). Moisture content in apple pomace varies from 6.55 to 11.34 per cent as observed by Sudha *et al.* (2007), Bhushan *et al.* (2008), Reis *et al.* (2014), Younas *et al.* (2015), Corral *et al.* (2016) and Jannati *et al.* (2018). Similarly, moisture content of 9.75 per cent was observed by Gazalli *et al.* (2014), 10.5 per cent by Jannati *et al.* (2018) and Azari *et al.* (2020), 8.90 per cent by Usman *et al.* (2020). Whereas a range of moisture content from 7.76 to 9.08 per cent on a dry weight basis in different varieties of apple pomace has been reported by Rana *et al.* (2021).

Alam *et al.* (2007) reported the moisture content in wheat flour varies from 9.69 to 10.35 per cent while Chuwa, (2022) recorded the moisture content of 10.49 per cent in whole wheat flour. Similarly, moisture content of 8.20 to 8.50 per cent was observed by Marathe (2002); 7.00 to 9.50 per cent by Prabhasankar and Rao (2001) and Ndife *et al.* (2011); 11.33 per cent by Schmiele *et al.* (2012); 4.79 to 6.55 per cent by Bae *et al.* (2013) and Makinde and Eytayo (2019); 13.22 per cent by Ekunseitan *et al.* (2017) and 7.70 to 12.40 per cent by Vetrmani *et al.* (2005), Gunathilake and Abeyrathne (2008), Pande *et al.* (2017) and Chauhan (2018).

The moisture content in red rice flour has been observed to range between 6.50 to 12.30 per cent (Sapna and Jaydeep, 2021); 5.30 to 14.63 per cent (Jun *et al.*, 2013; Vargas *et*

al., 2017; Sompong *et al.*, 2011, and Gusmao *et al.*, 2019. 9.75 to 11.49 per cent (Handoko *et al.*, 2021).

2.1.2 Ash content

Ash content measures the number of inorganic compounds present in a material, which mainly includes minerals. The pomace ash is white-grey and uniform in colour (Gowman *et al.*, 2019). The variation in ash content in apple pomace is due to the environmental conditions and cultivars of different apple varieties (Campbell and Sederoff, 1996). Total ash content in apple pomace has been found to range between 1.28 to 2.28 per cent as observed by Sudha *et al.* (2007), Ktenioudaki *e al.* (2013), Reis *et al.* (2014), Younas *et al.* (2015), Sahni and Shere (2017), Azari *et al.* (2020), Soni (2019) and Melikoglu *et al.* (2019). Further, Catana *et al.* (2018) revealed that 1.92 per cent and 1.75 per cent of ash content was found in Golden Delicious and Red Delicious apple pomace flour, respectively whereas slightly higher ash content was found to be 2.50 per cent as observed by Jannati *et al.* (2018). Similarly, Wang *et al.* (2019) recorded ash content of 1.80 per cent in apple pomace flour.

Ash is one of the major indicators of wheat flour's quality. Flour characterized by a higher ash level is usually less purified and contains more particles of fine bran and endosperm adjacent to the bran and also this variation is caused by the genotype, wheat class, and cultivar as well as the growing (Czaja *et al.*, 2020). The ash obtained from flour consists of mineral compounds of phosphorous, potassium, calcium, magnesium, iron, zinc, copper, and other elements (Piironen *et al.*, 2009). The ash content in wheat flour has been reported to be 1.21 per cent by Vetrmani *et al.* (2005); 1.42 per cent by Chuwa (2022); 1.50 to 1.60 per cent by Marathe *et al.* (2002), Prabhasankar and Rao (2001) and Ndife *et al.* (2011), 0.53 to 1.62 per cent by Akhtar *et al.* (2008), Maldoado *et al.* (2012) and Makinde and Eytayo (2019), 0.77 to 1.47 per cent by Schmiele *et al.* (2012), Bae *et al.* (2013) and Ekunseitan *et al.* (2017), 1.73 per cent by Pande *et al.*, 2017 and 1.05 per cent by Chauhan (2018) in whole wheat flour.

Total ash content in red rice flour has been found to range between 1.07 to 1.82 per cent as observed by Gusmao *et al.* (2019) and Vargas *et al.* (2017); 1.44 per cent by Kraithong *et al.* (2018); 0.62 to 1.34 per cent by Handoko *et al.* (2021) which was similar to values 0.69 to 1.10 per cent as reported by Severo *et al.* (2010) and Jun *et al.* (2013).

2.1.3 Fat content

Fat is an ester of fatty acid or a mixture of fatty acids found in food determined by the solvent extraction method. Apple pomace includes seeds, which contain majority of apple's fatty acids mostly as linoleic acid (18:2 n-6) and oleic acid (18:1 n-9) (Bhushan *et al.*, 2008). Fat content in apple pomace on dry weight basis was reported to be 47.00 per cent by Jin *et al.* (2002); 3.80 per cent by Wang *et al.* (2019); 2.70 per cent in Ktenioudaki *et al.* (2013) whereas, lowest fat content (0.60 %) was reported by Jannati *et al.* (2018).

In wheat, fats are mainly present in high amounts in wheat germ/embryo (Iqbal *et al.*, 2022). Ndife *et al.* (2011) reported fat content in whole wheat flour as 3.60 per cent. A similar result of fat content (2.73 %) as reported by Gomez *et al.* (2020). In another study, fat content in the range 1.90 to 2.00 was reported by Marathe *et al.* (2002); 0.87 to 1.75 per cent by Gunathilake and Abeyrathne (2008); 2.20 to 2.29 per cent by Kumar *et al.* (2011) and Ekunseitan *et al.* (2017); 1.56 to 2.92 per cent of fat was reported by Bae *et al.* (2013) and Makinde and Eyitayo (2019); and 1.47 per cent by Chuwa (2022).

The fats in rice are mainly confined to rice bran and are present as lipid bodies in the layer and bran. The major fatty acid present rice is linoleic, oleic and palmitic acid. Besides this, starch lipids also present in rice are composed of monocycle lipids complexed with amylose (Liu *et al.*, 2013). In a study, 0.20 to 0.80 per cent of fat in red rice was reported by Kaur *et al.* (2018); 1.15 to 1.82 per cent by Rathna *et al.* (2019) and Zubair *et al.* (2012); 2.67 to 3.10 per cent by Sompong (2011); 2.67 per cent by Vargas *et al.* (2017) whereas, 17.34 per cent and 0.33 per cent of fat were recorded in red rice bran and red rice starch, respectively

2.1.4 Fibre content

Apple pomace is considered as a potential source of dietary fibre (45-60 %) which includes pectin (5.50–11.70 %), cellulose (20.20–43.60 %), hemicelluloses (4.26–24.40 %), lignin (15.30–23.50 %) and gums. The fibre content in apple pomace ranges between 4.40 to 47.30 per cent as observed by Bhushan *et al.* (2008); 19.34 to 20.66 per cent by Ganai *et al.* (2006), Samkaria (2018), Negi *et al.* (2021) and Chaudhary (2021) on fresh weight basis. However, 21.51 per cent of crude fibre was reported by Sahni and Shere (2017) on dry weight basis. Comparatively, lower crude fibre 10.85 per cent was observed by Usman *et al.* (2020) on dry weight basis.

Total dietary fibre in wheat flour has been found to be 10.60 per cent by Gomez *et al.* (2020) whereas crude fibre in whole wheat flour on a dry weight basis was recorded as 2.68 per cent by Akhtar *et al.* (2008). A similar result of crude fibre (3.07 %) was recorded by Maldonado *et al.* (2012). Further, crude fibre content in whole wheat flour has been found in the range 0.51 to 4.50 per cent as observed by Gunathilake and Abeyrathne (2008) and Ndife *et al.* (2011); 0.44 to 1.50 per cent by Ekunseitan *et al.* (2017) and Makinde and Eyitayo (2019); 1.20 per cent by Chauhan (2018) and 1.42 per cent by Chuwa (2022). Comparatively larger value of crude fibre (4.50 %) was recovered by Ndife *et al.* (2011).

The total dietary fibre content in red rice has been found 6.84 per cent by Vargas *et al.* (2017); 8.80 per cent by Gusmao *et al.* (2019). Whereas, crude fibre was recorded as 0.28 to 0.61 per cent by Rathna *et al.* (2019) and 1.35 per cent by Kraithong *et al.* (2018) in red rice flour.

2.1.5 Protein content

Protein is a naturally occurring complex substance that consists of amino acid residues linked by peptide bonds. It is a macronutrient in food, essential for muscle building and is determined by the Kjeldahl method of digestion and distillation. The protein content in apple pomace varies from 3.20 to 5.80 g per 100 g as observed by Vasil'ev *et al.* (1976), Jin *et al.* (2002), Tiwari *et al.* (2008), Younis and Ahmad (2015), Jannati *et al.* (2018), Wang *et al.* (2019) and Zlatanovic *et al.* (2019). Comparatively, the lower protein content 1.20 and 2.40 per cent was reported by Jannati *et al.* (2018) and Ktenioudaki *et al.* (2013), respectively.

Wheat protein content varies widely depending on wheat class, growing region, type, and quality of soil, and of course fertilizers input (amount and timing), nitrogen in particular (Cato and Mullan, 2020). Protein content in wheat flour was reported as 9.40 to 11.30 per cent by Prabhasankar and Rao (2001); 11.70 by Maldonado *et al.* (2012); 11.70 to 15.10 per cent by Marathe *et al.* (2002) and Gomez *et al.* (2020); 9.90 to 12.47 per cent by Gunathilake and Abeyrathne (2008); Akhtar *et al.* (2008) and Ekunseitan *et al.* (2017); 12.35 to 15.04 per cent by Kumar *et al.* (2011), Ndife *et al.* (2011), Schmiele *et al.* (2012), Bae *et al.* (2013) and Pande *et al.* (2017). Whereas, slightly higher values of protein content were recorded as 13.44 and 14.90 per cent were reported by Makinde and Eyitayo (2019) and Chuwa (2022) in whole wheat flour, respectively.

Protein content in red rice was reported as 7.16 to 10.85 per cent by Rathna *et al.* (2019) and Sompong *et al.* (2011); 7.10 to 7.80 per cent by Zubair *et al.* (2012), and Seo *et al.* (2013); 8.10 to 9.67 per cent by Kaur *et al.* (2018) and Vargas *et al.* (2017). Likewise, 8.00 per cent protein content was reported by Vargas *et al.* (2017) and Gusmao *et al.* (2019) in red rice flour.

2.1.6 Total carbohydrates

Carbohydrates are energy-giving compounds that include sugars, starches and fibers found in fruits, grains, vegetables and milk. Apple pomace carbohydrates consist mainly of insoluble sugar including cellulose, hemicellulose, and lignin with simple sugar such as glucose, fructose, and galactose Gazalli *et al.* (2014). Negi (2018) recorded 67.09 per cent carbohydrate content in apple pomace powder. Similarly, 54.40 per cent carbohydrate observed by Carson *et al.* (1994); 44.20 to 49.50 g/100g by Zlatanovic *et al.* (2019) and 45.10 per cent by Wang *et al.* (2019).

The carbohydrate content in whole wheat flour ranged between 70.69 to 78.46 per cent as observed by Gunathilake and Abeyrathne (2008), while Ndife *et al.* (2011) reported 69.50 per cent carbohydrate content in whole wheat flour. Similarly, Makinde and Eyitayo *et al.* (2019) and Bae *et al.* (2013) observed 76.24 per cent and 78.07 per cent carbohydrates in whole wheat flour, respectively.

According to Rathna *et al.* (2019), Huang *et al.* (2016), Kaur *et al.* (2018), Gusmao *et al.* (2019), Sompong *et al.* (2011), Prasantha (2018), and Zubair *et al.* (2012) carbohydrates content varies from 70.75 to 82.29 per cent in red rice. Whereas, Vargas *et al.* (2017) and Kraithong *et al.* (2018) observed 80.20 per cent and 78.08 per cent carbohydrates in red rice flour respectively. Similarly, Gusmao *et al.* (2019) and Handoko *et al.* (2021) reported 76.30 and 78.07 per cent carbohydrates in red rice flour, respectively

2.1.7 Energy value

The energy and calorific value of food depend on the amount of energy yielding factors present in them and it can be determined by oxidation in a bomb calorimeter. The average values of energy are expressed as the number of calories per gram of the macronutrient. The calorific value depends on the nature of the food and the relative

proportion of proteins, fats, and carbohydrates present in that food. The energy value in apple pomace has been found to be 280.00 kcal/100g as observed by Hang and Woodams (1987). Whereas, slightly higher energy value 325.00 kcal/100g was reported by Samkaria (2018).

The energy value of wheat flour is dependent on the nutritional composition of flour and found to be 362.73 Kcal/100g as observed by Chauhan (2018). Likewise, 333.59 Kcal/g energy value was reported by Chuwa (2022) in whole wheat flour, while Cardoso *et al.* (2019) reported 402.20 Kcal/100g energy value in refined wheat flour. Similarly, Thakur (2018) obtained 357.20 Kcal/100g energy value in refined flour.

In red rice, Kaur *et al.* (2018) and Sompong *et al.* (2011) reported 323.37 Kcal/100g to 350.72 Kcal/100g energy value in red rice, respectively. Whereas, 326.33 Kcal/100g energy value was reported by Kaur and Prasad (2018) in parboiled red rice.

2.1.8 Sugar

Total Sugars include sugars naturally present in many nutritious foods and beverages, such as sugar in milk and fruits as well as any added sugars that may be present in the product by FDA (2020). An amount of 48.06 per cent of total sugars and 40.47 per cent of reducing sugars have been recorded by Devarajan (1997). The findings of Kaushal (2008) have revealed that the total sugar content in apple pomace on a dry weight basis as 38.78 per cent and reducing sugars as 13.85 per cent. The studies conducted by Chandel *et al.* (2016) have indicated 38.05 per cent of total sugars in apple pomace. Similarly, Maslovaric *et al.* (2015) estimated 30.29 per cent total sugars and 27.12 per cent reducing sugars. Similarly, Chaudhary (2021) reported total sugar content in the range 21.07 to 22.23 per cent whereas the value of reducing sugar content were found in the range 15.12 to 15.92 per cent.

Total sugar content in wheat flour varies from 2.50 to 3.50 per cent and reducing sugar varies from 0.74 to 1.85 per cent as observed by Boyacioglu and Hettiarachchy (1995), Zaied *et al.* (1996) and Kaur and Kaur (2013). However, Akubor *et al.* (2017) recorded 1.10 per cent total sugar and 0.90 per cent reducing sugar in whole wheat flour. Comparatively higher total sugar 5.18 per cent and 0.87 per cent reducing sugar was observed by Jan *et al.* (2021).

Red rice has been gaining popularity among the people due to its low glycemic index value (*i.e.*, below 55) which makes it extremely convenient option for diabetic as well as

heart patients. Jan *et al.* (2021) recorded 1.71 per cent of total sugars and 0.17 per cent of reducing sugars. The study conducted by Rao (1976) indicated 1.15 to 1.75 per cent total sugars in red rice. While, Mehra *et al.* (2020) estimated 3.76 per cent total sugars and 1.02 per cent reducing sugars. Further, Dhaliwal *et al.* (2021) recorded 1.32 per cent total sugar and 0.33 per cent reducing sugar in red rice.

2.1.9 Water activity

The lower water activity of the product ensures longer shelf life and microbial safety of the product during storage (Jung *et al.*, 2015). The studies of Soni (2019) revealed 0.43 water activity (a_w) in dried apple pomace. Whereas, according to the report of Zheng and Shetty (1998), fresh apple pomace has a water activity of 0.98. Gouw *et al.* (2017) and Parra *et al.* (2015) whereas, reported a lower water activity of 0.15 and 0.32 in dried apple pomace respectively.

The water activity of wheat flour was recorded in the range 0.30 to 0.60 by Liu *et al.* (2018). A similar result of water activity (0.46) was reported by Smith *et al.* (2016) in whole wheat flour. In another study, water activity in the range of 0.62 to 0.75 was reported in whole wheat flour by Carter *et al.* (2015).

Santos *et al.* (2020) revealed 0.55 water activity (a_w) in red rice. Similarly, Gusmao (2019) reported 0.56 water activity in red rice flour. Ansari (2022) reported 0.66 and 0.68 water activity in red rice and red rice flour, respectively in their investigations.

2.1.10 Pectin

Pectin is a family of complex variable polysaccharides extracted from the primary cell wall of higher plants. Pectin in apple pomace is mainly present in the form of protopectin, an acid-soluble polysaccharide (Schemin *et al.*, 2005). The studies of Chandel *et al.* (2016) showed that apple pomace contains 2.33 per cent of pectin (% as calcium pectate) on a fresh weight basis and 14.66 per cent of pectin on a dry weight basis. Paz *et al.* (2018) also observed that pectin content ranged in between 8.80 to 13.50 per cent in Golden Delicious apple fruit. Pectin content ranged from 0.71 to 0.93 per cent in apple fruit while 3.20 to 13.30 per cent in apple pomace on a fresh weight basis as observed by Skinner *et al.* (2018). Similarly, pectin content of 13.30 per cent was observed by Guzel and Akpınar (2019); 3.50

to 14.32 g/100g by Antonic *et al.* (2020) on dry weight basis. Further, Ryadinskaya *et al.* (2021) noticed a lower concentration of pectin *i.e.*, 6.40 per cent in the apple variety Zhigulevskoe.

2.1.11 Ascorbic acid

Apple pomace can be a potential source of healthy food. Ascorbic acid is a common antioxidant found in apple pomace, that can rapidly reduce quinones and inhibit enzymatic browning (Vlad *et al.*, 2022). Kumar (1992) reported 8.53 mg/100g of ascorbic acid on a dry weight basis in apple pomace, however, Garg *et al.* (2008) revealed a value of 18.50 mg/100g for ascorbic acid content in apple pomace. Similarly, Chandel *et al.* (2016) have reported 19.30 mg/100g of ascorbic acid in apple pomace. Similarly, Soni (2019) have reported 10.07 mg/100g ascorbic acid content in apple pomace flour, while the ascorbic acid content in the range 16.13 to 18.44 mg/100g reported by Chaudhary (2021) in apple pomace flour.

2.1.12 Total phenols

Phenolic compounds are also known as polyphenols and are generally found in two forms such as free and bounded (Arshad *et al.*, 2021). Total phenol content in apple pomace expressed as gallic acid equivalent was found to be 796.00 mg GAE/100g (Cetkovic *et al.*, 2008); 49.30 mg GAE/100g (Younas *et al.*, 2015); 578.00 mg/100g (Rana *et al.*, 2015) and 324.20 mg/100g (Corral *et al.*, 2016) in the pomace of the Golden Delicious variety of apples. Studies conducted by Azari *et al.* (2020) revealed the total phenolic content of 962.00 mg GAE/100g in apple pomace flour, while the phenolic content of 459.00 mg GAE/100g was observed in Royal Delicious apple pomace by Rana *et al.* (2021). Similarly, Negi *et al.* (2021) noticed total phenolic content of 550.00 mg GAE/100g in apple pomace. Total phenolic content of 975.00 mg GAE/ 100 g in apple pomace flour was recorded by Usman *et al.* (2020), likewise similar value of total phenols (894.00 mg GAE/100g) in apple pomace flour was observed by Gumul *et al.* (2021).

The total phenol content in whole wheat flour expressed as gallic acid equivalent was found to be 17.70 to 25.70 mg GAE/100g by Yu *et al.* (2001), 8.02 to 9.72 mg GAE/100g by Adom *et al.* (2003); 11.30 to 37.10 mg GAE/100g by Yu *et al.* (2004), 4.40 to 14.00 mg GAE/100g by Vaher *et al.* (2010), 36.50 mg GAE /100g by Narwal *et al.* (2017) and 6.97 to 13.60 mg GAE/100g by Wang *et al.* (2020).

Phenolic acids in rice grains are present in two forms including soluble and insoluble forms (Wongsa, 2020). The total phenol content in red rice expressed as gallic acid equivalent was found to be 118.47 mg GAE/100g by Rathna *et al.* (2019). 691.37 mg GAE/100g by Samyor *et al.* (2017), 170.00 to 570.00 mg GAE/100g by Seechamnaturakit *et al.* (2018) and Korumilli and Mishra (2014) and 366.30 mg GAE/100g by Das and Bhattacharya (2019) in red rice flour. Moreover, total phenol content in red rice flour has been reported in the range 79.18 to 691.37 mg GAE/100g by Sompong *et al.* (2011) and 210.10 to 233.17 mg GAE/100g by Handoko *et al.* (2021).

2.1.13 Antioxidant activity

Natural antioxidants are of plant origin and include vitamins, phenolic compounds, and flavonoids (Hussain *et al.*, 2004). Antioxidants act as oxygen scavengers and prevent oxidative damage by interfering with the oxidation process thereby scavenging free radicals, chelating and catalytic metals (Shahid and Wanasundara, 1997). The antioxidant capacity of apple pomace flour varied in the range of 33.50 to 55.10 per cent as observed by Usman *et al.* (2020), Rana *et al.* (2021) and Ranjbar *et al.* (2020). However, 58.00 per cent antioxidant activity was recorded by Azari *et al.* (2020) in apple pomace flour. A significantly higher antioxidant activity 93.00 per cent recorded by Gumul *et al.* (2021) and 87.88 to 98.47 per cent by Chaudhary (2021).

Antioxidant activity in wheat flour has been reported to be 12.30 per cent by Sharma and Gujral (2014) and as high as 14.45 per cent by Narwal *et al.* (2017). Similarly, antioxidant activity in wheat flour was found in the range of 8.75 to 14.32 per cent by Zilic *et al.* (2012); 7.40 to 8.90 per cent by Wang *et al.* (2020); 10.30 per cent by Bhat *et al.* (2019) and 7.40 per cent by Azari *et al.* (2020).

Proanthocyanidins were identified to be as dominant antioxidants in red rice flour. The antioxidant activity of red rice was found to be in the range from 12.99 to 56.36 per cent by Kaur *et al.* (2018). Similarly, 67.10 per cent antioxidant activity was observed by Maulani *et al.* (2019) and 61.00 per cent by Korumilli and Mishra (2014) in red rice. The significantly higher antioxidant activity of 91.80 per cent reported by Das and Bhattacharya (2019) and 90.00 per cent by Vargus *et al.* (2017) recorded in red rice flour.

2.1.14 Anthocyanin

Anthocyanins are water-soluble pigments belonging to the phenolic group are present in glycosylated forms. Anthocyanins responsible for the colors such as red, purple and blue, are present in fruits and vegetables. The total anthocyanin content in apple pomace has been found 5.00 to 13.00 mg/100g by Lyu *et al.* (2020), and 4.50 to 7.40 mg/100g by Yan and Kerr (2013). Whereas 13.00 mg/100g anthocyanin was reported by Lavelli and Kerr (2012) in apple pomace.

Anthocyanin are the primary functional components of pigment rice (Samyori *et al.*, 2017) and around eighteen anthocyanins are present in rice, four have been quantified (Cyaniding-3-0-glucoside, peonidin-3-0-glucoside, cyanidin-3-0-rutinoside, and cyanindin-3-0-galactoside) (Goufo and Trindade, 2014). Total anthocyanin content in red rice varied from 0.30 to 1.40 mg/100g as observed by Sompong *et al.* (2011), Maulani *et al.* (2019) and Rathna *et al.* (2019), 4.30 mg/100g by Limtrakul *et al.* (2016) and Caro *et al.* (2013) and also found as high as 8.78 mg/100g as observed by Mackon *et al.* (2021).

2.1.15 Colour

Colour is one of the most important appearance attributes of food material and minimal changes to this attribute after processing. LAB is three-dimensional, which covers the entire range of human colour perception. The 'L*' indicates the intensity of colour *i.e.*, lightness which varies from 'L*' equals to 100 for perfect white to 'L*' equals 0 for black. Whereas 'a*' is a chromatin designation of colour *i.e.*, the value of measured redness when positive, grey when zero, and greenness when negative 'b*' value represents the blue-yellow opponents with negative numbers towards blue and positive towards yellow (Prasad *et al.*, 2017). The 'L*', 'a*', and 'b*' values of apple pomace flour ranged between 71.50 to 75.70, 6.19 to 6.68, and 21.30 to 26.70, respectively as observed by Yan and Kerr (2013). While 76.39 'L*', 7.61 'a*', and 20.33 'b*' value was observed in apple pomace by Liu *et al.* (2019). In another study, Parra *et al.* (2019) analyzed the colour value in the range 40.10 to 54.10 'L*', 6.50 to 7.86 'a*', and 10.50 to 18.18 'b*', in 'L*', in apple pomace flour respectively.

The 'L*', 'a*', and 'b*' values of commercial wheat flour were 73.80, -0.90, and 13.30, respectively as reported by Hung *et al.* (2007). While, 83.63 'L*', -0.18 'a*', and 11.99 'b*' values were observed in whole wheat flour by Liu *et al.* (2017). In another study, Malik *et al.*

(2015) analyzed the colour value in whole wheat flour and recorded as 71.29 L*, 1.68 a*, and 29.19 b*. Similarly, 'L*', 'a*' and 'b*' value 79.73, 2.47 and 12.10 was reported by Pande *et al.* (2017); 85.70, 1.92 and 12.05 by Sharma and Gujral (2014) in whole wheat flour, respectively.

The colour of red rice is due to the presence of the pigment anthocyanin, which is also responsible for its better phenol content and increased antioxidant activity. Red rice derives its eye-grabbing colour from anthocyanin component and has much more nutrient value as compared to other varieties of rice. 'L*' value of red rice flour was reported as 75.30, 74.96, and 71.34 by Sapna and Jaydeep (2021), Gusmao *et al.* (2019), and Kraithong *et al.* (2018) respectively. However, the 'a*' value was observed to be 5.20 to 6.80 (Sapna and Jaydeep *et al.*, 2021); 3.99 (Gusmao *et al.*, 2019) and 11.22 (Kraithong *et al.*, 2018) in red rice flour. Similarly, the 'b*' value was recorded as 10.90 to 12.20 by Sapna and Jaydeep (2021); 11.48 by Gusmao *et al.* (2019), and 11.22 by Kraithong *et al.* (2018). The 'L*', 'a*' and 'b*' values of red rice were reported by Kaur *et al.* (2018) as 62.93 to 76.36, 1.23 to 7.99, and 14.01 to 16.70, respectively.

2.2 FUNCTIONAL PROPERTIES OF FLOURS

2.2.1 Apple pomace flour

Apple pomace is a very good source of dietary fibre since it contains nearly 40.00 per cent dietary fibre on a dry weight basis (Alongi *et al.*, 2019). According to AACC (2001), dietary fibre is a remnant of the edible part of the plant, it is analogous to carbohydrates that are resistant to digestion and absorption in the human small intestine and undergo complete or partial fermentation in the large intestine. Dietary fibre has many health benefits that may help in the treatment of obesity, atherosclerosis, coronary heart disease, colon cancer, and diabetes by decreasing blood glucose levels. It binds hydrochloric acid, metal ions, and cholesterol in the stomach and also stimulates the growth of probiotic microflora in the intestines (Kruczeck *et al.*, 2017). A recommended intake of total dietary fibre is 28 and 25 g per day for young men and women, respectively (USDA, 2007). It is also a good source of phytochemicals such as phenolics, flavonoids, and flavan-3-ols (Cetkovic *et al.*, 2008). Polyphenols are the secondary metabolites of plants that provides health-promoting properties such as antioxidant, antimicrobial, anti-cancerous, and cardiovascular protective activities (Bendini *et al.*, 2006).

2.2.2 Whole wheat flour

Cereal grains are one of the most important food groups, and their fibers are known to render health benefits that may be attributed to the nature of cell wall polymers and chemical architecture (Bunzel *et al.* 2001). Epidemiological studies have shown that consumption of wheat bran is associated with a reduced risk of colorectal and gastric cancer (Jacobs *et al.* 1995). Cereals contain a high amount of hydroxycinnamates (HCA) that may exert potential health benefits (Andreasen *et al.*, 2001). In cereals, HCA and their dimers exist mainly as esters bound to arabinoxylan. In many studies, phenolic antioxidants of wheat have been tested in their free form only (Zhou and Yu, 2004). To understand the total antioxidant activity of cereals, it is imperative to consider the contribution of their bound phenolics since under normal conditions phenolics occur mainly in the bound form (Andreasen *et al.*, 2001). Ferulic acid is the major phenolic acid in many cereals grains and exists predominantly in the seed coat, while traces may be present in the starchy endosperm. Oxidative stress arises when the generation of oxidative species exceeds the capacity of the antioxidant system in the body. The enhancement of naturally occurring endogenous antioxidant defense system through a balanced diet by consuming plant-derived foods may protect the body against oxidative stress (Zhou and Yu, 2004).

2.2.3 Red rice flour

The main active compounds in pigment rice are anthocyanins (Vargas *et al.*, 2000). They are derived from polyhydroxylated and methoxylated heterosides obtained from 2-phenyl benzopyrilium aglycon or the flavylum ion (anthocyanidin) Ferreira (2013). However, protocatechuic acid, synapic acid, vanillic acid, p-coumaric acid, and ferulic acid are the primary phenolic acids in pigment rice, where the level of soluble phenolic acids is approximately 81.00 per cent, making it a crucial factor in an index of grain resistance (Maisuthisakul and Changchub, 2014). Similarly, tricetin appears to be the main flavonoid in bran, accounting for about 77.00 per cent of all seven flavonoids. Flavonoids are the bioactive molecules produced by the phenylpropanoid metabolic pathway, which possess nutraceutical properties viz., antioxidant effect, inhibition of lipid peroxidation, sparing effect on vitamin E in erythrocyte membrane, antiviral, immunomodulatory, anti-tubercular, antiulcerogenic, anti-mutagenic, mildly estrogenic, anti-inflammatory and potent anticancer effects (Kim *et al.*, 2010). According to Laokuldilok *et al.* (2011), γ -oryzanol constitutes

around 51.80 per cent of the total antioxidant content in red rice and is a more powerful antioxidant than α -tocopherol due to its reducing effect on cholesterol oxidation. Pigment rice with high nutraceutical properties can be utilized for the production of value-added products to combat certain deficiencies and daily lifestyle diseases.

2.3 FOURIER TRANSFORM INFRA-RED SPECTROSCOPY OF FLOURS

2.3.1 Apple pomace flour

The FTIR spectra are mainly used for the structural analysis of the biomolecules based on the presence of the functional groups and provide results in the form of peaks. The FT-IR spectra of apple pomace flour confirmed the prevalence of lignocellulosic fibres (cellulose, hemicellulose, and lignin), already known as major compounds present in apple pomace, as reported by Chand *et al.* (2015) and Fan *et al.* (2012). Polysaccharides with different structures and compositions with absorption bands at $800 - 1200 \text{ cm}^{-1}$ were recorded in apple pomace flour by Kacurakova (2000). The most intense peak of apple pomace flour in the FT-IR spectra of cellulose and hemicellulose with the maximum in the area $1020-1046 \text{ cm}^{-1}$, originating from the C-C, C-OH, C-H group vibrations were observed in the spectra of apple pomace flour by Chand *et al.* (2014). The bands positioned at $2845-2849$ and $2916-2921 \text{ cm}^{-1}$ originated from stretching vibrations of -C-H and -C-H₂ groups of aliphatic carbon chains. Each tested sample had intense peaks observed at the wavelength of $3285-3315 \text{ cm}^{-1}$, corresponding to free water stretching vibration of phenol -OH groups studied by Chand *et al.* (2015), and also a peak was observed at the wavelength $1735-1741 \text{ cm}^{-1}$ originating from C=O, the most prevalent group in pectin and hemicellulose. Absorption at $1625-1641 \text{ cm}^{-1}$ originated from H-O-H bending vibration and was affected by the concentration of absorbed water read by Chargot *et al.* (2014).

2.3.2 Whole wheat flour

The FTIR spectra of the wheat flour samples showed peaks in the range of $3270-3300 \text{ cm}^{-1}$, which represents the O-H stretching. Even a minor shift in these peaks increases the moisture content, which proportionally increases the water absorption capacity of the wheat flour. The spectra for the C-H stretch of starch stand in the range of $2925-2935 \text{ cm}^{-1}$. The peaks that appear in the wavelength of 950 to 750 cm^{-1} are used for carbohydrate analysis (Wani *et al.*, 2014). These peaks help to distinguish the pyranoid or furanoid ring vibrations

of the mono and polysaccharides present in the flour (Amir *et al.*, 2013). Another study carried out by Amir *et al.* (2013) a band range for the anhydrous C=O stretch of the pyranoid ring was observed between 840 and 860 cm^{-1} . The presence of peaks in the range of 1625–1635 cm^{-1} represents the C=O stretch of amide I. The peaks of the NH bend or CN stretch of amide II of protein occur in the wavelength of 1520–1550 cm^{-1} (Amir *et al.*, 2013).

In a recent study reported by, Zhao *et al.* (2020) the two characteristic peaks found at 1720 cm^{-1} and 1610 cm^{-1} of the carbonyl (C=O) stretching in the acetyl groups and asymmetrical stretching in the C=O group of pyruvate groups, respectively. However, bands at 3360 and 2930 cm^{-1} in brown rice anthocyanin were attributed to O-H and C-H stretching vibrations, respectively. The bands at 1710 and 1640 cm^{-1} of the C-O vibration correspond to the benzopyran aromatic ring. While the peaks at 1600 and 1490 cm^{-1} were attributed to the benzene ring's C=C conjugate bond vibration, a band at 1280 cm^{-1} indicated the stretching vibration of the pyran ring of flavonoid compounds.

2.3.3 Red rice flour

Three different rice cultivars have been found to exhibit intense, distinct peaks that range from 3600 to 3700 cm^{-1} and 3200 to 3500 cm^{-1} . Broad bands at 3610-3640 cm^{-1} and 3200-3500 cm^{-1} are ascribed with OH stretching vibrations, suggesting the presence of phenolic OH. The asymmetrical and symmetrical stretching vibrations of the hydroxyl group are represented by the moderate C-H stretching band, which was found in rice cultivars at a range of about 2891 to 2937 cm^{-1} . The weak C-H stretching band in the FT-IR spectra may explain the presence of phenolic acid in some rice cultivars (Samyori *et al.*, 2017). Whereas, Korumilli and Mishra (2014) examined the rice powder pigment's spectra and found that the majority of its peak structures are identical to those of β -carotene (Baranska *et al.*, 2006). Peaks at 2943 and 2832 cm^{-1} are produced by symmetric and asymmetric stretching vibrations of the CH₂ and CH₃ groups, respectively (Ammawath and Bin, 2010). The (RH)C=C(RH) groups that are produced in the pigment have a peak tail vibration at 1020 cm^{-1} . Symmetric deformation of CH₃ and deformation vibration of CH₂ groups are the basis of the 1405 and 1448 cm^{-1} peaks, respectively. In addition, vibrational modes of water interference are responsible for the peaks at 3320, 1652, and 1020 cm^{-1} in the pigment under study.

2.4 UTILIZATION OF APPLE POMACE

Worldwide apple pomace production in million metric tonnes is expected to further increase in the future. However, the recovery rate of this by-product is very low. In India, only one percent of the apple pomace can be utilized as animal feed and dry products (Shalini and Gupta, 2010). Therefore, only a small amount of apple pomace is used due to its rapid spoilage in wet conditions (Bates and Roberts, 2001). It can also be utilized as charcoal briquettes from dried apple pomace and this charcoal is further used in water purification (Hang and Walters, 1989). Dried apple pomace is also used as fuel for steam generation in processing plants which can significantly contribute to the energy budget (Fischer, 1984). Apple pomace can be utilized for the preparation of edible products such as apple pomace jam and sauce, the production of citric acid, and the preparation of apple pomace papad (Hang and Woodams, 1984, Joshi *et al.*, 1996, and Kaushal *et al.*, 2002). Kaushal and Joshi (1995) prepared cookies by incorporating different amounts (10-50 %) of apple pomace powder in the dough. Sensory evaluation showed that incorporation of apple pomace up to 30.00 per cent could be appropriate for the preparation of good quality cookies.

Negi *et al.* (2021) utilized apple pomace powder (APP) for the formulation of fiber-enriched muffin pre-mix. Refined wheat flour was replaced with apple pomace powder at different concentrations ranging from 5.00 to 50.00 per cent and found that 33.00 per cent APP was highly acceptable. During six-month storage in polyethylene and aluminum laminated pouches, it was observed that the crude and total dietary fibre was found to be higher in fibre-enriched muffin pre-mix than in control, also it showed higher fat absorption and water holding capacity during the storage period. According to the cost analysis, apple pomace is a sustainable alternative as compared to traditional pre-mix muffins.

Xu *et al.* (2020) studied the incorporation of apple pomace powder (APP) for the development of Chinese raw noodles to introduce health benefits. The addition of APP has been studied in the proportion of 5.00, 10.00, 15.00 and 20.00 per cent to develop Chinese noodles. The data showed that the increase in the level of APP decreased the whiteness index, cohesiveness and tensile strength of the noodles from 77.20 to 54.10 per cent, 70.00 to 46.00 per cent, and 47.00 to 30.00 per cent, respectively, while increased cooking loss and water uptake from 4.00 to 6.40 per cent and 67.00 to 77.00 per cent, respectively. APP addition also affected the texture profile of the noodles such as gumminess, chewiness, and springiness to

different extents. Overall, the addition of 5.00 to 10.00 per cent of apple pomace powder was accepted for Chinese raw noodles.

Apple pomace is one of the main sources of fruit pectin and the common methods of extraction include enzymatic, chemical, and mechanical. Recently many novel methods have been proposed. The environment-friendly method with combined physical and enzymatic treatments to extract pectin from apple pomace was also utilized by Min *et al.* (2010). Wang *et al.* (2014) used supercritical water to extract pectin from apple pomace. The mixture was heated at different temperatures for a few min, then the supernatant was filtered, and the product i.e., pectin was collected by alcohol precipitation, washing, and drying. The highest pectin recovery rate (16.68 %) was found at 150 °C temperature.

The development of biodegradable packaging films based on natural polysaccharides has attracted intensive attention. Red apple pomace extract was utilized to develop chitosan and nano TiO₂ based film. The film has strong antioxidant and antimicrobial activity and also showed sensitive color variations, indicating its applicability as a freshness indicator (Lan *et al.*, 2021). Likewise, Riaz *et al.* (2020) utilized apple pomace powder to develop a chitosan-based film, which, the film delayed weight loss and retard the decay percentage of strawberries.

2.5 VALUE-ADDED PRODUCTS

2.5.1 WAFFLE CONE

Ice cream cone is a baked product made from a batter mixture mainly composed of wheat flour, vegetable oil, eggs, full cream milk, and sugar. There are two types of ice cream cones *i.e.*, wafer cones and waffle cones which are baked in a mold and rolled into a cone shape to serve ice cream. The difference is based on the percentage of each ingredient used in its batter and processing methods. Their distinct crunch and crispness contrast with the smooth texture of ice cream which makes it highly likable by consumers. They are calorie dense due to their fat and carbohydrate content. Waffle cones are also baked in a mold but are more flexible when fresh out of the flat-shaped mold. This allows it to be rolled and cooled into a conical shape using a plastic or metal roller. Both waffle and wafer cones fall under the category of biscuits according to Indonesian national standards due to their composition (Austin, 2021).

Waffle cones are often made with higher percentages of flour as compared to eggs and sugar. Due to this composition, their batter is more solid when cooked which does not allow it to be rolled or shaped in any way. They are made by filling a mold that has a gap in a shape of a cone and heated to cook and solidify inside the mold (Prayoga *et al.*, 2015; Kigozi *et al.*, 2016).

Kigozi *et al.* (2011) completely substituted wheat flour with whole white sorghum flour (200 g) unsieved and sieved, for utilization in cone making. Some ingredients in the sorghum cones recipe varied such as maize starch (60 g and 70 g), water (350 mL and 400 mL), while the quantity of all other ingredients i.e., as sugar, oil, soya lecithin, sodium, and ammonium bicarbonate, sodium metabisulphite, and salt. The data showed one-way, two-way, and three-way effects during the dough mixing to increase water and maize binder and reduction of flour size were found to be significant but the correlation between functionality (cream holding time) was found to be weak. Developed cones had higher cream holding time of 22 min and crispiness was maintained for consumer acceptance against the commercially available wheat cone. The consumer acceptance test was done by a panel of 31 people in two types of categories on a 9-point hedonic scale (appearance, colour, flavour, texture, and overall acceptability) and the food action rating scale (frequency of eating measurement). Sorghum cone was found higher in acceptance as compared to wheat cone in terms of texture, taste, overall acceptability, and FACT rating. The following parameter was measured 7.97 per cent moisture content, 10.17 g weight and 100.00 per cent backing ability.

Dom *et al.* (2020) substituted wheat flour with sweet potato peel flour (SPPF) (5, 10 and 15 %) to develop a waffle ice cream cone. The addition of SPPF had an impact on the quality of the waffle cone such as colour, odour, tensile strength, and texture properties. The results show that waffle cones obtained with the addition of SPPF turned darker than the control sample. The tensile strength of SPPF fibre material becomes balanced and stable with the cone structure. In addition to 5.00 per cent of SPPF, the texture was similar to the control but has higher crispiness as compared to 10.00 and 15.00 per cent SPPF of waffle cones.

Insiah *et al.* (2020) studied the effects of the substitution of purple sweet potato flour (PSPF) and different baking times, colour, flavor, taste and texture of ice cream cones. The flour was substituted at the levels of 100.00, 75.00, 50.00 and 25.00 per cent and the baking time varied from 20, 25 and 30 min. The result was observed on the basis of yield, thickness,

the resistance of ice cream cone, water content test, protein content and reducing sugar content. The best treatment was selected 75.00 per cent PSPF with 20 min of baking time based on consumer acceptance using an organoleptic test including 30 semi-trained panelists. The selected sample showed 4.07 per cent moisture content, 0.98 per cent yield, 2.67 mm thickness, 85 min resistance of cone, 27.46 mg/L protein content, 3.89 mg/l reducing sugar content and also the organoleptic values on the 5-point hedonic scale for colour, flavour, taste and texture were 3.73, 3.57, 3.57 and 2.97, respectively.

Phuenpipob *et al.* (2016) utilized okara powder (60 mesh size) utilization for the replacement of wheat flour in the making of ice cream cones. Okara and wheat flour in the ratio of 30:70, 35:65 and 40:60 was utilized for the purpose. The best treatment ratio of 35:65 was selected by thirty panelists on a 9-point hedonic scale basis. where, the score for odour, taste, texture, and overall acceptability were 6.80, 7.23, 7.23 and 7.30, respectively. The developed product was solid yellow-brown colour, 2.00 mm in thickness and had 16.00 N hardness, where the thickness and hardness showed a positive linear relationship with moisture content and water activity. At the end of 23 days of storage period at room temperature, the values for protein, fat, carbohydrate, ash, moisture, and crude fibre content of developed products were found to be 13.56, 17.22, 63.61, 1.14, 2.92, and 1.55, respectively. No microbial growth was found during the storage time in metalized or aluminum foil.

Zanariah *et al.* (2019) used banana peel flour (BPF) for the development of fibre enriched waffle cone. The BPF (5, 10 and 20 %) was used to substitute the wheat flour to make batter mix for making waffle cones. The addition of BPF affected the physico-chemical parameters such as pH, colour, odour and tensile strength. The results showed lower values of L* and b*, which indicates darker colour as compared to the control. The high-water holding capacity of BPF reduced the tensile strength of the waffle cone. It was found that substitution with 5.00 and 10.00 per cent BPF was accepted in terms of physical properties, however, increasing the BPF levels up to 20.00 per cent reduced the tensile strength and poor sensory characteristics.

2.6 STORAGE STUDIES

Food packaging of food products is done to protect them from outside influences and damage and to provide consumers with ingredient and nutritional information (Marsh and

Bugusu, 2007). According to Jan *et al.* (2017) the composition of gases (oxygen, carbon dioxide, inert gases, ethylene), pressure and/or mechanical stress, relative moisture (RH), light and temperature are the essential elements which impact the preservation qualities of the food product. Accelerated storage is another approach for determining shelf life, and the Arrhenius model is a standard model that connects the rate of a chemical reaction to temperature variations. This model is commonly used in a variety of temperature-dependent processing and storage studies. However, it is a source of worry as shelf-life determination is only valid for a certain combination of product composition, packaging and processing circumstances (Breda *et al.*, 2012; Ryavanki and Hemalatha, 2018).

Chapter - 3

MATERIALS AND METHODS

The present investigation entitled “**Development and evaluation of Apple pomace waffle cone**” was carried out under various experiments at the Department of Food Science and Technology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh. Different experiments and sub-experiments were laid down and standardized in a sequence to achieve the objectives of the study. Material used, experimental details and techniques employed during the investigation have been described in this chapter under the following heads:

3.1 RAW MATERIAL

3.2 EXPERIMENTAL DETAILS

3.3 DEVELOPMENT OF APPLE POMACE FLOUR BASED WAFFLE CONE

3.3.1 Optimization of recipe for the development of waffle cone

3.3.2 Optimization of ingredients for the development of waffle cones through Response Surface Methodology

3.3.3 Preparation of waffle cone

3.4 DEVELOPMENT OF APPLE POMACE FLOUR BASED WAFFLE CONE PRE-MIX

3.4.1 Optimization of recipe for development of waffle cone pre-mix

3.4.2 Optimization of ingredients for the development of waffle cone pre-mix through Response Surface Methodology

3.4.3 Formulations of waffle cone – premix

3.4.4 Preparation of waffle cone from pre-mix

3.5 EVALUATION OF STORAGE STABILITY OF DEVELOPED PRODUCT

3.5.1 Evaluation of storage stability of waffle cone

3.5.2 Evaluation of storage stability of waffle cone- premix

3.6 QUALITY EVALUATION OF RAW MATERIAL AND PROCESSED PRODUCTS

3.6.1 Physico-chemical characteristics of flour, waffle cones and waffle cone pre-mix

3.6.2 Characteristics of waffle cone batter, waffle cone and waffle cone pre-mix

3.6.3 Sensory evaluation of waffle cone and waffle cone pre-mix

3.6.4 Texture analysis

3.6.5 Colour

3.6.6 Microbial examination

3.7 STATISTICAL ANALYSIS

3.8 PREDICTION OF SHELF LIFE

3.9 COST OF PRODUCTION OF VALUE-ADDED PRODUCTS

3.1 RAW MATERIAL

Fresh apple pomace was collected from commercial processing unit, Department of Food Science and Technology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh. Apple pomace was firstly treated with potassium metabisulphite for prevention of enzymatic browning and colour retention, followed by spreading the apple pomace on the tray with the thickness of 2.00 to 2.50 cm and dried at 55.0 ± 2 °C for 15-20 h in a cabinet drier. The dried pomace was ground in electric grinder (WILLEY WM-500) and sieved through a 30 mesh-sieve. The pomace flour was packaged in polyethylene pouches and stored in the ambient temperature (22.0 to 28.0 °C) until further use. Other materials *viz.*, whole wheat flour, red rice flour, sugar powder, milk, milk powder, potato starch, ripe banana and butter etc. were procured from the local market.

3.2 EXPERIMENTAL DETAILS

The apple pomace flour with whole wheat flour and red rice flour was used for the development of apple pomace waffle cone, gluten-free apple pomace waffle cone, apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix. Developed products were then subjected to quality analysis and shelf-life studies.

3.3 DEVELOPMENT OF APPLE POMACE FLOUR BASED WAFFLE CONE

3.3.1 Optimization of recipe for development of waffle cone

Apple pomace waffle cone and gluten-free apple pomace waffle cone were prepared from apple pomace flour with whole wheat flour and apple pomace flour with red rice flour, respectively by using the recipe standardized by Kigozi *et al.* (2014) and Dom *et al.* (2020) for sorghum-based ice cream cone and sweet potato peel flour-based ice cream cone, respectively, with minor modifications. For the optimization of apple pomace flour-based

waffle cone, various pre-trials were conducted. On the basis of sensory properties, the recipe was selected for further studies. The desirable quantity of ingredients used for preparation of the apple pomace flour-based waffle cone is shown in Table 3.1.

Table 3.1 Optimization of ingredients for preparation of waffle cone

Ingredients	Quantity
Apple pomace flour	20 g
Whole wheat flour/ Red rice flour	8 g
Ripe mashed banana	15 g
Sugar powder	10 g
Butter	10 g
Milk	80-85 mL

Source: Kigozi *et al.* (2014) and Dom *et al.* (2020)

3.3.2 Optimization of ingredients for development of waffles cone through RSM

The central composite design (CCD) was selected for the study as it drastically reduces the number of experiments when more than three variables are involved. CCD was used to design the experiments without any blocking comprising of three independent variables (A: Apple pomace flour, B: Whole wheat flour and red rice flour and C: Sugar powder). The ranges for different independent variables (Table 3.2) for selection of ingredients for preparation of apple pomace waffle cone (Apple pomace flour with whole wheat flour) and gluten-free apple pomace waffle cone (Apple pomace flour with red rice flour) were selected on the basis of preliminary trials. Different combinations of variables were formulated as per the RSM model design. The quadratic and linear models were used to analyze the responses such as ice cream holding time (min), hardness (g), brittleness (mm), toughness (g.sec), crispiness and overall acceptability (On 9-point Hedonic scale) of apple pomace waffle cone (apple pomace with whole wheat flour) gluten-free apple pomace waffle cone (apple pomace flour with red rice flour), comprising of 20 experimental runs (Table 3.3).

$$Y = X_0 - X_1A_1 - X_2B_2 - X_3C_3 - X_{11}A_{11}^2 - X_{22}B_{22}^2 - X_{33}C_{33}^2 - X_{12}AB_{12} - X_{13}AC_{13} - X_{23}BC_{23} \text{ --Eq. (3.1)}$$

From this equation ‘y’ was the response variable, X_0 was intercepted, X_1 , X_2 , and X_3 were linear coefficients, X_{11} , X_{22} , and X_{33} were quadratic coefficients, X_{12} , X_{13} and X_{23} were interaction coefficients and A, B, C, A^2 , B^2 , C^2 and AB, AC and BC were the levels of independent variables (apple pomace flour, whole wheat flour/ red rice flour and sugar powder).

Table 3.2 Coded values of independent variables used for experimental design

Independent variables	Lower limit	Upper limit
A: Apple pomace flour (g)	16.00	24.00
B: Whole wheat flour and Red rice flour (g)	4.00	12.00
C: Sugar powder (g)	5.00	15.00

Table 3.3: Detail for the treatments for the preparation of waffle cone as designed by RSM

Run/ Treatment	Factor 1 A: Apple pomace flour (g)	Factor 2 B: Whole wheat flour and red rice flour (g)	Factor 3 C: Sugar powder (g)
T ₁	26.72	8.00	10.00
T ₂	16.00	4.00	15.00
T ₃	20.00	8.00	1.59
T ₄	20.00	8.00	10.00
T ₅	20.00	8.00	10.00
T ₆	20.00	8.00	18.40
T ₇	24.00	12.00	15.00
T ₈	16.00	12.00	5.00
T ₉	24.00	4.00	15.00
T ₁₀	24.00	4.00	5.00
T ₁₁	20.00	8.00	10.00
T ₁₂	20.00	14.72	10.00
T ₁₃	20.00	8.00	10.00
T ₁₄	20.00	8.00	10.00
T ₁₅	16.00	12.00	15.00
T ₁₆	20.00	1.27	10.00
T ₁₇	13.27	8.00	10.00
T ₁₈	16.00	4.00	5.00
T ₁₉	20.00	8.00	10.00
T ₂₀	24.00	12.00	5.00

Independent variables = Apple pomace flour, Whole wheat flour and red rice flour and Sugar powder

Dependent variables = ice cream holding time (min), Hardness (g), Brittleness (mm), toughness (g.sec), Crispiness, and Overall Acceptibility (Based on 9 point).

3.3.3 Preparation of waffle cone

For the preparation of waffle cone, powdered sugar and melted butter were mixed together, followed by the addition of mashed banana and milk to the mixture with continuous mixing until the consistency of the batter become soft and creamy. The dry ingredients such

as apple pomace flour, and whole wheat flour/ red rice flour were added with continuous mixing to attain the desirable viscosity of the batter. The batter was allowed to stand for 10 min in order to raise the air bubble to the top. The batter was poured on the waffle cone maker pan, baked for 2 min at 150 °C temperature. Each waffle was immediately folded into a cone shape by using a cone molder after it was removed from the pan. The waffle cone were initially warped in batter paper and then packed in low-density polyethylene and aluminium laminated pouches for further analysis.

3.4 DEVELOPMENT OF APPLE POMACE FLOUR BASED WAFFLE CONE PRE-MIX

3.4.1 Optimization of recipe for development of waffle cone pre-mix

The treatment standardized from the RSM mentioned in Table 3.3 with the recipe mentioned in Table 3.1 was further taken for the preparation of apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix with the replacement of wet ingredients to dry ingredients such as milk to milk powder and banana to potato starch.

For the optimization of apple pomace waffle cone pre-mix (Apple pomace flour with whole wheat flour) and gluten-free waffle cone pre-mix (Apple pomace flour with red rice flour) various pre-trials were conducted. On the basis of sensory properties, the recipe was selected for further studies. The desirable quantity of ingredients used for preparation of apple pomace flour-based waffle pre-mix is shown in Table 3.4.

Table 3.4 Optimization of ingredients for preparation of waffle cone from pre-mix

Ingredients	Quantity
Apple pomace flour	20 g
Whole wheat flour/ Red rice flour	8 g
Sugar powder	10 g
Milk powder	10 g
Potato starch	2 g
Water	80-85 mL

3.4.2 Optimization of ingredients for development of waffle cone pre-mix through RSM

Response surface methodology was used to determine the influence of independent variables on the responses of waffle cone pre-mix. The effect of the independent variables viz. milk powder (X_1) and potato starch (X_2) was observed on the different responses of the waffle cone. The variables were coded according to the equation:

$$X_i = (x_i - \hat{x}_i) / \Delta x_i$$

Whereas, X_i is the dimensionless value of an independent variable, \hat{x}_i is the real value of an independent variable at the centre point and Δx_i was the step change. The dependent variables taken were ice cream holding time (min), hardness (g), brittleness (mm), toughness (g.sec), crispiness, and overall acceptability (based on 9-point hedonic scale). The quadratic model was used to analyze the responses for the preparation of waffle cone, comprising of 13 experimental runs (Table 3.6).

$$Y = X_0 - X_1A_1 - X_2B_2 - X_{11}A_{11}^2 - X_{22}B_{22}^2 - X_{12}A_1B_2 \dots \dots \dots \text{eq.}$$

From the, 'y' is response variable, X_0 is intercept, X_1 and X_2 are linear coefficients, X_{11} and X_{22} are quadratic coefficients, X_{12} are interaction coefficient and A, B, A^2 , B^2 and AB are the levels of independent variables (milk powder and potato starch).

To evaluate model adequacy, regression coefficient (R^2) and statistical significance, analysis of variance (ANOVA) was used. To visualize the relationship between the response and independent variables, surface response and contour plots of the fitted regression equations, optimal conditions for the targeted responses were generated.

Table 3.5 Coded values of independent variables used for experimental design

Independent variable	Coded Values	
	Lower limit	Upper limit
A= Milk powder (g)	7.00	13.00
B= Potato starch (g)	1.00	3.00

Table 3.6 Experimental plan for preparation of waffle cone pre-mix as per the RSM design

Run / Treatments	Factor 1 A: Milk powder (g)	Factor 2 B: Potato starch (g)
T ₁	10.00	2.00
T ₂	10.00	0.59
T ₃	10.00	2.00
T ₄	14.24	2.00
T ₅	10.00	2.00
T ₆	10.00	2.00
T ₇	13.00	1.00
T ₈	10.00	3.41
T ₉	7.00	3.00
T ₁₀	10.00	2.00
T ₁₁	13.00	3.00
T ₁₂	7.00	1.00
T ₁₃	5.76	2.00

Independent variables = Milk powder and Potato starch

Dependent variables = ice cream holding time (min), Hardness (g), Brittleness (mm), toughness (g.sec), Crispiness, and Overall Acceptability (Based on 9 point)

3.4.3 Formulations of waffle cone pre-mix

The treatment standardized from the RSM and mentioned in Table 3.6 with the recipe mentioned in Table 3.4 was further taken for preparation of waffle cone pre-mix.

Various steps were followed for the preparation of the waffle cone pre-mix. For uniform mixing of the ingredients such as apple pomace flour, whole wheat flour, powder sugar, milk powder and potato starch powder for apple pomace waffle cone pre-mix and red rice flour on the replacement of whole wheat flour for gluten-free apple pomace waffle cone pre-mix were sieved 1-2 times through 30 mesh sizes which was then packed in low-density polyethylene pouches (LDPE) and Aluminium laminated pouches (ALP) and stored for further study.

3.4.4 Preparation of waffle cone from pre-mix

For the preparation of waffle cone from premix, the standardized amount of water (Table 3.4) and melted butter was added and mix thoroughly to make a batter from waffle cone premix. The batter then allowed to stand for 10 min in order to raise the air bubble to the top. The batter was poured on the waffle cone maker pan, baked for 2 min at 150 °C temperature. Each waffle was immediately folded into a cone shape by using a cone molder after it was removed from the pan. The waffle cone was properly stored for further analysis.

3.5 EVALUATION OF STORAGE STABILITY OF DEVELOPED PRODUCT

3.5.1 Evaluation of storage stability of waffle cone

Waffle cones prepared from apple pomace flour based (Apple pomace waffle cone and gluten-free apple pomace waffle cone) were packed in low density polyethylene pouches (LDPE) as well as in aluminium laminated pouches (ALP). The storage study was conducted in accelerated storage conditions at 0, 7, 14 and 21 days at 38 °C temperature with 90 per cent relative humidity as per the similar conditions maintained by Romani *et al.* (2015) and were analyzed every 7 days for storage stability.

3.5.2 Evaluation of storage stability of waffle cone pre-mix

Waffle cone pre-mix prepared from apple pomace flour based (Apple pomace waffle cone pre-mix and Gluten-free apple pomace waffle cone pre-mix) were packed in low density polyethylene pouches (LDPE) and aluminium laminated pouches (ALP). The storage study was conducted in accelerated storage conditions at 0, 7, 14 and 21 days interval where the temperature was maintained at 38⁰C and humidity at 90 per cent similar to conditions maintained by Jaya and Das (2005) and were analyzed every 7 days for storage stability.

3.6 QUALITY EVALUATION OF RAW MATERIAL AND PROCESSED PRODUCTS

3.6.1 Physico-chemical characteristics of flours, waffle cone and waffle cone pre-mix

3.6.1.1 Physical characteristics

The flours (apple pomace, whole wheat and red rice) were analyzed for following physical attributes:

3.6.1.1.1 Bulk density and tapped density (g/mL)

Bulk density and tapped density of fractioned flour were determined by method given by Goula *et al.* (2004). Bulk density was measured in graduated cylinder by gently adding 20 g of flour fraction in 50 mL graduated cylinder followed by gentle tapping and the volume was recorded. The ratio of mass of flour to the volume occupied in the cylinder denotes the bulk density. For tapped density, same cylinder was tapped on a bench for 100 times from a height of 10 cm and tapped density was calculated by dividing mass of flour with new volume occupied by the sample.

$$\text{Bulk density (g/mL)} = W/V_b$$

where,

W = weight of flour

V_b = bulk volume

$$\text{Tapped density (g/mL)} = W/V_t$$

where,

W = weight of flour

V_t = tapped volume

3.6.1.1.2 Hausner ratio and Carr compressibility

Carr Index (Carr, 1965) and Hausner Ratio (Hausner, 1967) was calculated from bulk and tapped density which determines the flowability and compressibility of powders. The scale of flowability according to the US Pharmacopeia (2016) is given in Table 3.7. The following formula was used:

$$\text{Carr compressibility (\%)} = \frac{\text{Tapped density} - \text{Bulk density}}{\text{Tapped density}} \times 100$$

$$\text{Hausner ratio (HR)} = \frac{\text{Tapped density}}{\text{Bulk density}}$$

Table 3.7 Scale of flowability of powders

Carr Compressibility (%)	Flow character	Hausner Ratio
10	Excellent	1.00-1.11
11-15	Good	1.12-1.18
16-20	Fair	1.19-1.25
21-25	Passable	1.26-1.34
26-31	Poor	1.35-1.45
32-37	Very poor	1.46-1.59
>38	Very, very poor	>1.60

3.6.1.2 Functional characteristics of flour

3.6.1.2.1 Water absorption capacity (g/g)

Water absorption capacity (WAC) was determined by method given by Beuchat (1977) with slight modifications. 2 g of sample was taken in pre-weighed 50 mL centrifuge tube, to which 20 mL of distilled water was added and mixed well. Solution was kept for 30 min at room temperature and was shaken after every 5 min followed by centrifugation in a revolutionary research centrifuge at 3000 rpm for 15 min. The supernatant was collected in the pre-weighed evaporating dish and kept at $102 \pm 2^\circ\text{C}$ for drying until it gets dry. The weight of remaining gel was noted after the removal of the supernatant and WAC was calculated as per the formula given.

$$\text{WAC (g/g)} = \frac{\text{Weight of gel obtained after removal of the supernatant (g)}}{\text{Weight of sample (g)}}$$

3.6.1.2.2 Water solubility index (WSI)

The amount of dried solids recovered by evaporating the supernatant from the WAC analysis was taken as water solubility index (WSI).

$$\text{WAI (g/g)} = \frac{\text{Weight of dry solids in supernatant (g)}}{\text{Weight of sample (g)}}$$

3.6.1.2.3 Oil absorption capacity (g/g)

Oil absorption capacity (OAC) was determined by method given by Kacou *et al.* (2018). 1 g of the sample was taken in a 50 mL pre-weighed centrifuge tube and mixed thoroughly with 10 mL of refined soybean oil by using vortex mixer. Samples were allowed to stand 30 min at room temperature and were shaken after every 5 min followed by centrifugation in a revolutionary research centrifuge at 3000 rpm for 15 min. After centrifugation, supernatant was carefully decanted and weight of gel obtained after removal of supernatant is noted and OAC was calculated as per the formula given.

$$\text{OAC (g/g)} = \frac{\text{Weight of gel obtained after removal of the supernatant (g)}}{\text{Weight of sample (g)}}$$

3.6.1.3 Chemical Characteristics

3.6.1.3.1 Moisture content (%)

The moisture content of flour, waffle cone, waffle cone pre-mix was evaluated by drying a weighed sample (5g) to a constant weight in a Moisture Analyzer, A&D Company, Limited Tokyo Japan. The weighed sample is spread on the pan evenly so that it is heated equally from all sides. Measurement accuracy is highest when the sample is measured at suitable drying temperature depending upon the sample characteristics. Therefore, moisture content of flour, waffle cone and waffle cone pre-mix was estimated at 140°C as per the inbuilt program of the Moisture Analyser instrument. The moisture content is calculated as per the formula given by (Ranganna, 2009).

$$\text{Moisture content (\%)} = \frac{\text{Wet sample mass} - \text{dried sample mass}}{\text{Wet sample mass}} \times 100$$

3.6.1.3.2 Water activity (a_w)

Computer digital water activity meter (Rotronic Hygropalm) was used to measure the water activity (a_w) of the sample at room temperature. Sample was filled in standard cuvette

upto rim and placed below the water activity meter sensor which gives direct reading of sample's water activity (AOAC, 2012).

3.6.1.3.3 Ash content (%)

Total ash was determined gravimetrically by taking the weighed sample in pre-weighed silica crucibles. The oven dried samples after moisture determination were heated on a hot plate until bulk of organic matter was burnt and no more fume formation occurs. The crucibles were then placed in a muffle furnace for ashing at 550°C for 5 hours to obtain a carbon free white ash with a constant weight. The ash content of samples was then calculated and expressed as per cent on fresh weight basis (Ranganna, 2009) as given below:

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample taken}}$$

3.6.1.3.4 Crude protein (%)

Crude protein was estimated by using the kjeldahl digestion and scrubber system (Buchi Pvt Ltd.). This method is based on the determination of amount of reduced nitrogen (NH₂ and NH) present in the sample and involved three basic steps, i.e., digestion, distillation and titration. About 1-2 g of finely ground sample was placed in digestion tube and catalyst tablet was added to the tube. Then about 10-20 mL of concentrated sulphuric acid was measured and added to digestion tube to complete the digestion of the sample. When sample boiled with conc. sulphuric acid, most of the nitrogenous compounds present in it were converted into ammonium sulphate (digestion). Ammonium sulphate thus formed, was decomposed with an alkali (NaOH), and liberated ammonia was absorbed in the excess of neutral boric acid solution which was then titrated against standardized acid (0.1 N HCl). Crude protein content (%) was calculated in the sample by multiplying per cent nitrogen with the factor of 6.25 (Ranganna, 2009) as given below:

$$\text{Nitrogen (\%)} = \frac{(\text{Sample titre} - \text{Blank titre}) \times \text{Normality of HCl} \times 14}{\text{Weight of sample} \times 1000} \times 100$$

$$\text{Crude protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

3.6.1.3.5 Crude fat (%)

Weighed sample of 3-10 g was kept in the oven initially for removal of moisture, which is then taken in thimble and inserted in extraction equipment for estimation of fat. Oil was extracted using petroleum ether (40 - 60°C BP) as solvent in Soxhlet Oil Extraction

Apparatus (M/s Velps Scientifica, SRL Italy) pre-programmed (130 ° C temperatures, 60 min washing time and 15 min recovery time). After extraction process of 2 hours, the ether extract was collected and poured in beaker. The beaker was then kept in hot air oven for one hour at 70° C for removal of remaining solvent before taking final weight for fat content. The fat content of samples was then calculated and expressed as per cent (Ranganna, 2009) using the formula given below:

$$\text{Crude fat (\%)} = \frac{W_2 - W_1}{W} \times 100$$

Where,

W = Weight of sample

W₂ = Weight of beaker after evaporation of solvent

W₁ = Weight of empty beaker

3.6.1.3.6 Crude Fiber (%)

0.5-1g of sample was weighed in crucibles for Raw Fiber Analyzer (Velp Scientifica). 150 mL H₂SO₄ was added up to 150 mL notch and boiled for 30 min from onset of boiling. Sulfuric acid was drained followed by washing with 30 mL of hot water. 150 mL of KOH and 3-5 drops of antifoaming reagent (H₂O₂) was added and boiled for 30 min. Then washing was done with hot water followed by cold water and acetone (25 mL). The crucibles were removed and dried in oven at 105°C for an hour upto constant weight. This weight represents crude fiber plus ash content (F₁). Crucibles were placed in muffle furnace and heated upto 550°C for 3 hours and reweighed after cooling in desiccator (F₂). Fiber content was calculated by using the following formula (AOAC, 2000):

$$\text{Crude fiber (\%)} = F_1 - F_2 / F_0 \times 100$$

Where,

F₀ = Weight of sample

3.6.1.3.7 Total Dietary Fiber (%)

For estimation of total dietary fiber, 1 g (duplicate) sample was weighed and mixed with 50 mL of phosphate buffer (pH 6). It was then subjected to sequential enzymatic digestion to remove protein and starch from the sample by incubating at 98 - 100°C for 30

min with heat stable 50µl (0.05mL) α-amylase. The pH was adjusted to 7.5 with 0.275 N NaOH and 100 µl (0.1mL) of protease was added and incubated at 60°C for 30 min. Then, the pH was adjusted to 4.5 with 0.325 N HCl and sample was incubated with 200 µl (0.2mL) amyloglucosidase at 60°C for 30 min. Ethanol (95%) was used to precipitate the dietary fiber overnight. Precipitates were filtered with whatman paper no. 42 filter paper. Then the residues were washed with alcohol and acetone and collected in crucibles to dry overnight at 105°C. After that, sample was weighed and analyzed for ash and protein. The per cent TDF (total dietary fiber) was calculated by deducting the weight of protein and ash (Mala *et al.*, 2018).

$$\% \text{ TDF} = [\text{R sample} - (\text{P sample} + \text{A sample}) / \text{Sample weight}] \times 100$$

Where,

TDF = Total Dietary Fiber

R = Average Residue Weight (mg)

P = Average Protein Weight (mg)

A = Average Ash Weight (mg)

3.6.1.3.8 Carbohydrate (%)

The total carbohydrate content was determined by subtracting the sum of per cent value of moisture, crude protein, crude fat, crude fiber and ash from 100 (NIN, 1983).

$$\text{Total carbohydrates (\%)} = 100 - (\% \text{ moisture content} + \% \text{ crude protein} + \% \text{ crude fiber} + \% \text{ crude fat} + \% \text{ ash})$$

3.6.1.3.9 Energy value (kcal/100g)

Energy value of the sample was measured in bomb calorimeter (Model Toshiwal DT-100); which is based on the principle that the amount of heat produced by burning the sample must be equal to the amount of heat absorbed by calorimeter assembly. Firstly, the crushed sample is dried in a hot air oven to remove the moisture and is converted into solid form. One gram of the dried sample was taken for measurement of energy value. The chamber was filled with 1500 mL of distilled water and was attached to one of the ignition wires. Central terminal on the bomb head and the second wire was attached to the socket provided on the bomb hanger. The thread was tied with ignition wire and pushed down into the sample. The

air was replaced with pure oxygen and with the rise in temperature, the sample burned automatically in the bomb calorimeter assembly and after complete burning of the sample the calorific value was produced on the display screen of the instrument as kcal/100g of sample (Kays and Barton, 2002).

3.6.1.3.10 Pectin content as calcium pectate (%)

The method given by Virk and Sogi (2004) was used for estimation of pectin content in which 50 g sample was extracted with HCl (400 mL, 0.05 M) for 2 h at 80–90°C. The mixture was then cooled, volume was made to 500 mL and filtered (Whatman No. 4). Filtrate (100 mL) was neutralized and then NaOH (10 mL, 1 M) was added with constant stirring. It was allowed to stand overnight. Acetic acid (50 mL, 1 M) was added and allowed to stand for 5 min. Following this, calcium chloride solution (25 mL, 0.5 M) was added, allowed to stand for 1 h, boiled for 1–2 min and filtered through previously prepared filter paper (filter paper wet in hot water, dried in an oven at 102°C for 2 h, cooled in a desiccator and weighed in a covered dish). The precipitates were washed with hot water until free from chloride (tested using 1% silver nitrate). Filter paper containing calcium pectate was dried over night at 100°C, cooled in desiccator and weighed.

$$\% \text{ Calcium pectate} = \frac{\text{Weight of calcium pectate} \times 500 \times 100}{\text{mL of filtrate taken for estimation} \times \text{weight of sample taken}}$$

3.6.1.3.11 Starch content (%)

Starch content of samples was determined using anthrone method described by Hodge and Hofreiter (1962) using glucose as standard (100 mg in 100 mL water). 0.1 to 0.5 g of sample was homogenized in hot 80 per cent ethanol to remove sugars and was centrifuged. The residue collected after centrifugation was dried over water bath followed by addition of 5 mL water and 6.5 mL 52 per cent perchloric acid. Mixture was than extracted at 0°C for 20 min, centrifuged and supernatant was collected. Extraction was repeated using fresh perchloric acid and supernatants were pooled to the final volume of 100 mL. 0.1 to 0.2 mL of supernatant was pipetted out and volume was made to 1 mL with distilled water. This was followed by addition of 4 mL anthrone reagent and boiling in hot water bath for 8 min. Content of test tubes were cooled and intensity of green to dark green color was read at 630 nm. Concentration of starch in samples was then determined using standard curve.

3.6.1.3.12 Total sugars (%)

The amount of total sugar in the sample was determined by Phenol sulphuric acid method using glucose as a standard. Standard curve was prepared by using different concentrations (10, 25, 50, 75 and 100 µg) of glucose in test tubes and volume of each tube was made 1mL by adding distilled water. 1mL of 5 per cent phenol and 5mL of 96 per cent sulphuric acid was added one by one to each tube and shaken well. After 10 min all the tubes were placed in water bath at 25-30 °C for 15 min. Blank was set with 1mL of distilled water and O.D. of was taken at 490nm with the help of UV/Visible spectrophotometer-800 Shimadzu, Tokyo, Japan. A standard calibration curve of glucose using its different concentrations was prepared. Then the whole process following phenol- sulphuric acid method was repeated with 0.2mL of sample and the O.D. of sample solutions were taken at 490 nm. The amounts of total sugars in the sample were determined using standard curve (AOAC, 2010).

3.6.1.3.13 Reducing sugars (%)

The amount of reducing sugar in the sample was determined by 3,5-Dinitrosalicylic acid (DNS or DNSA) method using glucose as a standard. Standard curve was prepared by using different concentrations (10, 25, 50, 75, 100 µg) of glucose in test tubes and volume of each tube was made 1mL by adding distilled water. To each test tube, 3 mL of DNS reagent was added and test tubes were placed in a boiling water bath for 5 min. While the contents of the tube were still warm, 1 mL of 40% Rochelle salt solution was added to each test tube. Contents were then cooled and intensity of dark red colour was read at 510 nm with the help of UV/Visible spectrophotometer-800 Shimadzu, Tokyo, Japan. For sample analysis, sugars in the sample (100 mg) were extracted with hot 80% ethanol twice (5 mL each time). Supernatant was collected and evaporated by keeping on hot water bath at 80°C. Residue was then dissolved in 10 mL water; out of which 0.5 to 3 mL of sample was taken and whole DNS method was repeated. Absorbance of sample solutions were taken at 510 nm. The amounts of reducing sugars in the sample were determined using standard curve (AOAC, 2010).

3.6.1.3.14 Total phenols (mg GAE/100g)

The amount of total phenols in the sample was estimated with Folin-Ciocalteu reagent using gallic acid as standard. 1 mg of sample was taken in pestle and mortar and

ground with 1 mL of methanol, and centrifuged (Revolutionary Research Centrifuges) for 20 min at 5000 rpm. An aliquot of 1 mL was taken in separate test tube and 5 mL of Folin-Ciocalteu reagent (10%) was added. After 10 min, 4 mL of sodium carbonate (7%) was added and mixed. Then the test tubes were placed in water bath at 30-40°C for 40 min and cooled. The sample optical density was recorded at 765 nm using the UV-VIS spectrophotometer (Model Shimadzu, Japan). The concentration was determined as per the standard procedure from the standard curve. The standard curve was prepared using different concentrations of gallic acid solution of 0, 50, 100, 150, 200 and 250 mg/l in methanol using the above procedure (Bray and Thorpe, 1954).

3.6.1.3.15 Antioxidant activity (%)

Antioxidant activity (Free radical scavenging activity) was measured as per the method given by Williams *et al.* (1995) with some modification. In this method, 6×10^{-5} DPPH (2,2-diphenyl-1-picrylhydrazyl) was used as free radical source. 0.1 mL of sample extract (1 g sample extracted with 10 mL of methanol) was taken in test tube and 3.9 mL of DPPH solution was added. Absorbance was measured at 515 nm after 30 min using UV-VIS spectrophotometer (Model Shimadzu, Japan). Methanol was used as blank. Antioxidant activity was calculated as per the formula:

$$\text{Antioxidant activity (\%)} = \frac{\text{Ab (B)} - \text{Ab (S)}}{\text{Ab (B)}} \times 100$$

Where,

Ab (B) = Absorbance of blank

Ab (S) = Absorbance of sample

3.6.1.3.16 Ascorbic Acid content (mg/100g)

Ascorbic acid content was determined by the method described by Ranganna (2009) by using 2,6-di-chlorophenol-indophenol visual titration method. The samples were prepared in 3 per cent meta-phosphoric acid solution and titrated against dye solution till pink colour persisted for few seconds. Ascorbic acid content was expressed as mg of ascorbic acid per 100g of sample.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Volume of sample taken} \times \text{Aliquot taken for estimation}} \times 100$$

3.6.1.3.17 Total anthocyanins (mg/100g)

About 1 g of sample was added to a mixture of 95 per cent ethanol and 1.0 mol/L citric acid (85:15). The extraction was performed in a thermostated cell, protected from light, under constant stirring. After processing, the extract was filtered using Whatman No. 1 filter paper and the residue was rinsed using the extraction solvent up to a volume of 25 mL. The extract was stored at -4°C in glass bottles. Total anthocyanin content of sample was quantified by UV/Visible spectrophotometer-800 Shimadzu, Tokyo, Japan at 535 nm. The anthocyanin expressed as cyanidin-3-glucoside (C3G) equivalents (mg/ 100g) of dry weight rice sample was determined using the formula mentioned below (AOAC, 2010).

$$\text{Total anthocyanins (TA)} = \frac{\text{Absorbance} \times \text{volume made up}}{\text{Weight of sample}} \times 100$$

3.6.1.3.18 Free Fatty Acid (mg/g)

Acid value also known as free fatty acid was estimated by standard procedure given by Ranganna (2009). A known quantity of sample containing neutral solvents (25 mL Diethyl ether + 25 mL 95 % alcohol + 1% phenolphthalein) was titrated against 0.1N KOH solution using phenolphthalein as an indicator. The acid value / free fatty acid was calculated by the following expression:

$$\text{Acid value (mg/KOH/g oil)} = \frac{\text{Titre} \times \text{Normality of KOH} \times 56.1}{\text{Weight of oil (g)}}$$

3.6.2 Characteristics of batter and waffle cone

3.6.2.1 Viscosity

The viscosity of the waffle cone batter was measured by using a Brookfield viscometer (Model DV-III, Stoughton, MA, US). Waffle cone batter was transferred to a beaker of 100 mL, and filled to the brim. The spindle speed was set at 20 rpm and for all experiments spindle No. 7 was used. Viscosity was measured immediately. The experiment was conducted at room temperature (25 ± 2 °C) (Srivastava *et al.*, 2012).

3.6.2.2 Weight (g)

Weight of waffle cone was observed with the help of digital weighing balance.

3.6.2.3 Thickness (mm)

Digital vernier caliper was used to determine the thickness of the waffle cone (Gomez *et al.*, 2008).

3.6.2.4 Ice-cream holding time (min)

Ice-cream holding time of waffle cone was determined by digital watch.

3.6.2.5 Baking loss (%)

The baking loss rate was calculated using the percentage of weight of the waffle cone after baking and the weight of the batter. (Mrabet *et al.*, 2015)

3.6.3 Sensory evaluation of waffle cone

The sensory evaluation of waffle cone was carried out using 9-point Hedonic scale method (where, 1= Dislike extremely and 9 = Like extremely). The sensory parameter includes texture, taste, colour and overall acceptability. Efforts were made to retain the same panel for sensory assessment during the whole study period. The samples were given to judges along with plain water to rinse their mouth between sample evaluation. No discussion was allowed during evaluation (Amerine *et al.*, 1965).

3.6.4 Texture analysis

Texture was accessed by Texture Profile Analysis (TPA) using a Texturometer texture Analyser, TAXT2i from Stable Microsystems, UK, equipped with 5 kg cell load. A single compression force required to cause breakage towards the waffle cone samples at room temperature was used to obtain the texture profile using a 75 mm diameter (P/75) cylindrical compression probe with the ice cream cone support ring (A/ICC). Test parameters comprised hardness, brittleness, toughness and crispiness. The instrument was operated at pre-test speed of 1.0 mm/s, test speed of 5.00 mm/s and post-test speed of 5.00 mm/s.

3.6.5 Colour

Sample colour was measured in a Lovibond Colour Tintometer Model PFX-I series spectrophotometer in which RYBN colour units were obtained along with CIE (Comission Internationale de l'éclairage) readings i.e., L*, a* and b* values. The L* value is a measure of product colour where lightness ranged between 100 and 0, 100 for perfect white and 0 for

black. The a* value represents the colour range green to red and the b* values represent the colour range yellow to blue. Each sample was measured three times for colour. Change in colour (ΔE), chroma (C*), hue (h^0), browning index (BI) and colour index (CI) were calculated by the following formula (Ranganna, 2009)

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

$$h^0 = \tan^{-1} b/a$$

$$\Delta E = \sqrt{(a^*)^2 + (b^*)^2}$$

3.6.5 Mineral content

The dry ashing method was used for mineral estimation. The ground sample was placed into a crucible overnight in an electric muffle furnace; the temperature was maintained between 410 to 440⁰ C. Ashing was done to destroy all of the organic matter present in the sample. The ash was removed from the crucible and allowed to cool in desiccators. Two gram of ash was digested with a mixture of HCl and nitric acid in the ratio 1:3. The digested sample was dissolved in 50 mL of distilled water and used for the assay of trace elements such as phosphorus, potassium, sodium, calcium, sulphur, magnesium, iron, copper, zinc, and manganese through atomic absorption spectrophotometer (Rajasekaran *et al.* 2005).

3.6.6 Microbial examination

The total plate count (TPC) was calculated by aseptically inoculating 1g of serially diluted sample in total plate count having agar medium prepared according to the Ranganna (2009). 1g of sample after serial dilutions was aseptically inoculated in pre-sterilized plates, followed by pouring total plate count agar (10-15mL) under sterilized condition of laminar air flow. Incubation of the plates were done at 37°C for 24-48 h prior to counting of microbes. The result of the total plate counts were then calculated in log cfu/mL of the sample.

3.7 STATISTICAL ANALYSIS

Data pertaining to sensory evaluation of waffle cone were analyzed by using randomized block design (RBD). Completely randomized design (CRD) were used before and during storage to analyse data on physico-chemical characteristics of different product

and Central composite design (CCD) was used for the optimization of ingredients in different experiments and various experiments conducted in this study were replicated three times. (Mahony, 1985)

3.8 PREDICTION OF SHELF LIFE

The shelf life of waffle cone and waffle cone pre-mix was predicted by Arrhenius graph plot. The order of reaction was determined as zero order reaction, first order reaction and second order reaction and the self-life determination were according to highest correlation coefficient (R^2). The Arrhenius graph was plot using rate of reaction (k) versus time (days).

$$\text{Determination of self-life } t = \frac{A_t - A_0}{K}$$

Where,

A_0 = Value at the time beginning of self-life

A_t = Value at end of self-life

t = Self-life

k = Quality degradation constant

3.9 COST OF PRODUCTION OF VALUE-ADDED PRODUCTS

Cost for the purchase of raw materials like apple pomace flour, whole wheat flour, red rice flour, sugar, butter, milk, milk powder, potato starch, low-density polyethylene pouch and aluminium laminated pouch was taken into account and throughout the evaluation @ 20 per cent charge was included in terms of the equipment depreciation value and processing charges.

Chapter - 4

RESULTS AND DISCUSSION

The present investigations entitled “**Development and evaluation of apple pomace waffle cone**” were carried out in the Department of Food Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during the year 2021-22. The results obtained in the different experiments have been described and explained under the following heads:

- 4.1 Quality characteristics of raw material**
- 4.2 Optimization of ingredients for the development of apple pomace waffle cone through response surface methodology**
- 4.3 Optimization of ingredients for the development of gluten-free apple pomace waffle cone through response surface methodology**
- 4.4 Physico-chemical characteristics of waffle cones**
- 4.5 Optimization of ingredients for the development of apple pomace waffle cone pre-mix through response surface methodology**
- 4.6 Optimization of ingredients for the development of gluten-free apple pomace waffle cone pre-mix through response surface methodology**
- 4.7 Quality characteristics of waffle cone pre-mixes**
- 4.8 Storage study of standardized products**
- 4.9 Prediction of shelf life of waffle cone and waffle cone pre-mix**
- 4.10 Cost of production**
- 4.11 Microbial quality**

4.1 QUALITY CHARACTERISTICS OF RAW MATERIAL

The physical, functional and optical quality of flour are presented in table 4.1, 4.2 and 4.3.

4.1.1 Physical Quality of flours

The bulk density and tapped density of apple pomace flour, whole wheat flour and red rice flour were recorded 0.684, 0.625 and 0.581 g/cm³ and 0.773, 0.819 and 0.832 g/cm³, respectively. The highest bulk density was recorded for apple pomace flour whereas the lowest was recorded for red rice flour. The similar values of bulk density in the range of 0.480- 0.557 g/cm³ were reported by Sahni and Shere, (2017), Negi, (2018) and Samkaria,

(2018) in apple pomace flour. Shafi *et al.* (2016), Suriya *et al.* (2017) and Manupriya *et al.* (2020) evaluated the bulk density for whole wheat flour found in the range of 0.520-0.710 g/cm³ and Dhaliwal *et al.* (2021) recorded bulk density for red rice flour in the range of 0.477-0.657 g/cm³. The variation of bulk and tapped density might be due to the moisture content of the flour as well as flour preparation methods. The low moisture content is associated with the high bulk and tapped density of flour (Goula *et al.*, 2004 and Zhao *et al.*, 2009). The carr index and hausner ratio is also influenced by the bulk and tapped density of the flours. The carr's index value for apple pomace flour, whole wheat flour and red rice flour was 11.514, 23.686 and 30.168 per cent and Hausner's ratio was 1.130, 1.310 and 1.432 respectively. The Carr's index represent the flowability of flour, whereas, Hausner's ratio showed the cohesiveness of the flour. Whole wheat flour and red rice flour were having fair flowability, whereas apple pomace flour had good flowability. It could be observed from the value of Hausner's ratio that apple pomace flour and whole wheat flour had intermediate cohesiveness, however red rice flour showed comparatively high cohesiveness. The values were calculated according to the classification made by US Pharmacopeia (2006).

Table 4.1: Physical quality of flours

Physical quality	Mean ± SD		
	Apple pomace flour (APF)	Whole wheat flour (WWF)	Red rice flour (RRF)
Bulk density g/cm ³	0.684 ± 0.00	0.625 ± 0.00	0.581 ± 0.00
Tapped density g/cm ³	0.773 ± 0.0	0.819 ± 0.00	0.832 ± 0.02
Carr's index %	11.514 ± 0.00	23.686 ± 0.00	30.168 ± 0.00
Hausner ratio	1.130 ± 0.00	1.310 ± 0.00	1.432 ± 0.00

4.1.2 Functional quality of flours

Functional quality of flour reported in the Table 4.2 showed water holding capacity (WHC), water absorption index (WAI), and fat absorption capacity (FAC). The WHC and WAI of apple pomace flour, whole wheat flour and red rice flour were observed to be 3.23 g/g and 3.11, 1.17 g/g and 1.08 and 1.53 g/g and 1.44, respectively. The apple pomace flour showed higher WHC and WAI as compared to whole wheat flour and red rice flour. Similar results for WHC for apple pomace flour in the range of 3.39-4.60 g/g was observed by Negi, (2018) and Gorjanovic *et al.* (2020), Alviola and Monterde (2018) and Chauhan (2018) reported WHC for whole wheat flour in the range of 1.31-4.20 g/g while, Boulemkahel *et al.*, 2021 observed WHC for red rice flour in the range of 1.43-1.93 g/g. at absorption capacity was recorded as 2.70, 1.02 and 1.39 g/g for apple pomace flour, whole wheat flour and red

rice flour, respectively. The result was almost near to the range of 1.30-2.24 analyzed by Gorjanovic *et al.* (2020) and Sahni and Shere, (2017) for apple pomace flour. Alviola and Monterde (2018) and Chauhan (2018) reported FAC for whole wheat flour in the range of 0.88- 2.60 g/g and Boulemkahel *et al.* (2021) analysed FAC for red rice flour in the range of 0.76-1.62 g/g. Apple pomace flour observed to have higher water holding capacity, water absorption index and fat absorption capacity as compared to whole wheat flour and red rice flour which may be due to the fact that high amount of fibre content is present in apple pomace flour.

Table 4.2: Functional quality of flours

Functional quality	Mean ± SD		
	Apple pomace flour (APF)	Whole wheat flour (WWF)	Red rice flour (RRF)
Water holding capacity (g/g)	3.23 ± 0.09	1.17 ± 0.05	1.53 ± 0.07
Water absorption index	3.11 ± 0.01	1.08 ± 0.01	1.44 ± 0.02
Fat absorption capacity (g/g)	2.70 ± 0.01	1.02 ± 0.04	1.39 ± 0.01

4.1.3 Optical quality of flours

Colour is a very important appearance attribute of food material for evaluating the properties of the raw material used for the processing which also provides information about end product composition and its quality. It is a critical parameter in defining the uses and acceptability of a product (Kaur *et al.*, 2018). Data presented in Table 4.3 and Fig 4.1 (a, b and c) represent the optical quality of apple pomace flour, whole wheat flour and red rice flour. The L *, a * and b * values of apple pomace flour were recorded as 48.35, 2.64 and 29.99, while in case of whole wheat flour these were recorded to be 79.29, -0.08 and 15.00 and 50.99, 2.10 and 17.55 for red rice flour, respectively. The lightness was recorded higher in whole wheat flour as compared to red rice flour and apple pomace flour due to the presence of anthocyanin content in red rice and apple pomace. Similar, values of optical properties were recorded in the range (40.10-54.10) L*, (6.50-7.86) a* and (10.50 to 18.18) b* by Perra *et al.* (2019) for apple pomace flour. Pande *et al.*, (2017) and Lie *et al.*, (2017) observed L *, a * and b * values for whole wheat flour in the range (79.73-83.63) L*, (-0.18-2.47) a* and (11.99-12.10) b*. Vargas *et al.* (2017) and Ansari (2022) reported L *, a * and b * values for red rice flour in the range (42.11-57.18) L*, (3.05-17.13) a* and (12.71-17.13) b*. The hue angle (h⁰) which is the dimension of the colour perceived was observed to be higher (84.96) in apple pomace flour followed by 83.17 in red rice flour and -89.69 in whole wheat flour.

Table 4.3: Optical quality of flours

Optical quality	Mean \pm SD		
	Apple pomace flour (WWF)	Whole wheat flour (WWF)	Red rice flour (RRF)
L* (lightness)	48.35 \pm 0.06	79.29 \pm 0.09	50.99 \pm 0.07
a* (redness-greenness)	2.64 \pm 0.01	-0.08 \pm 0.01	2.10 \pm 0.02
b* (yellowness- blueness)	29.99 \pm 0.05	15.00 \pm 0.02	17.55 \pm 0.03
Hue angle (h^o)	84.96 \pm 0.08	-89.69 \pm 0.09	83.17 \pm 0.07

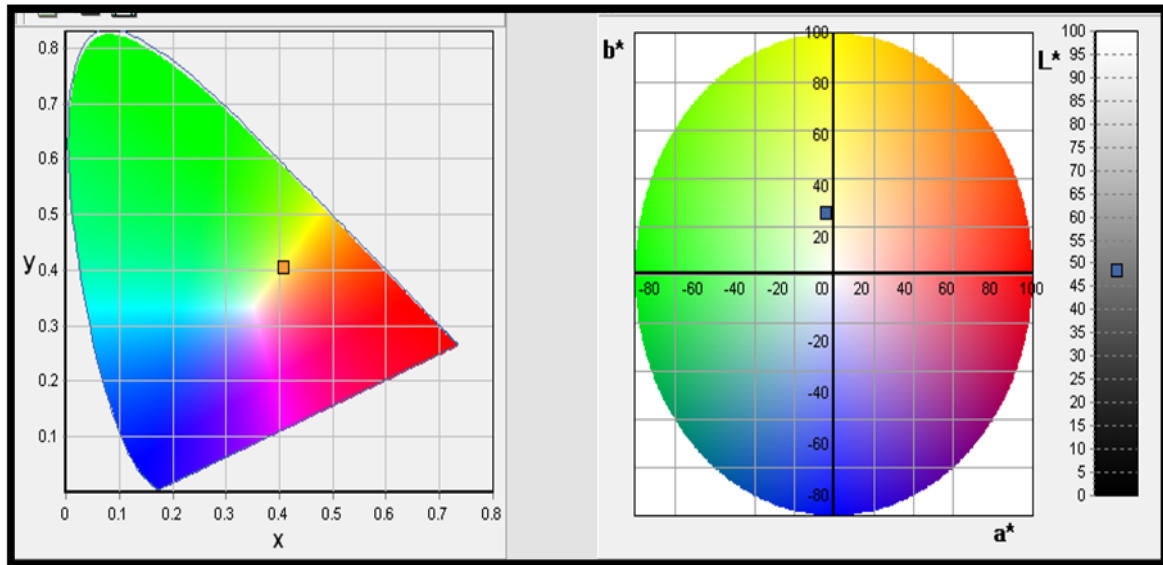


Figure 4.1 (a) CIE readings of apple pomace flour

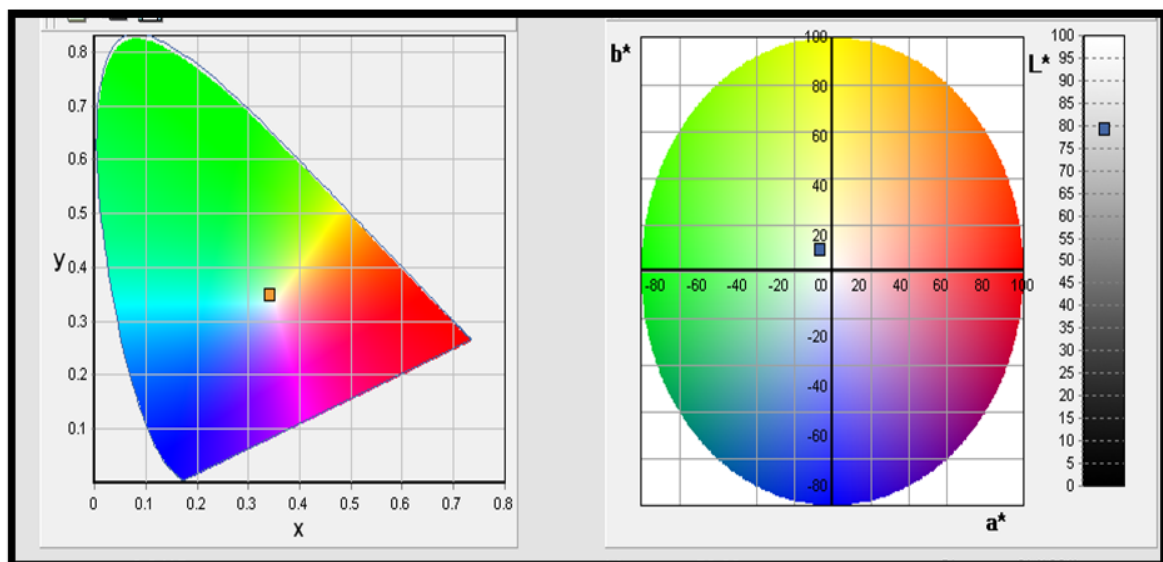
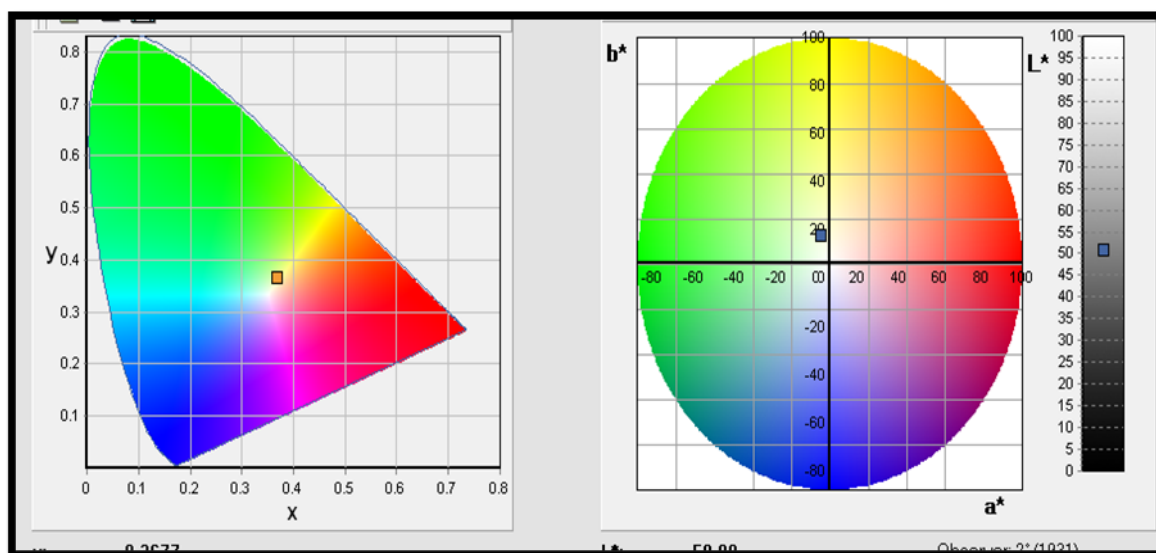


Figure 4.1 (b) CIE readings of whole wheat flour



i

Figure 4.1 (c) CIE readings of red rice flour

4.1.4 Spectral analysis

Fourier-transform infrared spectroscopy (FTIR) is a technique used to obtain an infrared spectrum of absorption or emission of a solid, liquid or gas. IR spectroscopy represents the measurement of the wavelength and intensity of the absorption of infrared light by a sample (Putzig *et al.*, 1994). FTIR is used to analyze varieties of samples due to its ability to identify functional group of chemical compounds, such as carbohydrate and ester, as well as inter atom chemical bonds (Smith, 1979). FTIR that operates in the mid infrared region (4000 to 400 cm^{-1}) is a powerful tool for quantitative analysis (Moh *et al.*, 1999). Fourier Transform-Infrared Spectroscopy (FT-IR) has substantial potential as a quantitative method in the food industry (Lobato *et al.*, 2018). The infrared absorption spectra of apple pomace flour, whole wheat flour and red rice flour were examined in a FTIR spectrometer (Shimadzu 8400 S) to identify the presence of major functional groups and compounds present in the red rice.

The FTIR spectrum of apple pomace flour, whole wheat flour and red rice flour revealed the presence of carbohydrates, proteins, fats, water, Phenols, alcohols, carboxylic acid and aliphatic nitro compounds as shown in Table 4.4 and in Fig 4.2 (a, b and c) with their respective peaks, area covered and the detected compounds. IR- spectra of organic matter, alcohol, fat, hemicellulose, lignin, polysaccharides, pectin, quinone (indication of color), carbon, amide (protein), amine, hydroxyl compounds, cellulose, ether, oxy

compounds, aromatic compound, aryl thioethers, thiol or thioether, disulfides, and alkyne compounds appeared as coupled stretching and bending as a pair of typical bands in the range of 900–4000 cm^{-1} at different peaks *i.e.*, 3268, 2921, 2854, 1804, 1745, 1689, 1410, 1372, 1242, 1153, 1019, 870, 821, 776, 706, and 676 cm^{-1} for apple pomace flour. Whereas, IR-spectra of wheat flour revealed the peaks of alkenes, ester, allenes, amides, primary and secondary amines, alcohols, carboxylic acid and nitro compound appeared as coupled stretching and bending as a pair of typical bands in the range of 3804-680 cm^{-1} at different peaks *i.e.*, 680, 817, 862, 1082, 1153, 1547, 1845, 1968, 2575, 2929, 3167 and 3372, 3372, 3417, 3696 and 3804 cm^{-1} . Furthermore, IR-spectra of alkenes, ester, allenes, amides, primary and secondary amines, phenols, alcohols, carboxylic acid and nitro compound appeared as coupled stretching and bending as a pair of typical bands in the range of 900-4000 cm^{-1} at different peaks *i.e.*, 933.94, 1000.89, 1082.93, 1143.94, 1353.96, 1968.99, 1994.98, 2117.09, 3227.93, 3268.94, 3286.94 and 3409.94 cm^{-1} for red rice flour

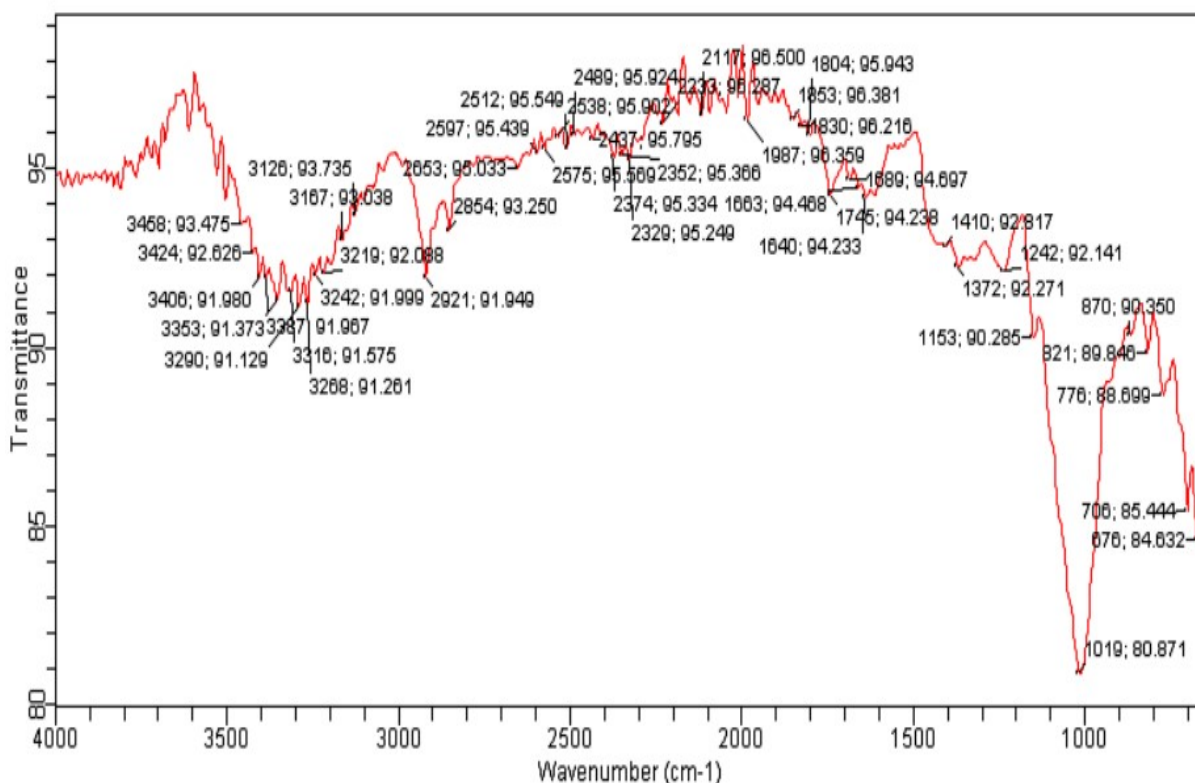


Fig 4.2 (a): FTIR spectra of apple pomace flour

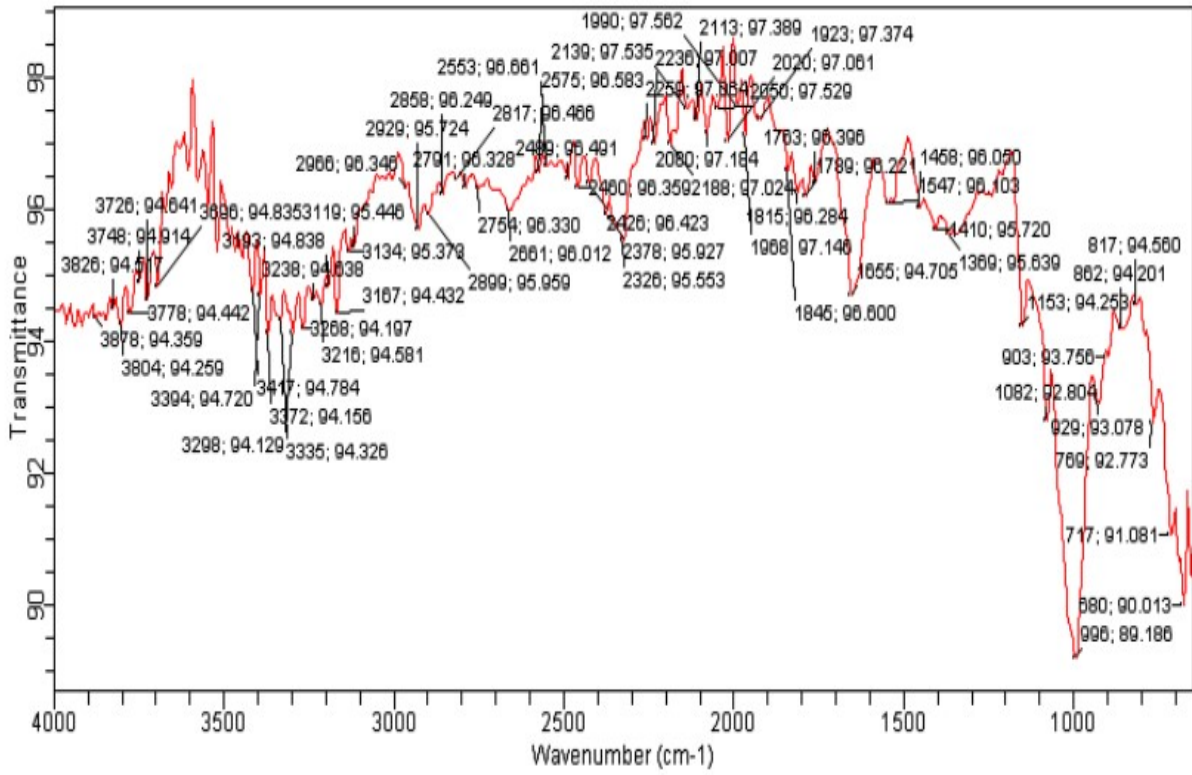


Fig 4.2 (b): FTIR spectra of whole wheat flour

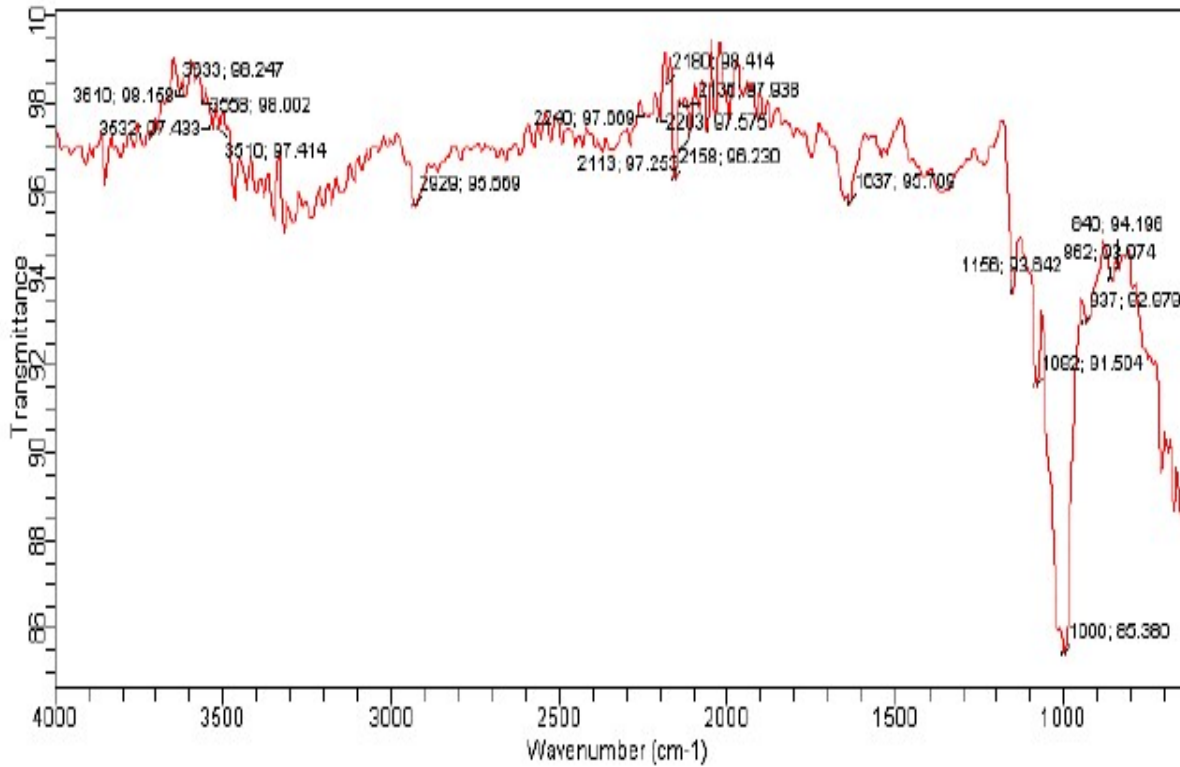


Fig 4.2 (c): FTIR spectra of red rice flour

Table 4.4: FTIR frequencies and their peak assignments for the spectra of red rice and wheat flour

Sr. No.	Apple pomace flour (APF)			Whole wheat flour (WWF)			Red rice flour (RRF)		
	Peak	Bond	Functions group	Peak	Bond	Functional group	Peak		Functional group
1	3268	C-H ring O-H stretching	Organic matter Alcohol	3804	O-H Stretching	Alcohol	840.94	C-H bending	Alkenes
2	2921	C-H stretching	Lignin compounds	3696			862.03		
3	2854	CH ₂ of lipids, Asymmetric CH ₂ stretching mode of the methylene chain in membrane lipid	Fat	3417			937.92		
4	1804	C=O vibration of triglycerides	Hemicellulose, lignin	3372			1000.85		
5	1745	Ester group C=O vibration of triglycerides C=O	Polysaccharides, pectin	3167	O-H Stretching	carboxylic acid	1082.91	=C-O stretching	Alcohols, ethers, esters, carboxylic acids, anhydrides
6	1689	Cyclic organic compound containing two carbonyl groups C=O, either adjacent or separated by vinylene group	Quinone (indication of color)	2929	N-H stretching	amine salt	1156.93	C-N	Amines
7	1410	Phenol or tertiary alcohol, OH bend Carbon related compound	Carbon	2575	S-H stretching	Thiol	1637.95	C=N	Imines and oximes
8	1372	Aliphatic nitro compounds	Amide (protein)	1968	C=C=C stretching	Allene	2003.97	X=C=Y	Allenes, ketenes, isocyanates, isothiocyanates
9	1242	C-N stretching	Amine	1845	C-H bending	aromatic compound	2013.96		
10	1153	Tertiary alcohol, C-H stretch	Alcohol and hydroxyl compounds	1547	N-O stretching	nitro compound	2128.98		
11	1019	C-C vibrations	Cellulose	1153	C-N stretching	Amine	2158.97	C=C Aromatic	Aromatic compounds
12	870	Peroxides, C-O-O- stretch	Ether and oxy zcompounds	1082	C-O stretching	primary alcohol	2180.97		
13	821	C-H 1,4-Disubstitution (para)	Aromatic compound	862	C-H bending	1,2,4- trisubstituted	2240.97		
14	776	C-S stretching, CH ₂ -S-(C-S stretch)	Aryl thioethers, Thiol or thioether	817	C-H bending	1,2,3,4- tetrasubstituted	2929.95		
15	706	C-S stretch	Disulphides	680	C=C bending	Aklene	3510.97	N-H	Primary and secondary amines and amides
16	676	Alkyne C-H bend	Alkyne, Spectral bands of cellulose, hemicellulose or pectin				3532.97		
17							3558.98		
18							3610.98	O-H	Free Alcohols, phenols
19							3633.98		

4.1.5 Chemical quality of flours

Table 4.5 appended the chemical quality of APF (Apple pomace flour), WWF (Whole wheat flour) and RRF (Red rice flour) for moisture, ash, crude fat, crude fibre, total dietary fibre, crude protein, carbohydrate energy, water activity, total sugar, reducing sugar, starch, pectin, total phenol, antioxidant activity, anthocyanin and ascorbic acid.

Moisture content (%)

The moisture content was observed 8.23, 10.52 and 11.02 per cent in the apple pomace flour, whole wheat flour and red rice flour, respectively. A similar moisture content was reported by Usman *et al.* (2020) for apple pomace flour and whole wheat flour of 8.90 per cent and 11.03 per cent, respectively. Gusmao *et al.* (2019) analysed moisture content of 11.00 per cent for red rice flour. The moisture content of the flour of the grain is an indicator of the shelf life of flour as it encourages microbial proliferation that leads to spoilage. The moisture content of all the flours were within the standard moisture content as per the standards (CODEX STAN 152-1982).

Ash (%)

The highest ash content of 2.06 per cent was recorded in apple pomace flour, followed by red rice flour (1.55 %) and whole wheat flour (1.42 %). The present study values confirm with the finding of 2.07 per cent, 1.60 per cent and 1.42 per cent given by Curutchet *et al.* (2021), Chauhan (2018) and Schmiele *et al.* (2012) for apple pomace flour, red rice flour and whole wheat flour, respectively.

Crude fat (%)

The highest crude fat of 2.39 per cent was recorded in apple pomace flour followed by red rice flour (1.95 %) and whole wheat flour (1.83 %). A similar result of fat content of 3.01 per cent was reported by Usman *et al.* (2020) for apple pomace flour while, 1.75 per cent and 1.91 per cent fat content was reported Pande *et al.* (2017) and Ansari (2022) for whole wheat flour and red rice flour, respectively.

Crude fibre (%)

The crude fibre content was observed as 20.68 per cent in apple pomace flour, 4.48 per cent in whole wheat flour and 2.60 per cent in red rice flour. The present study values

confirm with the findings of 20.48 per cent, 4.50 per cent and 2.71 per cent reported by Negi *et al.* (2021), Ndife *et al.* (2011) and Ansari (2022) for apple pomace flour, red rice flour and whole wheat flour, respectively.

Total dietary fibre (%)

The total dietary fibre content was recorded highest in apple pomace flour with a value of 43.26 per cent, followed by whole wheat flour (11.95 %) and red rice flour (10.12 %). The present study values are in close proximation to the values reported by Negi *et al.* (2021), Gomez *et al.* (2020) and Gusmao *et al.* (2019) who reported total dietary fibre content of 44.78 per cent, 10.60 per cent and 8.80 per cent for apple pomace flour, whole wheat flour and red rice flour, respectively.

Crude protein (%)

The crude protein determined in the present study was 3.12, 12.95 and 8.32 per cent in apple pomace flour, whole wheat flour and red rice flour, respectively. The whole wheat flour had higher protein content as compared to red rice and apple pomace flour. Similar result of crude protein content of 3.17 per cent, 12.60 per cent and 8.35 per cent were reported by Samkaria (2018) for apple pomace flour, Hung *et al.* (2007) for whole wheat flour and Chauhan (2018) for red rice flour, respectively.

Carbohydrate (%)

The carbohydrate was observed as 63.52, 68.82 and 74.56 per cent in flours of apple pomace, whole wheat and red rice, respectively. The results were in accordance with the findings of Sahni and Shere (2017), Hung *et al.* (2007) and Sompong *et al.* (2011) who reported carbohydrate content of 62.02 per cent, 68.80 per cent and 75.04 per cent for apple pomace flour, whole wheat flour and red rice flour, respectively.

Energy value (kcal/100g)

Red rice flour had the highest energy value (349.26 kcal/100 g) followed by whole wheat flour (340.25 kcal/100 g) and apple pomace flour (290.24 kcal/100 g). A similar energy value of 325.00 Kcal/100 g was reported by Samkaria (2018) for apple pomace flour. While, Chuwa (2022) and Sompong *et al.* (2011) analysed energy value of 333.59 Kcal/100 g and 350.72 Kcal/100 g for whole wheat flour and for red rice flour, respectively.

Water activity

The water activity was recorded as 0.48, 0.51 and 0.53 in apple pomace flour, whole wheat flour and red rice flour. A similar result of water activity 0.43 was reported by Soni (2019) for apple pomace flour, 0.46 reported by Smith *et al.* (2016) for whole wheat flour and 0.56 reported by Gusmao *et al.* (2019) for red rice flour.

Total sugar (%)

The highest total sugar content (25.29 %) observed in apple pomace flour followed by whole wheat flour (3.14 %) and red rice flour (2.10 %). The observed values of total sugar content were in agreement with the values of 22.75 per cent, 2.04 per cent and 1.32 per cent observed by Soni (2019), Kaur and Kaur (2013) and Dhaliwal *et al.* (2019) for apple pomace flour, whole wheat flour and red rice flour, respectively.

Reducing sugar (%)

The apple pomace flour had a considerably higher reducing sugar content (12.73 %) as compared to whole wheat flour (0.59 %) and red rice flour (0.37 %). The present study results were in accordance with those reported by Kaushal (2008), Kaur and Kaur (2013) and Dhaliwal *et al.* (2020) where, a reducing sugar content of 13.85 per cent, 0.25 per cent and 0.98 per cent was recorded for apple pomace flour, whole wheat flour and red rice flour, respectively.

Starch (%)

The starch content determined in the present study was 65.04, 57.14 and 13.28 per cent in red rice flour whole wheat flour and apple pomace flour. The red rice flour had higher starch content as compared to whole wheat flour and apple pomace flour. Similar result of starch content of 54.60 to 85.76 per cent, 52.70 per cent and 14.40 to 17.10 per cent were reported by Rao (1976) and Dhaliwal *et al.* (2016) for red rice flour, Bae *et al.* (2013) for whole wheat flour and Bhushan *et al.* (2008) for apple pomace flour, respectively.

Pectin (%)

Pectin is a family of complex variable polysaccharides extracted from the primary cell wall of higher plants. Pectin in apple pomace is mainly present in the form of protopectin, an acid-soluble polysaccharide (Schemin, 2005). The pectin content of apple pomace flour

expressed as calcium pectate was observed as 13.58 percent. A similar result of pectin content was observed in the range 14.25 to 15.13 per cent by Chaudhary (2021) for apple pomace in three different varieties.

Total phenol (mg GAE/100g)

Phenolic acids also known as polyphenols are generally found in two forms such as free and bounded (Arshad *et al.*, 2021). The highest amount of total phenol content 451.14 mg GAE/100g observed in apple pomace flour followed by red rice flour 394.26 mg GAE/100g and whole wheat flour 31.45 mg GAE/100g. The observed value of total phenol content was in agreement with the values of 550.00 mg GAE/100g, 366.30 mg GAE/100g and 36.50 mg GAE/100g reported by Negi *et al.* (2021), Ansari (2022) and Narwal *et al.* (2017) for apple pomace flour, red rice flour and whole wheat flour, respectively.

Table 4.5: Chemical Quality of flours

Chemical Quality	Mean \pm SD		
	Apple pomace flour (APF)	Whole wheat flour (WWF)	Red rice flour (RRF)
Moisture content (%)	8.23 \pm 0.05	10.52 \pm 0.07	11.02 \pm 0.08
Ash content (%)	2.06 \pm 0.01	1.42 \pm 0.02	1.55 \pm 0.08
Crude fat (%)	2.39 \pm 0.03	1.83 \pm 0.07	1.95 \pm 0.04
Crude fibre (%)	20.68 \pm 0.06	4.48 \pm 0.03	2.60 \pm 0.01
Dietary fibre (%)	43.26 \pm 0.08	11.95 \pm 0.05	10.12 \pm 0.04
Crude protein (%)	3.12 \pm 0.03	12.95 \pm 0.07	8.32 \pm 0.05
Carbohydrate (%)	63.52 \pm 0.07	68.82 \pm 0.05	74.56 \pm 0.06
Energy value (kcal/100g)	290.24 \pm 1.22	340.55 \pm 2.28	349.26 \pm 2.44
Water activity	0.48 \pm 0.01	0.51 \pm 0.02	0.53 \pm 0.01
Total sugar (%)	25.29 \pm 0.04	3.14 \pm 0.08	2.10 \pm 0.05
Reducing sugar (%)	12.73 \pm 0.02	0.59 \pm 0.01	0.37 \pm 0.01
Starch content (%)	13.28 \pm 0.01	57.14 \pm 0.06	65.04 \pm 0.08
Pectin content (%)	13.58 \pm 0.07	NF	NF
Total phenol content (mg AE/100g)	451.14 \pm 2.14	31.45 \pm 0.24	394.26 \pm 1.95
Antioxidant activity (%)	85.37 \pm 0.06	12.18 \pm 0.02	64.32 \pm 0.05
Anthocyanin content (mg/100g)	14.42 \pm 0.05	NF	9.34 \pm 0.04
Ascorbic acid (mg/100g)	12.21 \pm 0.03	NF	NF

Antioxidant activity (%)

Natural antioxidants are of plant origin and include vitamins, phenolic compounds, and flavonoids (Hussain *et al.*, 2004). The apple pomace flour had considerably higher antioxidant activity 85.37 per cent, as compared by red rice flour (64.32 %) and whole wheat flour (12.18 %). The present study results were in accordance with those reported by Chaudhary (2021), Ansari (2022) and Narwal *et al.* (2017) where, an antioxidant activity of 87.88 to 98.47 per cent, 66.66 per cent and 14.45 per cent recorded for apple pomace flour, red rice flour and whole wheat flour, respectively.

Anthocyanin (mg/100g)

Anthocyanins are water-soluble pigments (red to black) belonging to the phenolic groups. They are responsible for the colour of fruits, vegetables and pigmented cereals (Khoo *et al.*, 2017). Apple pomace flour had higher anthocyanin content of 14.42 mg/100g as compared to 9.34 mg/100g in red rice flour. Similar result of anthocyanin content of 5.00 to 13.00 mg/100g obtained by Lyu *et al.* (2020) for apple pomace flour while, Francavilla and Joye (2020) reported anthocyanin content of 9.40 mg/100g for red rice flour.

Ascorbic acid (mg/100g)

The ascorbic acid content of 12.21 mg/100g was found in apple pomace flour. Soni (2019) and Chaudhary (2021) analysed similar range of 10.07 to 18.44 mg/100g of ascorbic acid in apple pomace flour. The ascorbic acid content was not found in whole wheat flour and red rice flour.

4.1.6 Mineral composition of flours

The mineral composition includes phosphorus, potassium, sodium, calcium, sulphur, magnesium, iron, copper, zinc and manganese. The data for mineral composition is presented in Table 4.6 indicates that the apple pomace flour had higher phosphorus, potassium, sodium, sulphur, iron, copper and manganese as 6357.00 ppm, 8975.00 ppm, 1115.00 ppm, 1444.70 ppm, 97.00 ppm, 24.00 ppm and 47.80 ppm, respectively as compared to whole wheat flour and red rice flour. Among all three flours, red rice flour had higher calcium, magnesium and zinc content of 3225.00 ppm, 4075.00 ppm and 39.90 ppm, respectively. Similar results of mineral content of apple pomace flour was

investigated by Er and Ozcan (2010) and Antonic *et al.* (2020), in whole wheat flour reported by Pande *et al.* (2017) and by Gomez *et al.* (2020) and in red rice flour observed by Chauhan (2018).

Table 4.6: Mineral composition of flours

Mineral (ppm)	Mean \pm SD		
	Apple pomace flour (APF)	Whole wheat flour (WWF)	Red rice flour (RRF)
Phosphorus	6357.00 \pm 11.37	2750.20 \pm 4.44	4090.00 \pm 10.02
Potassium	8975.00 \pm 12.97	3500.00 \pm 5.24	3800.00 \pm 7.87
Sodium	1115.00 \pm 3.10	527.50 \pm 1.76	667.50 \pm 1.31
Calcium	1315.00 \pm 3.16	2775.00 \pm 4.98	3225.00 \pm 6.74
Sulphur	1444.70 \pm 4.49	1326.50 \pm 3.41	1369.20 \pm 3.54
Magnesium	1645.00 \pm 3.64	2605.00 \pm 4.26	4075.00 \pm 9.87
Iron	97.00 \pm 0.83	43.10 \pm 0.22	64.50 \pm 0.35
Copper	24.00 \pm 0.13	10.90 \pm 0.05	12.70 \pm 0.08
Zinc	23.70 \pm 0.11	34.60 \pm 0.15	39.90 \pm 0.16
Manganese	47.80 \pm 0.20	26.20 \pm 0.14	12.20 \pm 0.06

4.2 OPTIMIZATION OF INGREDIENTS FOR THE DEVELOPMENT OF APPLE POMACE WAFFLE CONE THROUGH RESPONSE SURFACE METHODOLOGY

To estimate the effect of responses and their interaction with varying independent components, the analytical data on physical and functional attributes were obtained from the central composite design (CCD) which was fitted to first and second-order, linear, and quadratic model types. Analysis of variance (ANOVA) was used to study the experimental data to assess the effects of apple pomace flour, whole wheat flour and sugar powder on hardness, brittleness, toughness, crispness, ice-cream holding time and overall acceptability (on the basis of sensory evaluation using 9-point hedonic scale) of the waffle cone. Using the analysis of variance, the significance of the linear, quadratic, and independent-variable interactions, as well as their lack of fit, were assessed. A model's capacity to describe the data in the experimental domain, where points were excluded from the regression, was evaluated using the lack of fit test. A successful model with a high coefficient of determination, defined as the percentage of response variation that could be attributed to the model rather than random error and same was also taken into consideration during experimentation.

Table 4.7: Independent and dependent variables used for experimental design

Independent variables	Lower limit	Upper limit	Dependent variables
Apple pomace flour (g)	16.00	24.00	Hardness (g), Brittleness (mm), Toughness (g.sec), Crispness, Ice-cream holding time (min), and Overall acceptability
Whole wheat flour (g)	4.00	12.00	
Sugar powder (g)	5.00	15.00	

Where, overall acceptability (Sensory evaluation on 9-point hedonic scale)

4.2.1 Optimization of quantity of milk based on desired viscosity

Viscosity of the batter is a major parameter which is directly linked to the quality characteristics of waffle cone development such as volume, texture, sheet development etc. The viscosity of batter was maintained in the range of 4500 to 5000 mPa in waffle cone batter as optimized in the pretrials by the addition of milk according to dry ingredients (apple pomace flour, whole wheat flour and sugar powder). Table 4.8 shows the quantity of milk as per designed by RSM.

Table 4.8: Optimization of quantity of milk based on desired viscosity (4500-5000 mPas)

S. No	Independent variables			Quantity of milk (ml)
	Apple pomace flour (g)	Whole wheat flour (g)	Sugar powder (g)	
1	26.72	8.00	10.00	105.00
2	16.00	4.00	15.00	60.00
3	20.00	8.00	1.59	90.00
4	20.00	8.00	10.00	85.00
5	20.00	8.00	10.00	85.00
6	20.00	8.00	18.40	80.00
7	24.00	12.00	15.00	95.00
8	16.00	12.00	5.00	85.00
9	24.00	4.00	15.00	90.00
10	24.00	4.00	5.00	95.00
11	20.00	8.00	10.00	85.00
12	20.00	14.72	10.00	90.00
13	20.00	8.00	10.00	85.00
14	20.00	8.00	10.00	85.00
15	16.00	12.00	15.00	70.00
16	20.00	1.27	10.00	80.00
17	13.27	8.00	10.00	60.00
18	16.00	4.00	5.00	65.00
19	20.00	8.00	10.00	85.00
20	24.00	12.00	5.00	100.00

The quantity of milk increased with an increase in the concentration of apple pomace flour as well as whole wheat flour, this might be due to the high fibre content in apple pomace flour and starch content in whole wheat flour. The highest quantity of milk was required for the treatment 1 which had the highest amount of apple pomace flour (26.72 g). While, the minimum quantity of milk was required for the treatment 17 which had the lowest amount of apple pomace flour (13.27 g). The water absorption capacity of any flour depends upon the amount of starch and dietary fibre present in the flour (Chandra and Smasher, 2013). On the other hand, the quantity of milk decreased with increase in sugar powder content

4.2.2 Effect of independent variables on the different responses

Table 4.9 shows different independent and dependent variables evaluated during the study to determine the effect of independent variables on the dependent variables. The data in Table 4.9 shows that the hardness (g) of the waffle cone prepared from apple pomace ranged between 550.74 g to 1130.17g. Whereas, the maximum value of brittleness (5.20 mm) was recorded in treatment T₁₉ and lowest in treatment T₃ (1.30 mm).

Table 4.9: Effect of independent variables on the different responses

Sn	Independent variables			Dependent variables					
	APF (g)	WWF (g)	SP (g)	Hardness (g)	Brittleness (mm)	Toughness (g.sec)	Crispness	Ice cream holding time (min)	Overall acceptability
1	26.72	8.00	10.00	910.25	3.73	950.74	11.00	27	7.40
2	16.00	4.00	15.00	927.60	3.16	980.40	14.00	29	7.96
3	20.00	8.00	1.59	550.74	1.30	560.00	7.00	19	6.10
4	20.00	8.00	10.00	921.68	4.55	1026.84	17.00	31	8.20
5	20.00	8.00	10.00	921.66	4.53	1036.82	17.00	31	8.24
6	20.00	8.00	18.40	1130.17	2.66	1165.31	17.00	32	7.68
7	24.00	12.00	15.00	1070.54	4.50	1110.60	13.00	36	7.20
8	16.00	12.00	5.00	850.74	1.78	900.34	11.00	22	6.70
9	24.00	4.00	15.00	950.65	4.62	1010.54	15.00	27	7.00
10	24.00	4.00	5.00	750.66	2.58	810.00	8.00	19	6.20
11	20.00	8.00	10.00	921.60	4.51	1021.83	17.00	29	8.39
12	20.00	14.72	10.00	960.85	5.20	1077.10	14.00	34	7.38
13	20.00	8.00	10.00	921.57	4.50	1029.81	17.00	33	8.30
14	20.00	8.00	10.00	921.58	4.49	1026.80	16.00	31	8.32
15	16.00	12.00	15.00	1109.00	2.74	1120.30	15.00	37	7.90
16	20.00	1.27	10.00	640.27	4.90	710.00	13.00	25	6.30
17	13.27	8.00	10.00	1050.14	2.45	1002.39	14.00	33	7.76
18	16.00	4.00	5.00	710.55	3.41	760.44	9.00	27	6.62
19	20.00	8.00	10.00	995.35	5.40	1130.21	16.00	31	8.62
20	24.00	12.00	5.00	600.21	2.52	630.47	9.00	20	6.80

APF- Apple pomace flour, WWF- Whole wheat flour, SP- Sugar powder
Overall acceptability (Sensory evaluation on 9-point hedonic scale)

However, the maximum toughness of the waffle cone recorded in treatment T₆ with a value of 1165.31 (g.sec) and a minimum of 560.00 (g.sec) in treatment T₃. The maximum crispness in the product (17.00) was observed in treatments T₄, T₅, T₆, T₁₁ and T₁₃ and the minimum (7.00) in treatment T₃. The ice cream holding time was recorded in the range of 19.00 to 37.00 min. The maximum value of overall acceptability was observed as 8.62 in treatment T₁₉ and the lowest value of overall acceptability was 6.10 in treatment T₃.

a) Hardness

The correlation between independent variables (apple pomace flour, whole wheat flour, and sugar powder) with the hardness of the apple pomace waffle cone is mentioned in eqⁿ....4.2(a).

$$\text{Hardness} = + 933.90 -33.75 A + 60.74 B + 155.24 C - 44.02 AB + 24.38 AC + 38.94 B C + 16.61 A^2 - 46.94 B^2 - 32.79 C^2 \dots \text{eq}^n 4.2 (a)$$

$$R^2 = 0.9486$$

Equation 4.2 (a) displays the regression coefficient from the stepwise regression fitting model and the analysis of variance. The determination coefficient (R²) value demonstrated that the model was fitted, as explained by 94.86 per cent of the variability in the hardness of the waffle cone. The hardness of the waffle cone was found significantly affected by independent variables. It was observed that Run 3 (20.00 g of apple pomace flour, 8.00 g of whole wheat flour and 1.59 g of sugar powder) had the lowest hardness of the waffle cone with a value of 550.74 g and Run 6 (20.00 g of apple pomace flour, 8.00 g of whole wheat flour and 18.40 g of sugar powder) had the highest hardness of waffle cone *i.e.*, 1130.17 g.

First-order analysis as with the R-square value of 94.86 per cent and P-value (0.0001) less than 0.05 indicated that model terms was significant. In the second-order analysis, the derived equation (4.2 a) showed that apple pomace flour had a negative quadratic effect, while whole wheat flour and sugar powder had a positive quadratic effect on the preparation of the waffle cone. The effect of apple pomace after 20 g and 10 g of sugar found to have negative effect as the hardness decreased with the increase in apple pomace and sugar quantity. This might be due to the reason that with the increase in apple pomace and sugar the gelatinization of starch slowed significantly that lead to less porosity and decrease in hardness. The results were in accordance to Kigozi *et al.* (2016) in sorghum ice cream cone.

While the interaction between apple pomace flour and whole wheat flour had a negative quadratic effect, apple pomace flour and sugar powder had a positive quadratic effect. Likewise, whole wheat flour with sugar powder also had a positive quadratic effect on the preparation of the waffle cone (Figure 4.3).

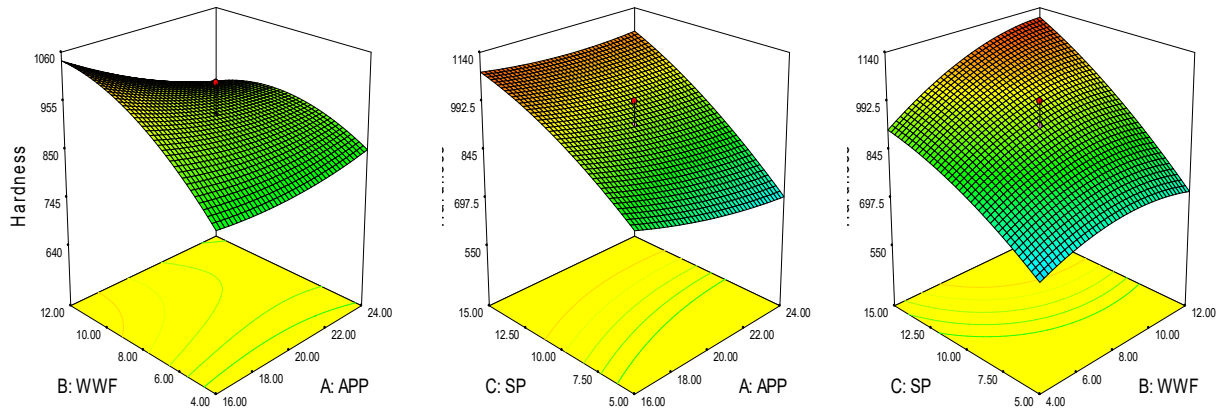


Figure (4.3)- Three-dimensional response surface for the hardness of waffle cone

b) Brittleness

The correlation between independent variables (apple pomace flour, whole wheat flour, and sugar powder) with the brittleness of the apple pomace waffle cone is mentioned in eqⁿ 4.2 (b).

$$\text{Brittleness} = + 4.67 + 0.39 A - 0.13 B + 0.51 C + 0.23 AB + 0.41 AC + 0.14 BC - 0.58 A^2 + 0.11 B^2 - 0.98 C^2 \dots 4.2 (b)$$

$$R^2 = 0.9463$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in Equation 4.2 (b). The model was a proper fit as indicated by a determination coefficient (R^2) value of 94.63 per cent. The brittleness of the waffle cone was found significantly affected by independent variables. Independent factors were shown to have a substantial impact on brittleness. Run 19 (20.00 g of apple pomace flour, 8.00 g of whole wheat flour, and 10 g of sugar powder) observed the highest brittleness of the waffle cone with a value of 5.40 mm.

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 94.63 per cent, first-order analysis and P-values (0.0001) less

than 0.05 suggested that the model results were significant. In second-order analysis, the derived equation (4.2 b) showed that apple pomace flour and sugar powder had a positive quadratic effect, while whole wheat flour had a negative quadratic effect. Further, all the interactions, such as the interaction between apple pomace flour with whole wheat flour, apple pomace flour with sugar powder and whole wheat flour with sugar powder, had a positive quadratic effect on the preparation of the waffle cone. This might be due to the increase in fibre content which hindered the binding capacity of materials in waffle cone. Similar results were found by Kushwaha *et al.* (2023) in jackfruit seed flour-based waffle cone (Figure 4.4).

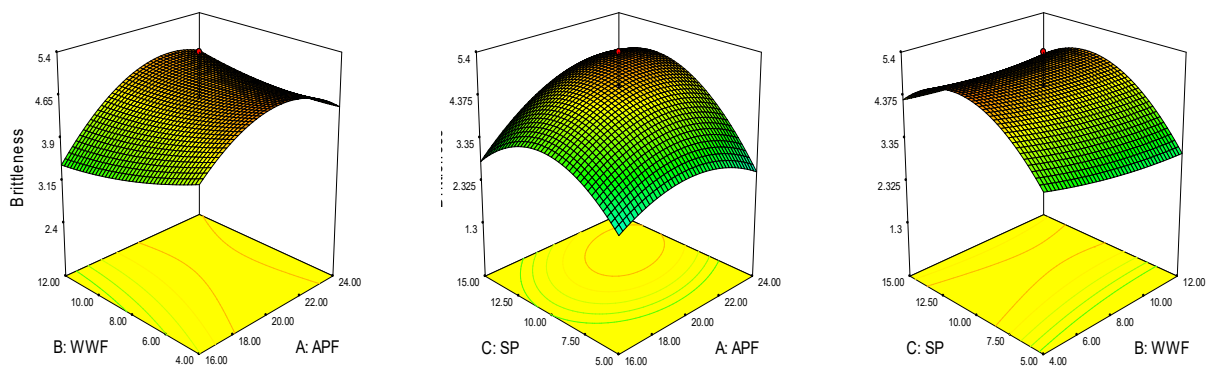


Figure (4.4)- Three-dimensional response surface for brittleness of waffle cone

c) Toughness

The correlation between independent variables (apple pomace flour, whole wheat flour, and sugar powder) with the toughness of the apple pomace waffle cone is mentioned in equation 4.2 (c)

$$\text{Toughness} = + 1045.03 - 21.02 A + 59.83 B + 156.57 C - 44.91 AB + 30.09 AC + 34.95 BC - 21.69 A^2 - 51.07 B^2 - 61.96 C^2 \dots 4.2 (c)$$

$$R^2 = 0.9140$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in Equation 4.2 (c). The model was properly fitted by 91.40 per cent as shown by the determination coefficient (R^2) value. The toughness of the waffle cone was found significantly affected by independent variables. Independent factors were shown to have a substantial impact on the toughness of waffle cones. Run 6 (20.00 g of apple pomace

flour, 8.00 g of whole wheat flour, and 10.00 g of sugar powder) recorded the highest toughness of the waffle cone *i.e.*, 1165.31 (g.sec).

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 91.40 per cent, according to first-order analysis, and P-values (0.0003) less than 0.05 suggest that model results were significant. In second-order analysis, the derived equation (4.2 c) shows that apple pomace flour had a negative quadratic effect due to high fibre content and whole wheat flour and sugar powder had a positive quadratic effect due to high binding capacity with gelatinization of starch and caramelization of sugar. Similar observations were found by Dom *et al.* (2020). While the interaction between (apple pomace flour with whole wheat flour) had a negative quadratic effect (apple pomace flour with sugar powder) and (whole wheat flour with sugar powder) had a positive quadratic effect, on the preparation of the waffle cone (Figure 4.5).

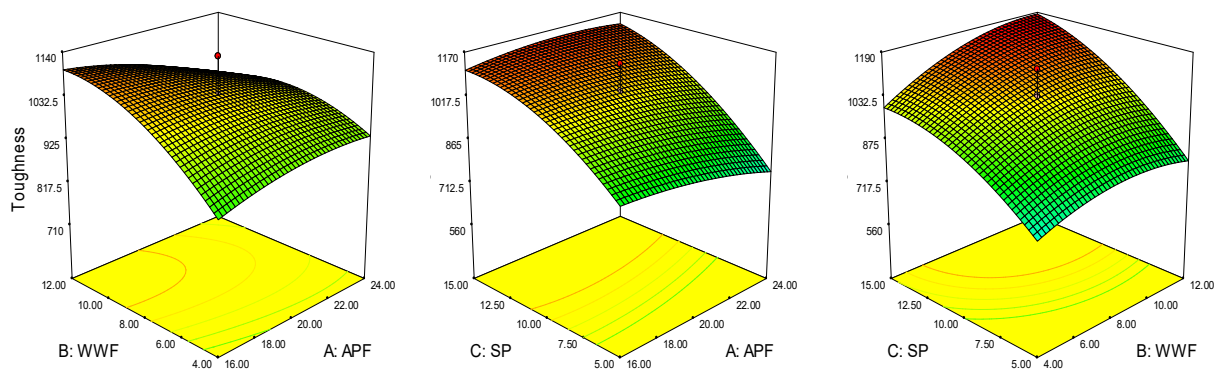


Figure (4.5)- Three-dimensional response surface for the toughness of waffle cone.

d) Crispness

The correlation between independent variables (apple pomace flour, whole wheat flour, and sugar powder) with the crispness of the apple pomace waffle cone is mentioned in eqⁿ 4.2 (d)

$$\text{Crispness} = + 16.69 - 0.66 A + 0.27 B + 2.69 C - 0.50 AB + 0.25 AC - 0.50 BC - 1.62 A^2 - 1.26 B^2 - 1.79 C^2 \dots \text{4.2 (d)}$$

$$R^2 = 0.9779$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in Table 4.2 (d). The model was properly fitted by 97.79 per cent as

shown by the determination coefficient (R^2) value. The crispness of the waffle cone was found significantly affected by independent variables. Independent factors were shown to have a substantial impact on the crispness of waffle cones. Run 3 (20.00 g of apple pomace flour, 8.00 whole wheat flour, and 1.59 g of sugar powder) reflected the minimum crispness of the waffle cone *i.e.*, 7.00.

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 97.79 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results were significant. In second-order analysis, the derived equation (4.2 d) shows that apple pomace flour had a negative quadratic effect and whole wheat flour and sugar powder had a positive quadratic effect. While the interaction between apple pomace flour with whole wheat flour had a negative quadratic effect, apple pomace flour with sugar powder had a positive quadratic effect and whole wheat flour with sugar powder had a negative quadratic effect on the preparation of the waffle cone. The decrease in crispness with increase in sugar content may be due to the sugar present in the cone competes with the water molecules which is required for starch gelatinization. The results were similar to Manohar *et al.* (1997) Figure (4.6).

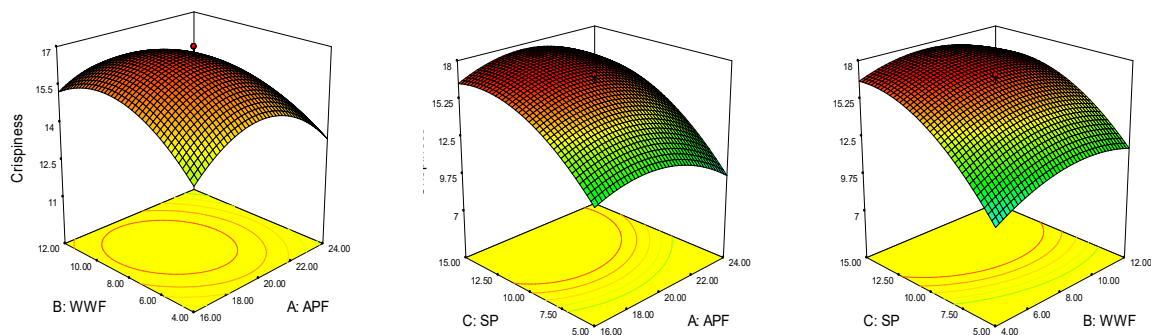


Figure (4.6)- Three-dimensional response surface for crispness of waffle cone

e) Ice cream holding time

The correlation between independent variables (apple pomace flour, whole wheat flour, and sugar powder) with the ice-cream holding time of apple pomace waffle cone is mentioned in eqⁿ 4.2 (e)

$$\text{Icecream holding time} = + 31.03 - 1.69 A + 2.06 B + 4.60 C + 0.87 AB + 0.88 AC + 2.63 B C - 0.58 A^2 - 0.75 B^2 - 2.17 C^2 \dots 4.2 (e)$$

$$R^2 = 0.9571$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in Table 4.2 (e). The model was properly fitted by 95.71 per cent as shown by the determination coefficient (R^2) value. The ice cream holding time of the waffle cone found to be significantly affected by independent variables. Independent factors were shown to have a substantial impact on the ice cream holding time of the waffle cones. Run 3 (20.00 g of apple pomace flour, 8.00 whole wheat flour, and 1.59 g of sugar powder) observed the minimum ice-cream holding time of the waffle cone *i.e.*, 19.00 min.

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 95.71 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results were significant. In second-order analysis, the derived equation (4.2 e) shows that apple pomace flour had a negative effect, and whole wheat flour and sugar powder had a positive quadratic effect. This may be due high water absorption capacity of apple pomace flour as the water absorption capacity of any product is dependent on the amount of starch and dietary fibre of the ingredients (Chandra and Smasher, 2013). While the interaction between apple pomace flour with whole wheat flour, apple pomace flour with sugar powder, and whole wheat flour with sugar powder had a positive quadratic effect (Figure 4.7).

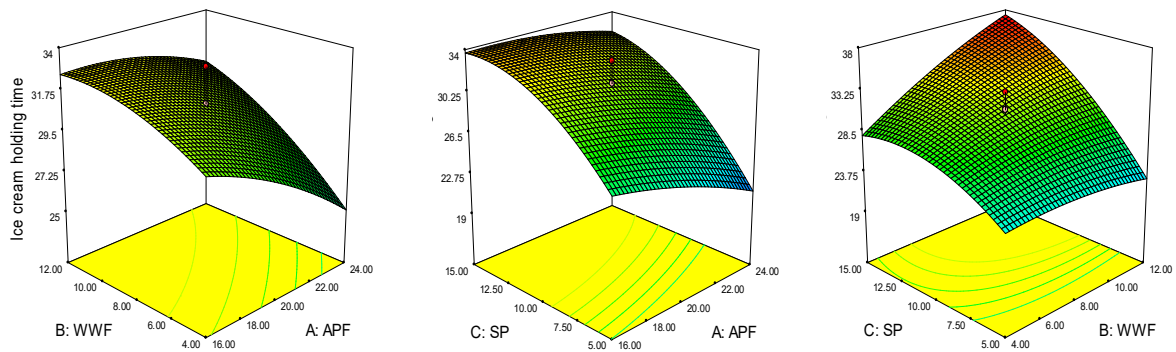


Figure (4.7)- Three-dimensional response surface for ice-cream holding time of waffle cone

f) Overall acceptability (9-point hedonic scale)

The correlation between independent variables (apple pomace flour, whole wheat flour, and sugar powder) with the overall acceptability of apple pomace waffle cone is mentioned in eqⁿ 4.2 (f).

$$\text{Overall acceptability} = + 8.34 - 0.19 A + 0.19 B + 0.47 C + 0.097 AB - 0.17 AC - 0.067 BC - 0.27 A^2 - 0.53 B^2 - 0.51 C^2 \dots 4.5 (f)$$

$$R^2 = 0.9718$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in equation 4.2 (f). The model was properly fitted by 97.18 per cent as shown by the determination coefficient (R^2) value. The overall acceptability of the waffle cone was found significantly affected by independent variables. Independent factors were shown to have a substantial impact on the overall acceptability of waffle cones. Run 19 containing 20.00 g of apple pomace flour, 8.00 g whole wheat flour, and 10.00 g sugar powder showed the maximum overall acceptability for waffle cone of 8.62 based on 9-point hedonic scale sensory evaluation.

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 97.18 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results were significant. In second-order analysis, the derived equation (4.2 f) showed that apple pomace flour had a negative quadratic effect and whole wheat flour and sugar powder had a positive quadratic effect may be due to the caramelization with fruity flavour of the natural sugar present in apple pomace waffle cone. Similar results were reported by Negi *et al.* (2021) in apple pomace flour supplemented muffin. While the interaction between apple pomace flour with whole wheat flour had a positive quadratic effect, apple pomace flour with sugar powder had a negative quadratic effect and whole wheat flour with sugar powder had also a negative quadratic effect on the preparation of the waffle cone (Figure 4.8).

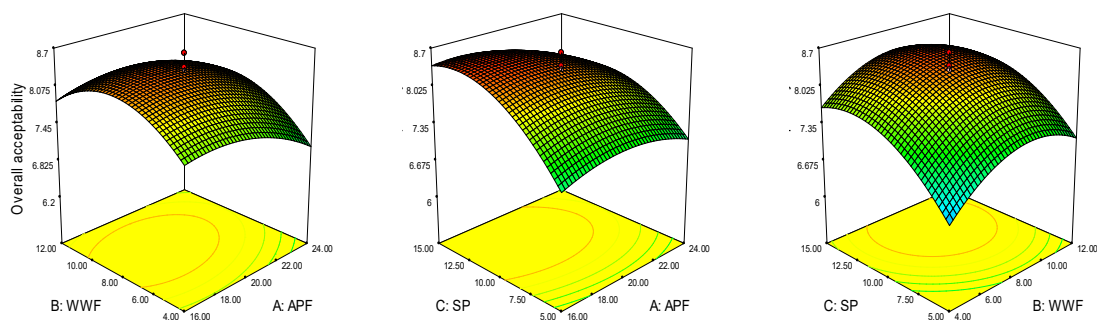


Figure (4.8)- Three-dimensional response surface for overall acceptability of waffle cone

4.2.3 Optimization of ingredients for the preparation of apple pomace waffle cone through desirability

The result generated from the RSM plot indicated that the dependence of independent variables (apple pomace flour, whole wheat flour, and sugar powder) on dependent variables (hardness, brittleness, toughness, crispness, ice-cream holding time, and

overall acceptability) of the waffle cone prepared from apple pomace based were predicted by using the Design expert-07 software by setting optimum goal requirements as presented in Table 4.10 which resulted in the predicted values. Response surface plots were taken into consideration for optimization since the best result came from interactions between the various responses. The optimization process was based on desirability which is a multiple response approach. The optimization approach considers each variable's priorities and desires, and the scores of each dependent variable were converted into scores for desirability, which ranged from 0 for undesirable to 1.0 for high desirable. The geometric mean of the individual desirability was used to calculate the overall desirability of the outcomes at various levels of the response variable.

Table 4.10: Optimization of ingredients for apple pomace waffle cone through desirability

S. No.	Factor of responses	Goal	Lower limit	Upper limit	Importance	Predicted value
1	A: Apple pomace flour (g)	equal to >	16.00	24.00	3	20.00
2	B: Whole wheat flour (g)	equal to >	4.00	12.00	3	8.00
3	C: Sugar powder (g)	target	5.00	15.00	3	10.00
4	Hardness (g)	is in range	550.74	1130.17	3	933.90
5	Brittleness (mm)	is in range	1.30	5.40	3	4.66
6	Toughness (g. sec)	is in range	560.00	1165.31	3	1045.03
7	Crispness	maximize	7.00	17.00	3	16.68
8	Ice cream holding time (min)	maximize	19.00	37.00	3	31.03
9	Overall acceptability	maximize	6.10	8.62	3	8.34

Table 4.11: Predicted and observed values of responses of apple pomace waffle cone

Sr. No.	Responses	Predicted value	Observed values
1	Hardness (g)	933.90	921.66
2	Brittleness (mm)	4.66	4.53
3	Toughness (g. sec)	1045.03	1036.82
4	Crispness	16.68	17.00
5	Ice cream holding time (min)	31.03	31.00
6	Overall acceptability	8.34	8.24
7	Desirability (%)	87.00	-

The responses of ingredients for the development of waffle cone from apple pomace predicted by using the Design expert-07 software result hardness 933.90 g, brittleness 4.66 mm, toughness 1045.03 g.sec crispness 16.68 ice-cream holding time 31.03 min and overall

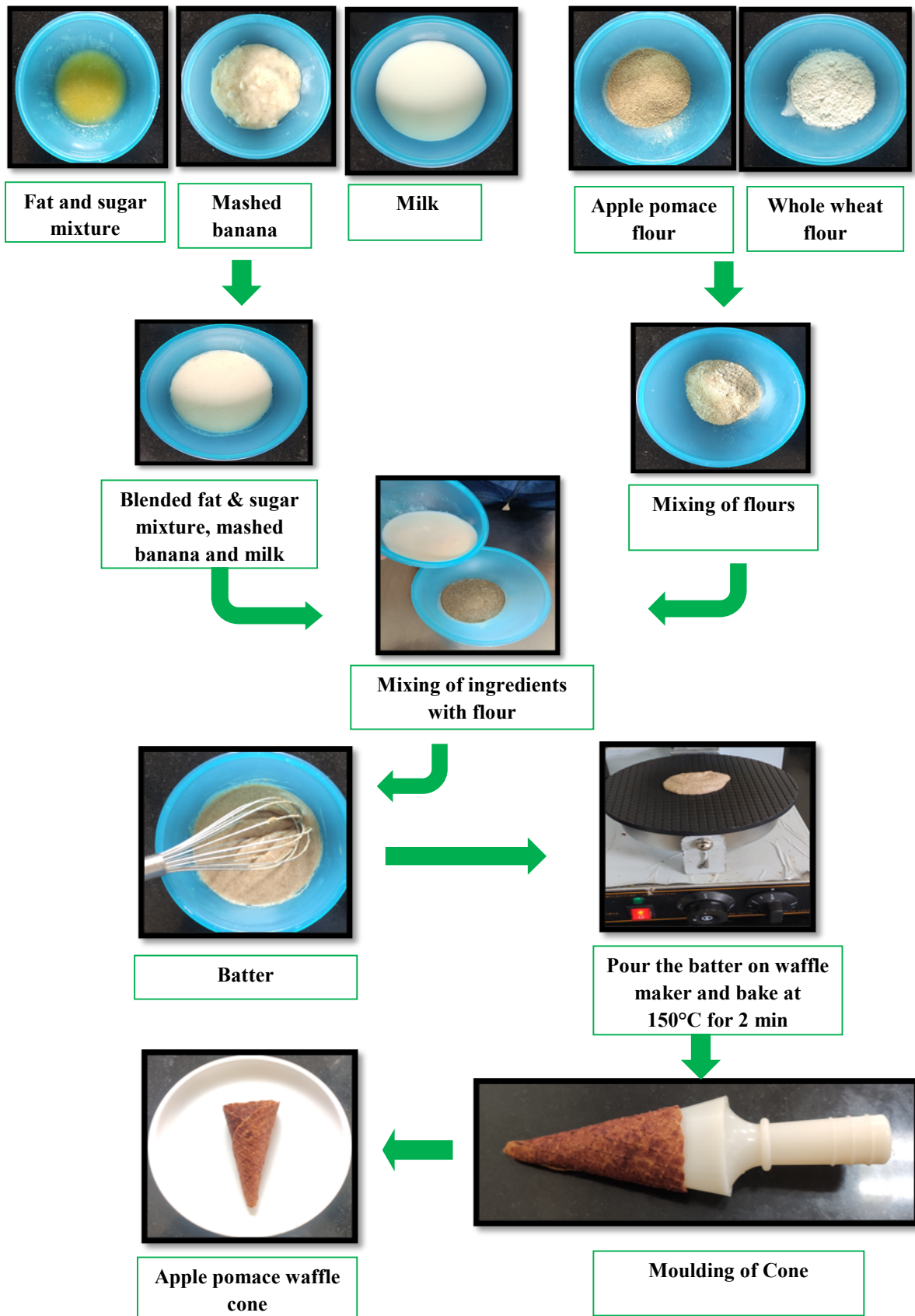


Plate 1- Flow chart for the preparation of apple pomace waffle cone (apple pomace with whole wheat flour)

acceptability 8.34 based on 9-point hedonic scale. The closeness of observed value with predicted values for hardness 921.66 g, brittleness 4.53 mm, toughness 1036.82 g.sec with observed values of crispness 17.00 ice-cream holding time 31.00 min, and overall acceptability 8.24 approved the validation of response surface methodology (RSM) model (Table 4.11). The desirability scores 87.00 per cent for the preparation of apple pomace waffle cones was within the most acceptable limits.

4.3 OPTIMIZATION OF INGREDIENTS FOR THE DEVELOPMENT OF GLUTEN-FREE APPLE POMACE WAFFLE CONE THROUGH RESPONSE SURFACE METHODOLOGY

To estimate the effect of responses and their interaction with varying independent components, the analytical data on physical and functional attributes were obtained from the central composite design (CCD) which was fitted to first and second-order, linear, and quadratic model types. Analysis of variance (ANOVA) was used to study the experimental data to assess the effects of apple pomace flour, red rice flour, and sugar powder on hardness, brittleness, toughness, crispness, ice-cream holding time and overall acceptability (on the basis of sensory evaluation using 9-point Hedonic scale) of the gluten-free apple pomace waffle cone. Using the analysis of variance, the significance of the linear, quadratic, and independent-variable interactions, as well as their lack of fit, were assessed. A model's capacity to describe the data in the experimental domain, where points were excluded from the regression, was evaluated using the lack of fit test. A successful model with high coefficient of determination, defined as the percentage of response variation that could be attributed to the model rather than random error and same was also taken into consideration during experimentation.

Table 4.12: Independent and dependent variables used for experimental design

Independent variables	Lower limit	Upper limit	Dependent variables
Apple pomace flour (g)	16.00	24.00	Hardness (g), Brittleness (mm), Toughness (g.sec), Crispness, Ice-cream holding time (min), and Overall acceptability
Red rice flour (g)	4.00	12.00	
Sugar powder (g)	5.00	15.00	

Where, overall acceptability (Sensory evaluation on 9-point hedonic scale)

4.3.1 Optimization of quantity of milk based on desired viscosity

Viscosity of the batter is a major parameter which is directly linked to the quality characteristics of waffle cone development such as volume, texture, sheet development *etc.*

The viscosity of batter was maintained in the range of 4500 to 5000 mPa in waffle cone batter as optimized in the pretrials by the addition of milk according to dry ingredients (apple pomace flour, red rice flour and sugar powder). Table 4.13 showed the quantity of milk as per designed by RSM. The quantity of milk increased with increase in the concentration of apple pomace flour as well as red rice flour, this might be due to the high fibre content in apple pomace flour and starch content in whole wheat flour. The highest quantity of milk was required for the treatment 1 which had the highest amount of apple pomace flour (26.72 g). While, the minimum quantity of milk was required for the treatment 17 which had the lowest amount of apple pomace flour (13.27 g). The water absorption capacity of any flour depends upon the amount of starch and dietary fibre present in the flour (Chandra and Smasher, 2013). On the other hand, the quantity of milk decreased with increase in sugar powder content.

Table 4.13: Optimization of quantity of milk based on desired viscosity (4500-5000 mPas)

S. No	Independent variables			Quantity of milk (ml)
	Apple pomace flour (g)	Red rice flour (g)	Sugar powder (g)	
1	26.72	8.00	10.00	100.00
2	16.00	4.00	15.00	55.00
3	20.00	8.00	1.59	85.00
4	20.00	8.00	10.00	80.00
5	20.00	8.00	10.00	80.00
6	20.00	8.00	18.40	75.00
7	24.00	12.00	15.00	90.00
8	16.00	12.00	5.00	80.00
9	24.00	4.00	15.00	85.00
10	24.00	4.00	5.00	90.00
11	20.00	8.00	10.00	80.00
12	20.00	14.72	10.00	85.00
13	20.00	8.00	10.00	80.00
14	20.00	8.00	10.00	80.00
15	16.00	12.00	15.00	65.00
16	20.00	1.27	10.00	75.00
17	13.27	8.00	10.00	55.00
18	16.00	4.00	5.00	60.00
19	20.00	8.00	10.00	80.00
20	24.00	12.00	5.00	95.00

4.3.2 Effect of independent variables on the different responses

The perusal of data represents the different dependent variables for the preparation of gluten-free apple pomace waffle cones from different concentrations of ingredients such as apple pomace flour (g), red rice flour (g), and sugar powder (g). The data in the table (4.14)

shows that the hardness (g) of the gluten-free waffle cone prepared from apple pomace based ranged from 565.19 to 1412.15 g. The brittleness (mm) was highest in Run 12 *i.e.* (5.50 mm) and lowest in run 3 (1.50 mm). Whereas, the toughness (g.sec) of the gluten-free waffle cone ranged from 580.00 to 1100.00 (g.sec) and the crispness was ranging from 6.00 to 19.00. However, the ice cream holding time of the product was ranging between 17.00 to 34.00 min, and the overall acceptability of the gluten-free apple pomace waffle cone was observed to range from 6.10 to 8.30 based on sensory evaluation of the 9-point hedonic scale. The data were analyzed to observe the effect of independent variables on these responses.

Table 4.14: Effect of independent variables on the different responses

Sn	Independent variables			Dependent variables					
	APF (g)	RRF (g)	SP (g)	Hardness (g)	Brittleness (mm)	Toughness (g.sec)	Crispness	Ice cream holding time (min)	Overall acceptability
1	26.72	8.00	10.00	1112.19	4.21	1050.92	12.00	24	7.21
2	16.00	4.00	15.00	1093.53	3.42	1014.11	14.00	25	7.74
3	20.00	8.00	1.59	565.19	1.50	580.00	6.00	17	6.10
4	20.00	8.00	10.00	1362.86	4.74	1088.39	18.00	29	7.95
5	20.00	8.00	10.00	1336.27	4.76	1089.62	18.00	29	7.92
6	20.00	8.00	18.40	1412.15	2.52	1100.00	19.00	31	7.37
7	24.00	12.00	15.00	1128.25	4.81	1024.41	16.00	33	6.83
8	16.00	12.00	5.00	637.67	2.00	729.87	10.00	22	6.81
9	24.00	4.00	15.00	975.66	4.87	950.00	14.00	25	6.80
10	24.00	4.00	5.00	625.61	2.73	690.17	8.00	19	6.20
11	20.00	8.00	10.00	1338.33	4.77	1090.88	17.00	28	7.90
12	20.00	14.72	10.00	855.63	5.50	914.23	14.00	31	6.80
13	20.00	8.00	10.00	1336.20	5.20	1098.95	17.00	32	8.00
14	20.00	8.00	10.00	1339.46	4.71	1087.44	17.00	29	7.96
15	16.00	12.00	15.00	1062.65	2.49	960.74	16.00	34	7.50
16	20.00	1.27	10.00	674.25	5.40	750.03	12.00	23	6.20
17	13.27	8.00	10.00	950.25	2.11	900.42	13.00	31	7.60
18	16.00	4.00	5.00	671.50	3.86	640.52	9.00	26	6.70
19	20.00	8.00	10.00	1255.21	4.30	1010.87	17.00	29	8.30
20	24.00	12.00	5.00	950.04	2.10	790.22	7.00	21	6.60

APF- Apple pomace flour, RRF- Red rice flour, SP- Sugar powder
Overall acceptability (Sensory evaluation on 9-point hedonic scale)

a) Hardness

The correlation between independent variables (apple pomace flour, red rice flour, and sugar powder) with the hardness of the gluten-free apple pomace waffle cones is mentioned in eqⁿ 4.3 (a).

$$\text{Hardness} = + 1328.45 + 35.52 A + 52.32 B + 204.93 C + 67.72 AB - 39.84 AC - 21.11 BC - 107.28 A^2 - 201.47 B^2 - 122.33 C^2 \text{ eq}^n \dots 4.3 \text{ (a)}$$

$$R^2 = 0.9782$$

Equation 4.3 (a) displays the regression coefficient from the stepwise regression fitting model and the analysis of variance. The determination coefficient (R^2) value demonstrated that the model was fitted explained by 97.82 per cent of the variability in hardness of the gluten-free waffle cone. The hardness of the gluten-free waffle cone was found significantly affected by independent variables. It was observed that Run 6 (20.00 g of apple pomace flour, 8.00 g of red rice flour, and 18.40 g of sugar powder) had the highest hardness of the gluten-free waffle cone with a value of 1412.15 g and Run 3 (20.00 g of apple pomace flour, 8.00 g of red rice flour and 1.59 g of sugar powder) had the lowest hardness of gluten-free waffle cone *i.e.*, 565.19 g.

First-order analysis showed that the R-square value of 97.82 per cent and P-value (0.0001) less than 0.05 indicated that model terms are significant. In second-order analysis, the derived equation (4.3 a) shows that apple pomace flour, red rice flour, and sugar powder had a positive quadratic effect. While the interaction between apple pomace flour with red rice flour had a positive quadratic effect, apple pomace flour with sugar powder had a negative quadratic effect, and red rice flour with sugar powder had also a negative quadratic effect on the preparation of gluten-free waffle cone. This might be due to the reason that the sugar concentration in the formulation had a significant effect on gelatinization characteristics of starch. The higher the concentration of sugar, slower was the gelatinization process resulting in incomplete gelatinization that resulted in decreased hardness of gluten free waffle cones. The statement is justified as per the studies of Kigozi *et al.* (2016) Figure (4.9).

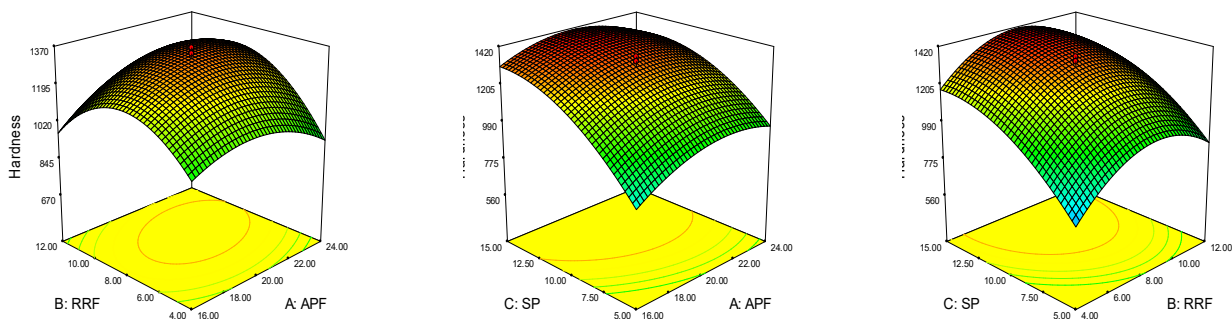


Figure (4.9)- Three-dimensional response surface for the hardness of gluten-free waffle cone.

b) Brittleness

The correlation between independent variables (apple pomace flour, red rice flour, and sugar powder) with the brittleness of gluten-free apple pomace waffle cones is mentioned in eqⁿ 4.3 (b).

$$\text{Brittleness} = + 4.75 + 0.46 A - 0.24 B + 0.48 C + 0.26 AB + 0.60 AC + 0.19 BC - 0.60 A^2 + 0.21 B^2 - 1.01 C^2 \dots 4.3 (b)$$

$$R^2 = 0.9438$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in Equation 4.3 (b). The model was properly fitted by a 94.38 per cent determination coefficient (R^2) value. The brittleness of the gluten-free waffle cone was found significantly affected by independent variables. Independent factors were shown to have a substantial impact on brittleness. Run 12 (20.00 g of apple pomace flour, 14.72 g of red rice flour, and 10.00 g of sugar powder) recorded the highest brittleness of the gluten-free waffle cone with a value of 5.50 mm.

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 94.38 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results were significant. In second-order analysis, the derived equation (4.3 b) showed that apple pomace flour and sugar powder had positive effect due to high fibre and sugar content which decreased binding capacity significantly and increased porosity in the baked waffle cone structure and red rice flour had a negative quadratic effect. Similar trend was observed by Huang *et al.* (1988) in ice cream waffle cone. While the interaction between apple pomace flour with red rice flour, apple pomace flour with sugar powder, and red rice flour with sugar powder had a positive quadratic effect on the preparation of gluten-free waffle cones (Figure 4.10).

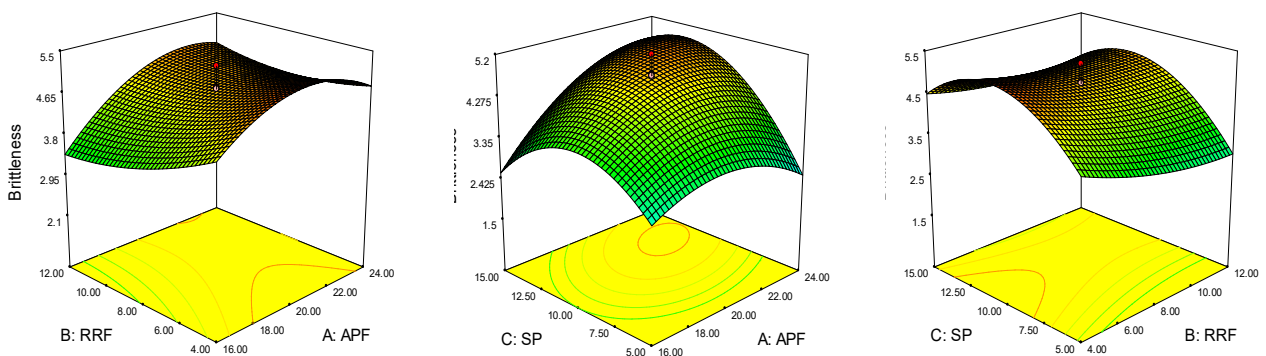


Figure (4.10)- Three-dimensional response surface for brittleness of gluten-free waffle cone.

c) Toughness

The correlation between independent variables (apple pomace flour, red rice flour, and sugar powder) with the toughness of gluten-free apple pomace waffle cones is mentioned in eqⁿ ...4.3 (c)

$$\text{Toughness} = + 1078.40 + 26.51 A + 35.54 B + 144.42 C + 17.31 AB - 13.80 AC - 21.05 BC - 40.47 A^2 - 91.24 B^2 - 88.45 C^2 \dots 4.3 (c)$$

$$R^2 = 0.9742$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in Equation 4.3 (c). The model was properly fitted by 97.42 per cent as shown by the determination coefficient (R^2) value. The toughness of the gluten-free waffle cone was found significantly affected by independent variables. Independent factors were shown to have a substantial impact on the toughness of the gluten-free waffle cone. Run 3 (20.00 g of apple pomace flour, 8.00 g of red rice flour, and 1.59 g of sugar powder) observed the lowest toughness of the gluten-free waffle cone *i.e.*, 580.00 (g.sec).

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 97.42 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggest that model results were significant. In second-order analysis, the derived equation (4.3 c) shows that apple pomace flour, red rice flour, and sugar powder had a positive quadratic effect. While the interaction between apple pomace flour with red rice flour had a positive effect, apple pomace flour with sugar powder and red rice flour with sugar powder had a negative quadratic effect, on the preparation of gluten-free waffle cones. This was due to incomplete gelatinization because of higher sugar concentration (Kigozi *et al.*, 2016) Figure (4.11).

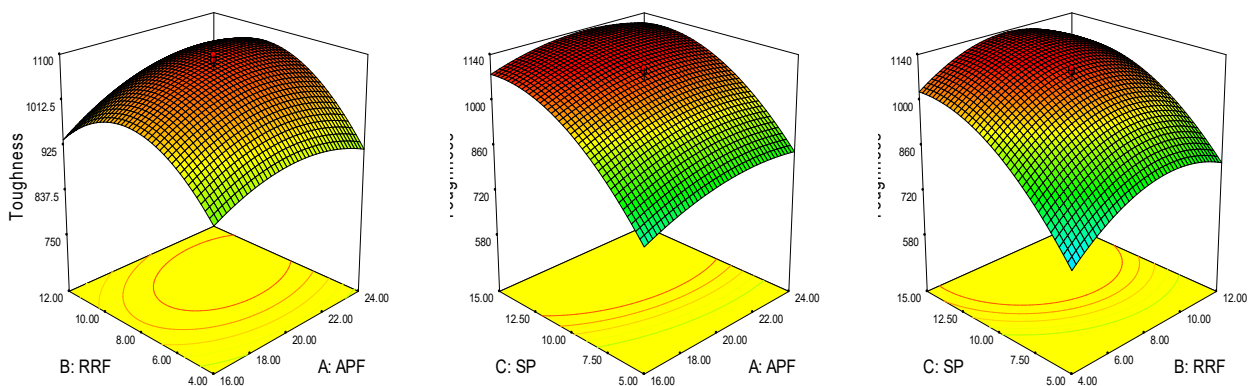


Figure (4.11)- Three-dimensional response surface for the toughness of gluten-free waffle cone.

d) Crispness

The correlation between independent variables (apple pomace flour, red rice flour, and sugar powder) with the crispness of gluten-free apple pomace waffle cones is mentioned in eqⁿ4.3 (d)

$$\text{Crispness} = + 17.35 - 0.42 A + 0.54 B + 3.50 C - 0.25 AB + 0.50 AC + 0.50 BC - 1.84 A^2 - 1.67 B^2 - 1.84 C^2 \dots 4.3 (d)$$

$$R^2 = 0.9849$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in equation 4.3 (d). The model was properly fitted by 98.49 per cent as shown by the determination coefficient (R^2) value. The crispness of the gluten-free waffle cone was found significantly affected by independent variables. Independent factors were shown to have a substantial impact on the crispness of gluten-free waffle cones. Run 3 (20.00 g of apple pomace flour, 8.00 red flour, and 1.59 g of sugar powder) recorded the minimum crispness of the gluten-free waffle cone *i.e.*, 6.00.

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 98.49 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results were significant. In second-order analysis, the derived equation (4.3 d) shows that apple pomace flour had a negative quadratic effect and red rice flour and sugar powder had a positive quadratic effect. While the interaction between apple pomace flour with red rice flour had a negative quadratic effect, apple pomace flour with sugar powder and red rice flour with sugar powder had a positive quadratic effect on the preparation of gluten-free waffle cone as due to high fibre content in apple pomace, more amount of milk was utilized for the preparation of batter. Therefore, the increase in fibre and protein content resulted in harder and crispier structure of cone. The results were well agreed with Kushwaha *et al.* (2023) in Jackfruit seed flour-based waffle cone (Figure 4.12).

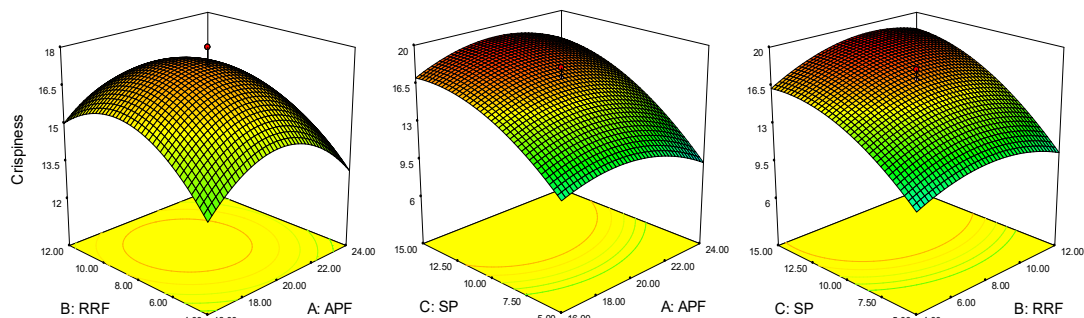


Figure (4.12)- Three-dimensional response surface for crispness of gluten-free waffle cone.

e) Ice cream holding time

The correlation between independent variables (apple pomace flour, red rice flour, and sugar powder) with ice-cream holding time of gluten-free apple pomace waffle cones is mentioned in eqⁿ....4.3 (e)

$$\text{Icecream holding time} = + 29.34 - 1.52 A + 2.08 B + 3.85 C + 0.63 AB + 0.87 AC + 2.38 BC - 0.72A^2 - 0.90 B^2 - 1.96 C^2 \dots 4.3 (e)$$

$$R^2 = 0.9523$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in equation 4.3 (e). The model was properly fitted by 95.23 per cent as shown by the determination coefficient (R^2) value. The ice cream holding time of the gluten-free waffle cone found to be significantly affected by independent variables. Independent factors were shown to have a substantial impact on the ice cream holding time of the gluten-free waffle cone. Run 15 (16.00 g of apple pomace flour, 12.00 red rice flour and 15.00 g of sugar powder) had the maximum ice-cream holding time of the gluten-free waffle cone *i.e.*, 34.00 min.

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 95.23 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results were significant. In second-order analysis, the derived equation (4.3 e) showed that apple pomace flour had a negative effect due to high fibre content of apple pomace which contributed to high water absorption capacity leading to lesser ice cream holding time. Whereas, red rice flour and sugar powder had a positive quadratic effect. While the interaction between apple pomace flour with red rice flour, apple pomace flour with sugar powder, and red rice flour with sugar powder had a positive quadratic effect (Figure 4.13).

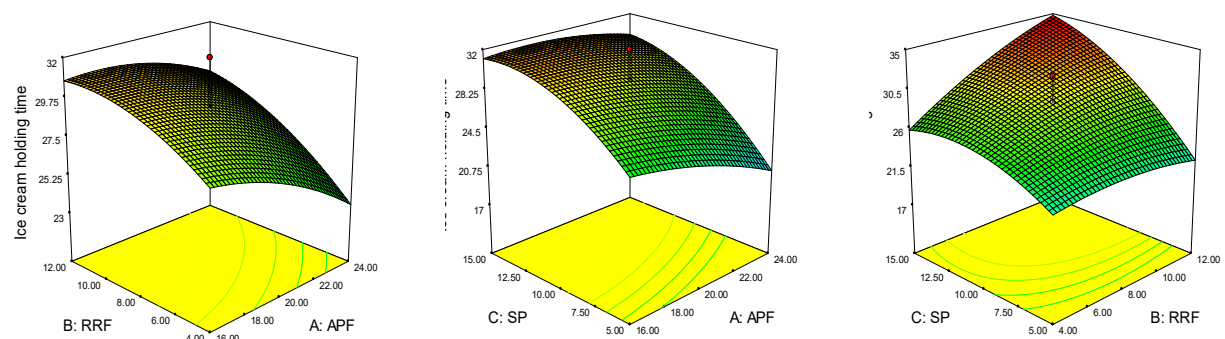


Figure (4.13)- Three-dimensional response surface for ice-cream holding time of gluten-free waffle cone

f) Overall acceptability (9-point hedonic scale)

The correlation between independent variables (apple pomace flour, red rice flour, and sugar powder) with the overall acceptability of gluten-free apple pomace waffle cones is mentioned in eqⁿ 4.3 (f)

$$\text{Overall acceptability} = + 8.00 - 0.22 A + 0.095 B + 0.34 C + 0.070 AB - 0.11 AC - 0.090 BC - 0.19 A^2 - 0.51 B^2 - 0.43 C^2 \dots 4.3 (f)$$

$$R^2 = 0.9656$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in equation 4.3 (f). The model was properly fitted by 96.56 per cent as shown by the determination coefficient (R^2) value. The overall acceptability of the gluten-free waffle cone was found significantly affected by independent variables. Independent factors were shown to have a substantial impact on the overall acceptability of the gluten-free waffle cone. Run 3 (20.00 g of apple pomace flour, 8.00 g red rice flour, and 1.59 g sugar powder) recorded the minimum overall acceptability gluten-free waffle cone *i.e.*, 6.10.

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 96.56 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results were significant. In second-order analysis, the derived equation (4.3 f) shows that apple pomace flour had a negative quadratic effect, and red rice flour and sugar powder had a positive quadratic effect may be due to the caramelization with fruity flavour of the natural sugar present in apple pomace waffle cone. Similar results were reported by Alongi *et al.* (2019) in apple pomace flour supplemented biscuits. While the interaction between apple pomace flour with red rice flour had a positive quadratic effect, apple pomace flour with sugar powder and red rice flour with sugar powder had a negative quadratic effect on the preparation of gluten-free waffle cone (Figure 4.14).

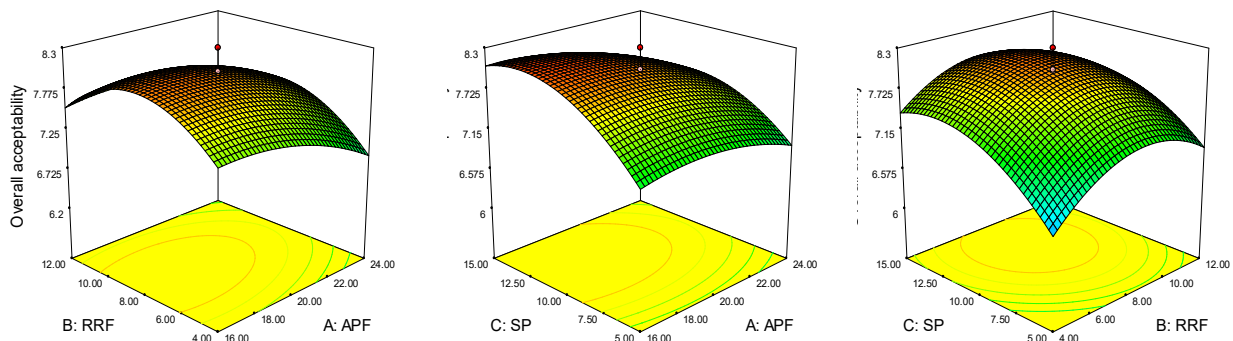


Figure (4.14)- Three-dimensional response surface for overall acceptability of gluten-free waffle cone

4.3.3 Optimization of ingredients for the preparation of gluten-free apple pomace waffle cones through desirability

The result generated from the RSM plot indicated the dependence of independent variables (apple pomace flour, red rice flour, and sugar powder) on dependent variables (hardness, brittleness, toughness, crispness, ice-cream holding time, and overall acceptability) of the gluten-free waffle cone prepared from apple pomace based were predicted by using the Design expert-07 software by setting optimum goal requirements as presented in Table 4.15 which resulted in the predicted values. Response surface plots were taken into consideration for optimization since the best result came from interactions between the various responses. The optimization process was based on desirability which is a multiple-response approach. The optimization approach considers each variable's priorities and desires, and the scores of each dependent variable were converted into scores for desirability, which ranged from 0 for undesirable to 1.0 for very desirable. The geometric mean of the individual desirability was used to calculate the overall desirability of the outcomes at various levels of the response variable.

Table 4.15: Optimization of ingredients for gluten-free apple pomace waffle cone through desirability

S. No.	Factor of responses	Goal	Lower limit	Upper limit	Importance	Predicted value
1	A: Apple pomace flour (g)	equal to >	16.00	24.00	3	20.00
2	B: Red rice flour (g)	equal to >	4.00	12.00	3	8.00
3	C: Sugar powder (g)	target	5.00	15.00	3	10.00
4	Hardness (g)	is in range	565.19	1412.15	3	1328.45
5	Brittleness (mm)	is in range	1.50	5.50	3	4.75
6	Toughness (g. sec)	is in range	580.00	1100.00	3	1078.40
7	Crispness	maximize	6.00	19.00	3	17.35
8	Ice cream holding time (min)	maximize	17.00	34.00	3	29.34
9	Overall acceptability	maximize	6.10	8.30	3	8.00

Table 4.16: Predicted and observed values of Responses of gluten-free apple pomace waffle cone

Sr. No.	Responses	Predicted value	Observed values
1	Hardness (g)	1328.45	1336.27
2	Brittleness (mm)	4.75	4.76
3	Toughness (g. sec)	1078.40	1089.62
4	Crispness	17.35	18.00
5	Ice cream holding time (min)	29.34	29.00
6	Overall acceptability	8.00	7.92
7	Desirability (%)	86.00	

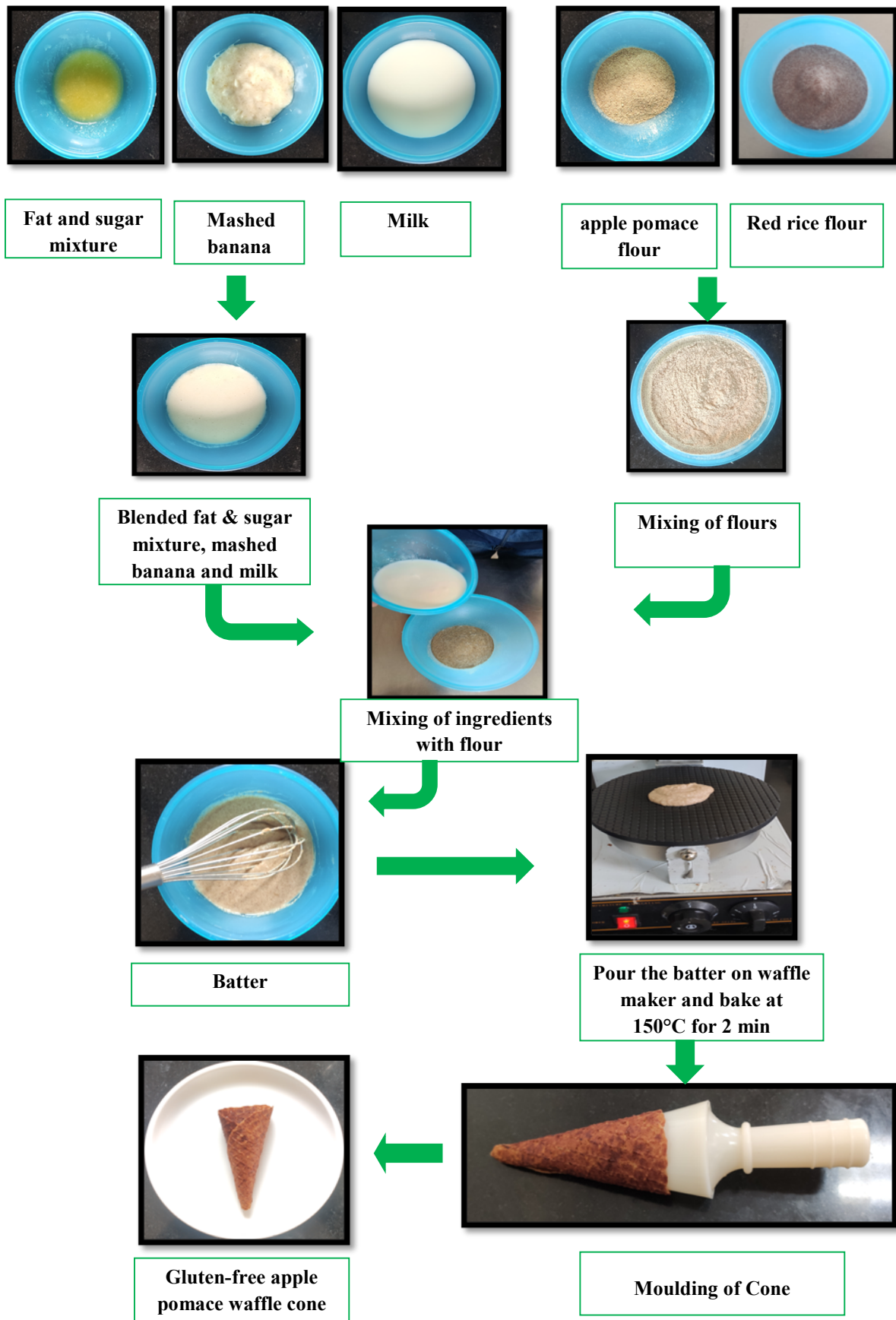


Plate 2- Flow chart for the preparation of gluten-free apple pomace waffle cone (apple pomace with red rice flour)

The responses of ingredients for the development of gluten-free waffle cone from apple pomace predicted by using the Design expert-07 software result hardness 1328.45 g, brittleness 4.75 mm, toughness 1078.40 g.sec crispness 17.35 ice-cream holding time 29.34 min and overall acceptability 8.00 based on 9-point hedonic scale sensory evaluation. The closeness of observed value with predicted values for hardness 1336.27 g, brittleness 4.76 mm, toughness 1089.62 g.sec with observed values of crispness 18.00 ice-cream holding time 29.00 min, and overall acceptability 7.92 approved the validation of response surface methodology (RSM) model (Table 4.16). The desirability scores 86.00 per cent for the preparation of gluten-free apple pomace waffle cones was within the most acceptable limits.

4.3 Quality characteristics of waffle cones

4.3.1 Physical and functional quality of waffle cones

The data illustrated in the Table 4.17 shows that the weight and thickness of apple pomace waffle cone was recorded significantly higher *i.e.*, 10.20 g and 2.57 mm as compared to 10.02 and 2.51 mm in gluten-free apple pomace waffle cone and 8.00 g and 2.50 mm in market waffle cone. The ice cream holding time (ICHT) of market waffle cone was higher with a value of 34.00 min followed by 31.00 min in apple pomace waffle cone and 29.00 min in gluten-free apple pomace waffle cone. The apple pomace waffle cone and gluten-free apple pomace waffle cone had lower ice cream holding time which might be due to the less amount of binding agent and higher amount of fibre content that leads to increase in the water absorption capacity which allowed faster migration and adsorption of water at the interface. Similar results were given by Mhatre *et al.* (2022). A non-significant difference was recorded between baking loss apple pomace waffle cone (66.00 %) and gluten-free apple pomace waffle cone (66.60 %).

Table 4.17: Physical and functional quality of waffle cones

Physical and functional quality	Mean \pm SD			
	Market waffle cone	Apple pomace waffle cone	Gluten-free apple pomace waffle cone	CD
Weight (g)	8.00 ^c \pm 0.05	10.20 ^a \pm 0.06	10.02 ^b \pm 0.06	0.04
Thickness (mm)	2.50 ^b \pm 0.01	2.57 ^a \pm 0.01	2.51 ^b \pm 0.01	0.02
Ice cream holding time (min)	34.00 ^a \pm 0.19	31.00 ^b \pm 0.17	29.00 ^c \pm 0.16	1.08
Baking loss (%)	NA	66.00 ^a \pm 0.26	66.60 ^a \pm 0.25	NS

4.3.2 Texture quality of waffle cones

Textural quality is one of the most important characteristics of waffle cone and is strongly related with the consumers perception of products freshness (Table 4.18). The product hardness is a one of the crucial texture attributes. Gluten-free apple pomace waffle cone was recorded to have significantly higher hardness of 1336.27 g as compared to market waffle cone (1244.73 g) and apple pomace waffle cone (921.66 g). Similarly, toughness was observed to be highest in case of market waffle cone (1151.09 g.sec) followed by gluten-free apple pomace waffle cone (1089.62 g.sec) and apple pomace waffle cone (1036.82 g.sec). significant difference in the toughness was due to the fact that higher amount of binding agent was present in market waffle cone. Whereas, the brittleness and crispness were recorded maximum in gluten-free apple pomace waffle cone (4.76 mm and 18.00) followed by apple pomace waffle cone (4.53 mm and 17.00) and market waffle cone (3.73 mm and 15.00). The perception of crispness is equal in importance to freshness and is related to consumers, enjoyment of waffle cone. Due to the presence high fibre in apple pomace flour as compared to whole wheat flour and red rice flour more liquid is required to get a good mix for cone and the cone prepared from material having high absorption end to be hard and ultimately crispier. Similar results were reported by Silva *et al.* (2022) in the study where the cones were developed using jackfruit seed flour.

Table 4.18: Texture quality of waffle cone

Texture quality	Mean \pm SD			
	Market waffle cone	Apple pomace waffle cone	Gluten-free apple pomace waffle cone	CD
Hardness (g)	1244.73 ^b \pm 3.15	921.66 ^c \pm 2.50	1336.27 ^a \pm 3.54	10.16
Brittleness (mm)	3.73 ^c \pm 0.05	4.53 ^b \pm 0.06	4.76 ^a \pm 0.07	0.07
Toughness (g. sec)	1151.09 ^a \pm 2.90	1036.82 ^c \pm 2.67	1089.62 ^b \pm 2.85	12.23
Crispness	15.00 ^c \pm 0.10	17.00 ^b \pm 0.11	18.00 ^a \pm 0.13	0.22

4.3.3 Sensory quality of waffle cones based on 9-point hedonic scale

The data appended in Table 4.19 shows the sensory quality of waffle cones based on 9-point hedonic scale. The apple pomace waffle cone scored significantly higher for texture 8.50, taste 8.20, colour 8.10 and overall acceptability 8.27 as compared to gluten-free apple pomace waffle cone and market waffle cone scores. The apple pomace waffle cone and gluten-free apple pomace waffle cone were given high sensory scores owing to the fruity

flavor, aroma and brownish-red colour of apple pomace flour. Similar results were given by Alongi *et al.* (2019) in biscuit prepared by apple pomace supplementation.

Table 4.19: Sensory quality of waffle cone based on 9-point hedonic scale

Sensory quality	Mean \pm SD			
	Market waffle cone	Apple pomace waffle cone	Gluten-free apple pomace waffle cone	CD
Texture	8.10 ^c \pm 0.05	8.50 ^a \pm 0.07	8.20 ^b \pm 0.05	0.06
Taste	7.50 ^c \pm 0.04	8.20 ^a \pm 0.05	7.90 ^b \pm 0.04	0.04
Colour	7.80 ^b \pm 0.04	8.10 ^a \pm 0.04	8.00 ^a \pm 0.05	0.15
Overall Acceptability	7.80 ^c \pm 0.03	8.24 ^a \pm 0.05	7.92 ^b \pm 0.04	0.10

4.3.4 Colour quality of waffle cones

Table 4.20 and figure 4.15 (a, b and c) delineates the colour quality of waffle cones by tintometer. The L* (lightness) was recorded higher in market waffle cone 54.43 and lower 24.14 in apple pomace waffle cone and 17.15 in gluten-free apple pomace waffle cone due to brown-red colour of apple pomace and red colour of red rice. Similar results of lightness were given by Parra *et al.* (2015) in cookies prepared with addition of apple pomace. Generally, the incorporation of a flour obtained from a fruit by-product leads to a reduction of L* values in cookies (Toledo *et al.* 2017). Gluten-free apple pomace waffle cone had more a* value (redness-greenness) as 7.94 while it was 6.49 in apple pomace waffle cone and 3.51 in market waffle cone which had a lower redness-greenness. The b* (yellowness-blueness) and h (hue angle) was recorded 26.66 and 82.49 in market waffle cone, 37.08 and 80.07 in apple pomace waffle cone and 28.37 and 79.91 in gluten-free waffle cone. The chroma and ΔE were recorded to be 10.83 and 13.56 in apple pomace waffle cone and 32.17 and 13.66 in gluten-free apple pomace waffle cone which clearly indicate the difference in colour intensity of apple pomace-based waffle cone as compared to market waffle cone.

Table 4.20: Colour quality of waffle cone

Colour quality	Mean \pm SD			
	Market waffle cone	Apple pomace waffle cone	Gluten-free apple pomace waffle cone	CD
L	54.43 ^a \pm 0.22	24.14 ^b \pm 0.12	17.15 ^c \pm 0.10	0.25
a*	3.51 ^c \pm 0.02	6.49 ^b \pm 0.04	7.94 ^a \pm 0.05	0.07
b*	26.66 ^c \pm 0.13	37.08 ^a \pm 0.20	28.37 ^b \pm 0.14	0.16
Hue	82.49 ^a \pm 0.25	80.07 ^b \pm 0.24	79.91 ^c \pm 0.24	0.49
Chroma	-	10.83 ^b \pm 0.06	13.56 ^a \pm 0.07	0.03
ΔE	-	32.17 ^a \pm 0.18	13.66 ^b \pm 0.08	0.06

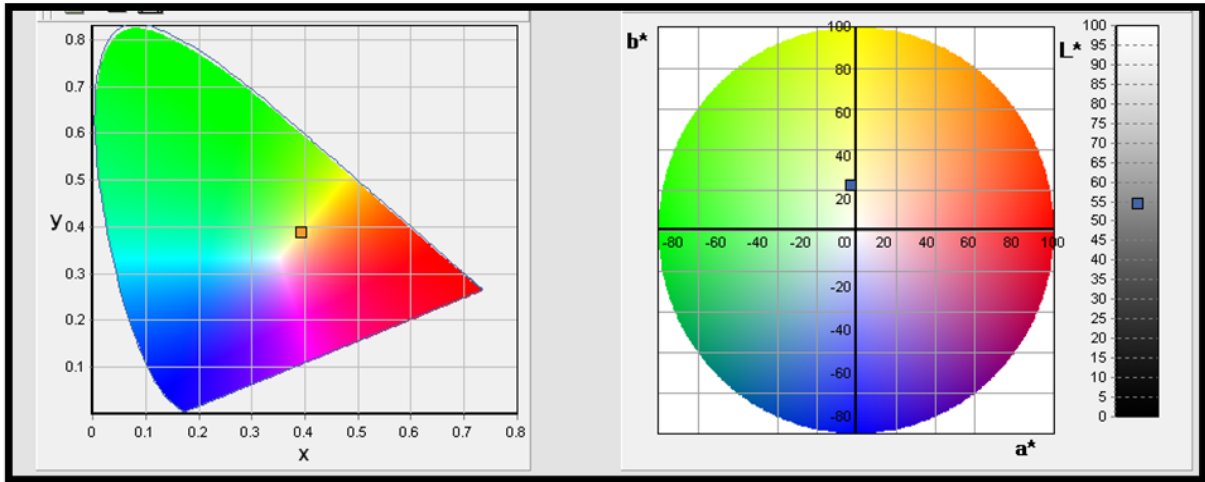


Figure 4.15 (a) CIE readings of market waffle cone

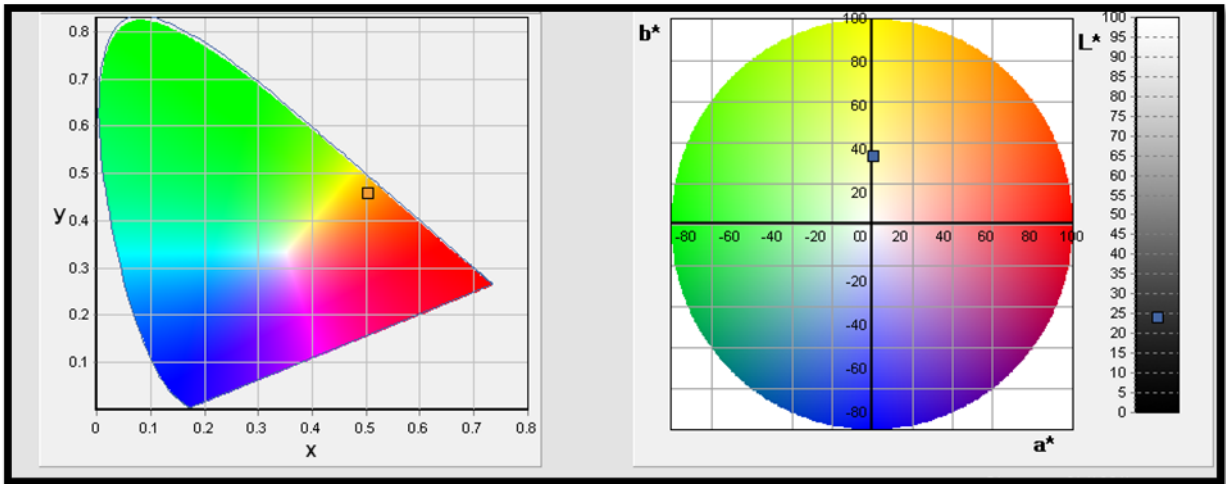


Figure 4.15 (b) CIE readings of apple pomace waffle cone

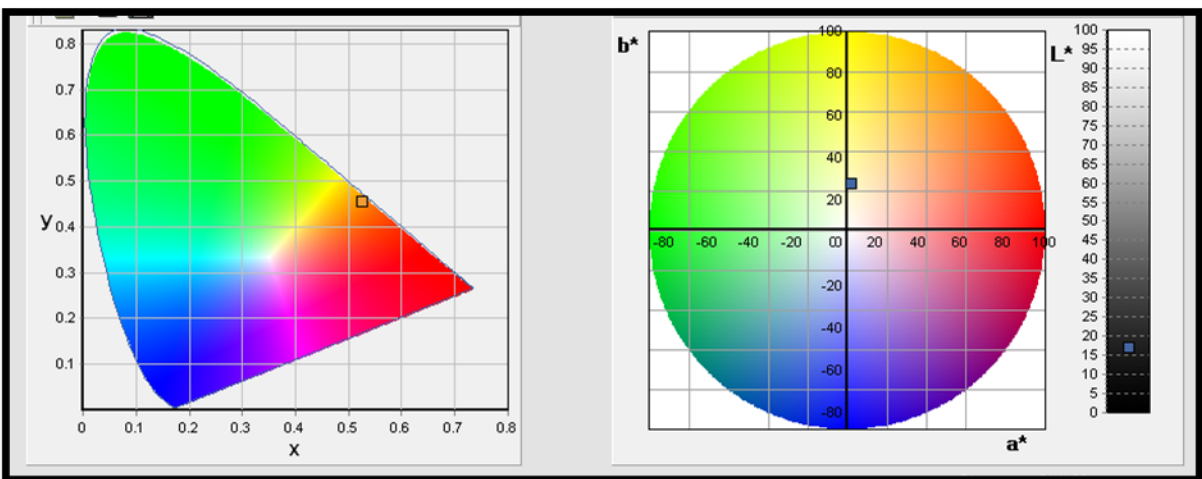


Figure 4.15 (b) CIE readings of gluten-free apple pomace waffle cone

4.3.5 Chemical quality of waffle cones

Data presented in Table 4.21 shows the chemical quality of waffle cones. The moisture content, ash content, crude fat, crude fibre, total dietary fibre, crude protein, total phenol, antioxidant activity and anthocyanin content were recorded higher in apple pomace flour-based waffle cone (apple pomace and gluten-free apple pomace waffle cone) due to nutritional profiles of apple pomace flour and whole wheat flour as well as red rice flour. Whereas, among all three waffle cones the moisture content, ash content, crude fat, crude fibre, total dietary fibre and crude protein were found significantly higher in apple pomace waffle cone (7.25 %, 2.42 %, 11.54 %, 7.13 %, 16.22 % and 8.75 %), respectively. This might be due to the use of apple pomace flour with whole wheat flour for product development. Similarly, increase in fibre content of apple pomace enriched cookies given by Zlatanovic *et al.* (2019). The higher content of total phenol, antioxidant activity and anthocyanin content were recorded in gluten-free apple pomace waffle cone (225.36 mg GAE/100g, 70.42 % and 5.04 mg/100g), respectively as compared to apple pomace waffle cone and market waffle cone. Similar result for phytochemicals and antioxidant activity were observed by Yadav and Gupta (2015) in noodles and Sudha *et al.* (2016) in buns with incorporation of apple pomace. However, carbohydrates (82.68 %) were observed higher in market waffle cone than 65.38 per cent in gluten-free apple pomace waffle cone and 62.91 per cent in apple pomace waffle cone.

Table 4.21: Chemical quality of waffle cones

Chemical quality	Mean \pm SD			CD
	Market waffle cone	Apple pomace waffle cone	Gluten-free apple pomace waffle cone	
Moisture content (%)	6.81 ^c \pm 0.03	7.25 ^a \pm 0.05	7.12 ^b \pm 0.05	0.10
Ash content (%)	1.20 ^c \pm 0.01	2.42 ^a \pm 0.02	2.31 ^b \pm 0.03	0.10
Crude fat (%)	1.62 ^c \pm 0.00	11.54 ^a \pm 0.09	10.58 ^b \pm 0.06	0.17
Crude fibre (%)	1.24 ^c \pm 0.02	7.13 ^a \pm 0.04	6.73 ^b \pm 0.04	0.11
Total dietary fibre (%)	9.54 ^b \pm 0.05	16.22 ^a \pm 0.10	15.97 ^a \pm 0.09	0.34
Crude protein (%)	6.45 ^c \pm 0.03	8.75 ^a \pm 0.06	7.88 ^b \pm 0.04	0.24
Carbohydrate (%)	82.68 ^a \pm 0.32	62.91 ^a \pm 0.15	65.38 ^b \pm 0.16	0.92
Energy Value Kcal/100g)	370.82 ^c \pm 2.33	406.92 ^b \pm 2.80	409.90 ^a \pm 2.95	3.55
Water activity	0.36 ^b \pm 0.00	0.40 ^a \pm 0.01	0.39 ^a \pm 0.00	0.01
Total phenol content (mg GAE/100g)	2.50 ^c \pm 0.01	180.12 ^b \pm 1.21	225.36 ^a \pm 1.85	4.25
Antioxidant activity (%)	6.74 ^c \pm 0.04	62.13 ^b \pm 0.14	70.42 ^a \pm 0.18	2.39
Anthocyanin content (mg/100g)	NF	3.81 ^b \pm 0.03	5.04 ^a \pm 0.03	0.03

The energy value was significantly lower in market waffle cone 370.82 Kcal/100 g as compared to apple pomace waffle cone 406.92 Kcal/100 g and gluten-free apple pomace waffle cone 409.90 Kcal/100 g.

4.3.6 Mineral composition of waffle cones

The data illustrated in Table 4.22 shows mineral content in waffle cones which includes phosphorous, potassium, sodium, calcium, sulphur, magnesium, iron, copper, zinc and manganese indicating that the apple pomace flour utilized for the development of waffle cone (apple pomace waffle cone and gluten-free apple pomace waffle cone) observed higher mineral content due to presence of high mineral content in apple pomace. Among all three waffle cones mineral content such as phosphorous, potassium, sodium, calcium, magnesium, zinc and manganese were found significantly higher in apple pomace waffle cone (1863.70 ppm, 6125.00 ppm, 3617.50 ppm, 17575.00 ppm, 2940.00 ppm, 22.90 ppm and 6.90 ppm), respectively as compared to apple pomace waffle cone and market waffle cone. Whereas, apple pomace waffle cone and gluten-free apple pomace waffle cone were recorded significantly lower 1595.70 ppm and 1408.00 ppm sulphur, 10.40 ppm and 9.42 ppm copper, as compared to 2484.00 ppm and 11.40 ppm in market waffle cone, respectively. The high amount of mineral content was found in apple pomace-based waffle cone might be due to the higher amount of minerals present in apple pomace. Similar results of mineral content was observed by Cantero *et al.* (2022) in bread after incorporation of apple pomace flour.

Table 4.22: Mineral composition of waffle cones

Mineral (ppm)	Mean \pm SD			CD
	Market waffle cone	Apple pomace waffle cone	Gluten-free apple pomace waffle cone	
Phosphorus	983.00 ^c \pm 3.11	1863.70 ^a \pm 4.21	1633.20 ^b \pm 3.80	11.43
Potassium	1425.00 ^c \pm 3.80	6125.00 ^a \pm 9.50	5350.00 ^b \pm 9.30	15.81
Sodium	3400.00 ^b \pm 6.95	3617.50 ^a \pm 7.11	3212.76 ^c \pm 7.40	17.05
Calcium	7950.00 ^c \pm 10.50	17575.00 ^a \pm 21.98	16275.60 ^b \pm 18.9	26.91
Sulphur	2484.00 ^a \pm 5.24	1595.70 ^b \pm 4.02	1408.40 ^c \pm 3.51	13.65
Magnesium	1375.00 ^c \pm 3.44	2940.00 ^a \pm 6.10	1835.40 ^b \pm 4.10	10.18
Iron	39.00 ^c \pm 0.16	44.70 ^b \pm 0.30	49.30 ^a \pm 0.28	0.75
Copper	11.40 ^a \pm 0.12	10.40 ^b \pm 0.11	9.42 ^c \pm 0.07	0.65
Zinc	20.00 ^c \pm 0.14	22.90 ^a \pm 1.56	22.26 ^b \pm 0.11	0.46
Manganese	6.20 ^c \pm 0.07	6.90 ^a \pm 0.08	6.60 ^b \pm 0.05	0.08

4.5 OPTIMIZATION OF INGREDIENTS FOR THE DEVELOPMENT OF APPLE POMACE WAFFLE CONE PRE-MIX THROUGH RESPONSE SURFACE METHODOLOGY

To estimate the effect of responses and their interaction with varying independent components, the analytical data on physical and functional attributes were obtained from the central composite design (CCD) which was fitted to first and second-order, linear and quadratic model types. Analysis of variance (ANOVA) was used to study the experimental data to assess the effects of independent variables *i.e.*, milk powder (g) and potato starch (g) on dependent variables *i.e.*, hardness (g), brittleness (mm), toughness (g.sec), crispness, ice-cream holding time (min) and overall acceptability (based on sensory evaluation 9-point hedonic scale) of the waffle cone prepared from apple pomace with whole wheat flour. Using the analysis of variance, the significance of the linear, quadratic, and independent-variable interactions, as well as their lack of fit were assessed. A capacity of a model to fit to describe the data in the experimental domain, where points were excluded from the regression, was evaluated using the lack of fit test. A successful model with a high coefficient of determination, defined as the percentage of response variation that could be attributable to the model rather than random error and same was also taken into consideration during experimentation.

Table 4.23: Independent and dependent variables used for experimental design

Independent variables	Lower limit	Upper limit	Dependent variables
Milk powder (g)	7.00	13.00	Hardness (g), Brittleness (mm), Toughness (g.sec), Crispness, Ice-cream holding time (min), and Overall acceptability
Potato starch (g)	1.00	3.00	

Overall acceptability (Sensory evaluation on 9-point hedonic scale)

4.5.1 Optimization of quantity of water based on desired viscosity

Viscosity of the batter is a major parameter which is directly linked to the quality characteristics of waffle cone development such as volume, texture, sheet development *etc.* The viscosity of batter was maintained in the range of 4500 to 5000 mPa in waffle cone batter as optimized in the pre-trials by the addition of water according to dry ingredients (milk powder and potato starch). Table 4.24 shows the quantity of water as per designed by RSM. The quantity of water increased with increase in the concentration of milk powder as well as

potato starch. This might be due to the high protein content in milk powder and starch content in potato starch. The highest quantity of water was required for the run 11 which had the highest amount of milk powder (13.00 g) and potato starch (3.00 g). While, the minimum quantity of water was required for the run 13 which had the lowest amount of milk powder (5.76 g) and potato starch (2.00 g). The water absorption capacity of any ingredient depends upon the amount of starch and protein present in the ingredients. Similar statement given by Chandra and Smasher (2013) for water absorption capacity of flours which depends on starch and fibre content present in flour and Kushwaha *et al.* (2023) observed that more liquid was required for preparation of jack fruit seed flour ice cream cone when higher protein and fibre present in jack fruit seed flour.

Table 4.24: Optimization of quantity of water based on desired viscosity (4500-5000 mPas)

S No	Milk powder (g)	Potato starch (g)	Quantity of water (ml)
1	10.00	2.00	85.00
2	10.00	0.59	82.00
3	10.00	2.00	85.00
4	14.24	2.00	90.00
5	10.00	2.00	85.00
6	10.00	2.00	85.00
7	13.00	1.00	85.00
8	10.00	3.41	90.00
9	7.00	3.00	80.00
10	10.00	2.00	85.00
11	13.00	3.00	92.00
12	7.00	1.00	78.00
13	5.76	2.00	76.00

4.5.2 Effect of independent variables on the different responses

The perusal of data in Table 4.25 revealed the effect of different dependent variables for the preparation of waffle cones from apple pomace flour-based pre-mix on different concentrations of ingredients such as milk powder (MP) and potato starch (PS). It was observed that the hardness (g) of the waffle cone prepared from pre-mix ranged from 642.63 to 1190.14 (g). The brittleness and toughness of the waffle cone ranged between 2.00 to 4.35 (mm) and 654.87 to 1267.36 (g sec), respectively. However, the maximum crispness was recorded in treatment T₁₀ with a value of (20.00) and a minimum (9.00) in treatment T₂. The ice-cream holding time of the waffle cone was found minimum (17.00 min) in treatment T₂ and a maximum (35.00 min) in treatment T₈. The overall acceptability of the waffle cone

was found to be (8.50) sensory evaluation on 9-point hedonic scale which was found maximum in treatment T₃ and a minimum (5.48) was recorded in treatment T₂. The data were analyzed to observe the effect of independent variables on these responses.

Table 4.25: Effect of independent variables on the different responses

Sn	Independent variables		Dependent variables					
	MP (g)	PS (g)	Hardness (g)	Brittleness (mm)	Toughness (g.sec)	Crispness	Ice cream holding time (min)	Overall acceptability
1	10.00	2.00	1051.20	3.45	1110.42	18.00	32	8.20
2	10.00	0.59	642.63	2.00	654.87	9.00	17	5.48
3	10.00	2.00	1020.41	3.50	1120.36	19.00	30	8.50
4	14.24	2.00	1140.20	3.32	1204.21	19.00	31	7.90
5	10.00	2.00	1060.35	3.40	1150.68	18.00	32	8.00
6	10.00	2.00	1065.24	3.30	1140.74	18.00	33	8.05
7	13.00	1.00	705.30	2.30	680.77	10.00	20	5.70
8	10.00	3.41	1170.25	4.35	1230.75	19.00	35	7.50
9	7.00	3.00	780.67	3.24	823.48	15.00	26	6.00
10	10.00	2.00	1110.54	3.60	1221.31	20.00	31	8.15
11	13.00	3.00	1190.14	3.97	1267.36	19.00	34	7.80
12	7.00	1.00	650.58	2.10	680.20	11.00	19	5.75
13	5.76	2.00	740.75	2.40	792.51	13.00	21	5.90

MP- Milk powder, PS- Potato starch

Overall acceptability based on sensory evaluation of the 9-point hedonic scale

a) Hardness

The correlation between independent variables (milk powder and potato starch) with the hardness of apple pomace waffle cone prepared from pre-mix is mentioned in eqⁿ 4.5 (a).

$$\text{Hardness} = + 1061.68 + 128.67 A + 170.37 B + 88.69 AB - 83.46 A^2 - 101.09 B^2 \dots 4.5 (a)$$

$$R^2 = 0.9537$$

Equation 4.5 (a) displays the regression coefficient from the stepwise regression fitting model and the analysis of variance. The determination coefficient (R²) value demonstrated that the model was fitted explained 95.37 per cent of the variability in the hardness of the waffle cone. The hardness of the waffle cone was found significantly affected by independent variables. It has been noticed that the waffle cone prepared from Run 2 (10.00 g of milk powder and 0.59 g of potato starch) had the lowest hardness of 642.63 g which employed and Run 11 (13.00 g of milk powder and 3.00 g of potato starch) had the highest hardness of 1190.14 g.

First-order analysis showed that the R-square value is 95.37 per cent, and P- values (0.0001) less than 0.05 indicate model values are significant. In second-order analysis, from the derived equation it was revealed that the independent variables and interaction between the milk powder and potato starch had a positive quadratic effect on the hardness of the waffle cone. The positive effect on hardness may be due to potato starch and milk powder enhanced high starch and protein content of the waffle cone responsible for the hardy structure of cones. Similar results were recorded by Kushwaha *et al.* (2023) in Jackfruit seed flour-based waffle cone (Figure 4.16).

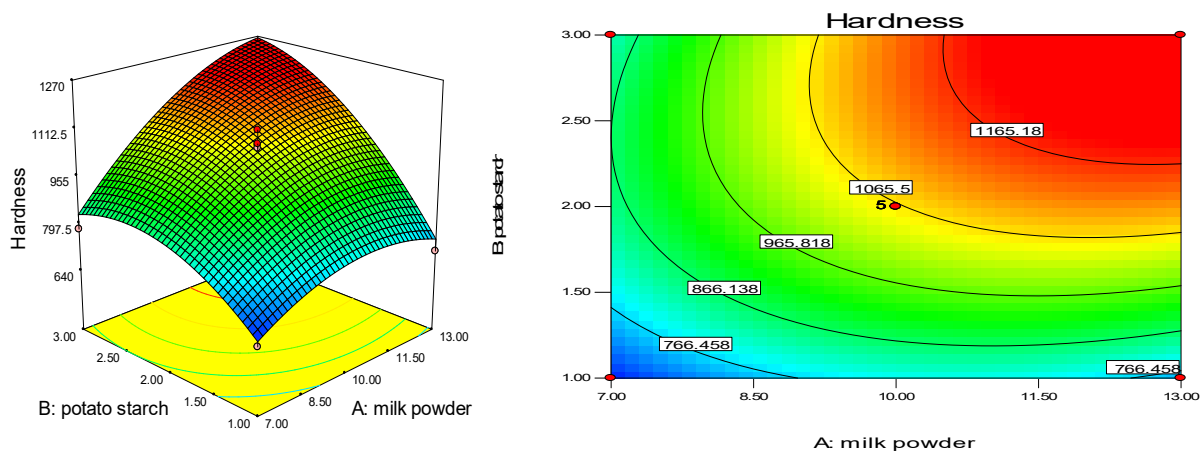


Figure (4.16)- Three-dimensional response surface and two-dimensional contour plots for hardness of waffle cone prepared from pre-mix

b) Brittleness

The correlation between independent variables (milk powder and potato starch) with the brittleness of apple pomace waffle cone prepared from pre-mix is mentioned in eqⁿ 4.5 (b).

$$\text{Brittleness} = + 3.45 + 0.28 A + 0.77 B + 0.13 AB - 0.32 A^2 - 0.17 B^2 \dots 4.5 (b)$$

$$R^2 = 0.9800$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in Equation 4.5 (b). The model was properly fitted as a value of 98.00 per cent was obtained for the determination coefficient (R^2). The brittleness of the waffle cone was found significantly affected by independent variables. Run 2 (10.00 g of milk powder and 0.59 g of potato starch) observed the lowest brittleness of the waffle cone *i.e.*, 2.00 mm.

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 98.00 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggest that model results are significant. In second-order analysis, from the derived equation it was revealed that the independent variables had a positive quadratic effect. While the interaction of milk powder with potato starch had a positive quadratic effect on the brittleness of the waffle cone. This may be due to sugar content of milk powder, apple pomace flour as well as extra addition of sugar powder, leads to slow gelatinization. The results were in accordance with Kigozi *et al.* (2016) in Sorghum ice cream cone (Figure 4.17).

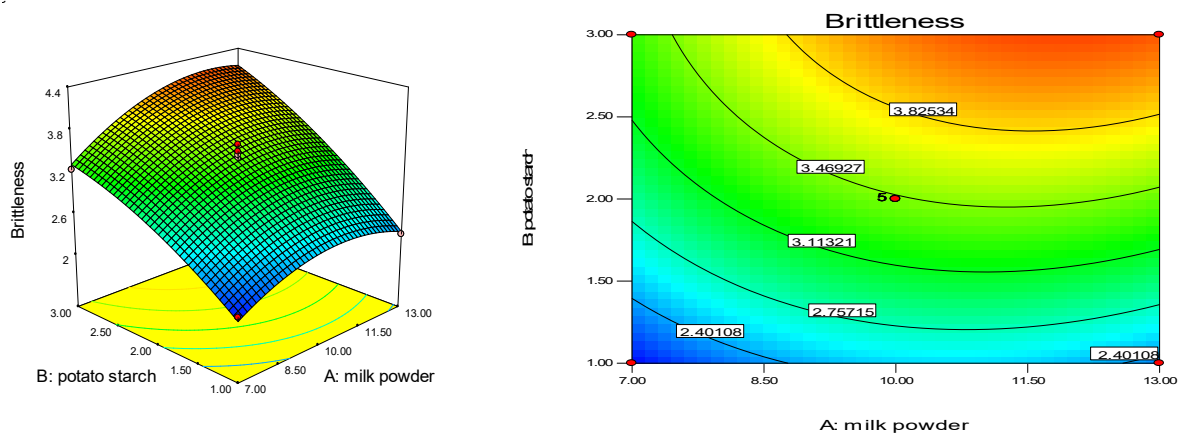


Figure (4.17)- Three-dimensional response surface and two-dimensional contour plots for brittleness of waffle cone prepared from pre-mix

c) Toughness

The correlation between independent variables (milk powder and potato starch) with the toughness of apple pomace waffle cone prepared from pre-mix is mentioned in eqⁿ 4.5 (c)
 Toughness = +1148.86 + 128.37 A + 193.31B + 110.83 AB - 102.04 A²- 130.59 B²....4.5 (c)
 R²=0.9505

Equation 4.5 (c) displays both the variance analysis and the regression coefficient from the stepwise regression fitting model. The determination coefficient (R²) value demonstrated the appropriate fit of the model with a 95.05 per cent value. It was discovered that independent factors considerably impacted the toughness of waffle cones. Independent variables were found to have a significant influence on the toughness of the waffle cone. Run 11 (13.00 g of milk powder and 3.00 g of potato starch) reflected the toughness of the waffle

cone *i.e.*, 1267.36 g sec and Run 2 (10.00 g of milk powder and 0.59 g of potato starch) reflected the lowest toughness of the waffle cone with the value of 654.87 g sec.

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 95.05 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results are significant. In second-order analysis, from the derived equation it was observed that the independent variables and interaction of milk powder and potato starch had a positive quadratic effect on the toughness of the waffle cone. The effect of independent variable may be due to starch content of potato lead to high gelatinization with good binding as well as toughness results confirmed with the reports of Dom *et al.* (2020) in waffle cone prepared from potato peel flour (Figure 4.18).

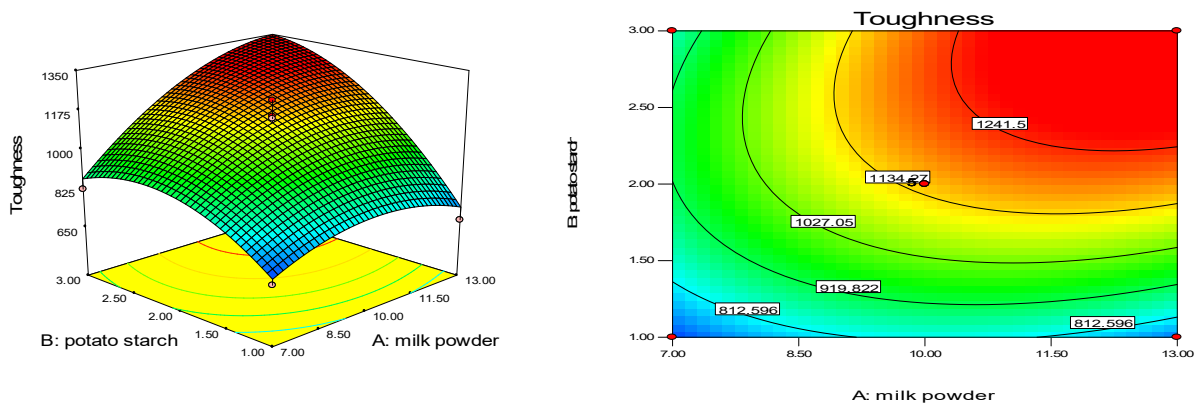


Figure (4.18)- Three-dimensional response surface and two-dimensional contour plots for toughness of waffle cone from pre-mix

d) Crispness

The correlation between independent variables (milk powder and potato starch) with the crispness of apple pomace flour + whole wheat flour waffle cone prepared from pre-mix is mentioned in eqⁿ 4.5 (d).

$$\text{Crispness} = + 18.60 + 1.44 A + 3.40 B + 1.25 AB - 1.61 A^2 - 2.63 B^2 \dots 4.5 (d)$$

$$R^2=0.9447$$

The determination coefficient (R^2) result indicated that the model was correctly fitted with a value of 94.47 per cent. Independent variables were found to have a significant influence on the crispness of the waffle cone. Run 2 (10.00 g of milk powder and 0.59 g of potato starch) observed the lowest crispness of the waffle cone *i.e.*, 9.00 and Run 10 (10.00 g

of milk powder and 2.00 g of potato starch) waffle cone was observed the highest crispness of 20.00.

R-square values of 94.47 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results are significant. In second-order analysis, from the derived equation it was observed that the independent variables and the interaction of milk powder and potato starch had a positive quadratic effect on the crispness of the waffle cone due to high starch and fibre content of potato starch and apple pomace, respectively also affect the water absorption capacity which made desirable results related to crispness of the cone. Similar results were observed by Hadiyanto *et al.* (2007) Figure (4.19).

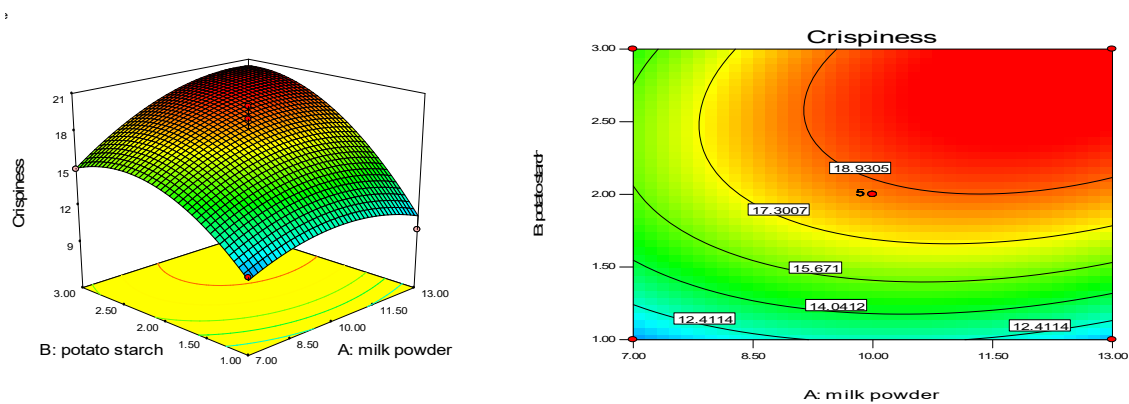


Figure (4.19)- Three-dimensional response surface and two-dimensional contour plots for crispness of waffle cone prepared from pre-mix

e) Ice cream holding time

The correlation between independent variables (milk powder and potato starch) with the ice-cream holding time of apple pomace flour + whole wheat flour waffle cone prepared from pre-mix is mentioned in eqⁿ 4.5 (e).

$$\text{Ice-cream holding time} = + 31.60 + 2.89 A + 5.81B + 1.75 AB - 3.11 A^2 - 3.13 B^2 \dots 4.5 (e)$$

$$R^2=0.9708$$

The determination coefficient (R^2) result indicated that the model was correctly fitted with a value of 97.08 per cent. It was observed that the independent factors considerably impacted the ice cream holding time. Run 2 (10.00 g of milk powder and 0.59 g of potato starch) was observed with the minimum ice-cream holding time in waffle cone for the value of 17.00 (min) and Run 8 (10.00 g of milk powder and 3.41 g of potato starch) was recorded with the highest ice-cream holding time in a waffle cone *i.e.*, 35.00 (min).

R-square values of 97.08 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results were significant. In second-order analysis, from the derived equation it was revealed that the independent variables and the interaction between the milk powder and potato starch had a positive quadratic effect on the ice-cream holding time of the waffle cone due to high binding capacity of potato starch and milk protein. The findings were in accordance with Kigozi *et al.* (2011) observed positive interaction between maize starch and sorghum protein results in increased the ice holding time in sorghum ice cream cone (Figure 4.20).

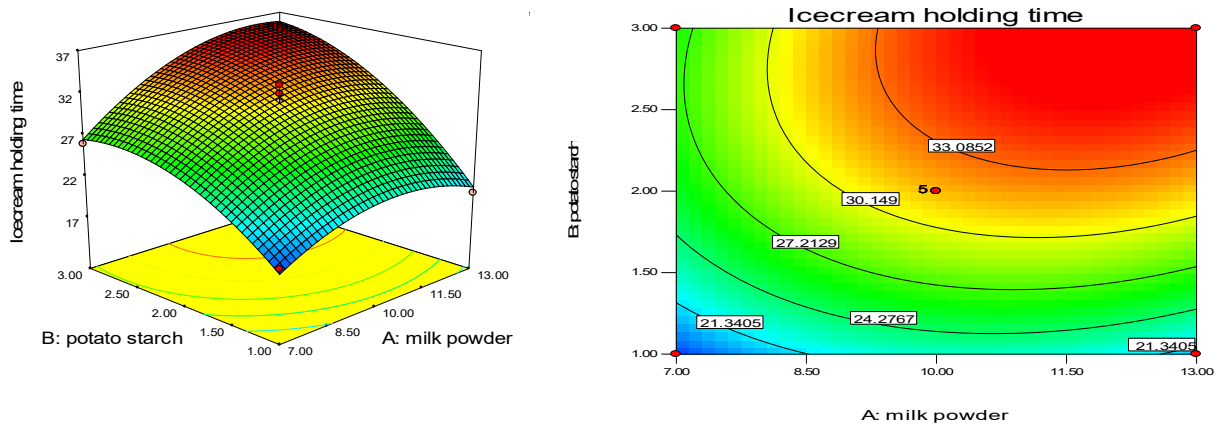


Figure (4.20)- Three-dimensional response surface and two-dimensional contour plots for ice cream holding time of waffle cone prepared from pre-mix

f) Overall acceptability (9-point hedonic scale)

The correlation between independent variables (milk powder and potato starch) with the overall acceptability of apple pomace flour + whole wheat flour waffle cone prepared from pre-mix is mentioned in eqⁿ 4.5 (f).

$$\text{Overall acceptability} = + 8.18 + 0.57 A + 0.65 B + 0.46 AB - 0.74 A^2 - 0.95 B^2 \dots 4.5 (f)$$

$$R^2=0.9623$$

The determination coefficient (R^2) result indicated that the model was correctly fitted having a value of 96.23 per cent. Independent variables were found to have a significant influence on the overall acceptability of waffle cones. Run 3 (10.00 g of milk powder and 2.00 g of potato starch) recorded the maximum overall acceptability in the waffle cone *i.e.*, 8.50 and Run 2 (10.00 g of milk powder and 0.59 g of potato starch) waffle cone recorded minimum overall acceptability in the waffle cone *i.e.*, 5.48.

R-square values of 96.23 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggest that model results were found significant. In second-order analysis, from the derived equation it was recorded that the independent variables and their interaction (milk powder and potato starch) had a positive quadratic effect on the overall acceptability of the waffle cone may be due to the caramelization with fruity flavour of the natural sugar present in apple pomace waffle cone. Similar results were reported by Alongi *et al.* (2019) in apple pomace flour supplemented biscuits (Figure 4.21).

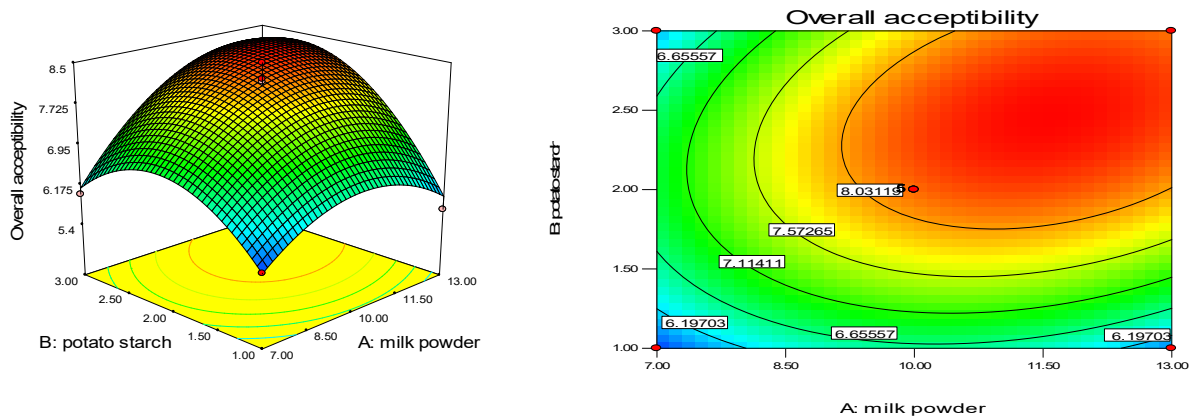


Figure (4.21)- Three-dimensional response surface and two-dimensional contour plots for overall acceptability of waffle cone prepared from pre-mix

4.5.3 Optimization of ingredients for apple pomace waffle cone through desirability

The RSM result indicated the output of independent variables (milk powder and potato starch) on dependent variables (hardness, brittleness, toughness, crispness, ice-cream holding, and overall acceptability) of the apple pomace waffle cone prepared from pre-mix. Response surface plots were taken into consideration for optimization since the best result came from interactions between the various responses. The optimization process was based on desirability with is a multiple-response approach. The optimization approach considers each variable's priorities and desires, and the scores of each dependent variable were converted into scores for desirability, ranged from zero for undesirable to 1.0 for very desirable. The geometric mean of the individual desirability was used to calculate the overall desirability of the outcomes at various level of the responses variable. The predicted values were observed by setting optimum goals for independent and dependent variables to be in range, maximum, minimum, or target, varying accordingly before final optimization as depicted in Table 4.26.

Table 4.26: Optimization of ingredients through desirability

S. No.	Factor of responses	Goal	Lower limit	Upper limit	Importance	Predicted value
1	A: Milk powder (g)	equal to >	7.00	13.00	3	10.00
2	B: Potato starch (g)	target	1.00	3.00	3	2.00
3	Hardness (g)	is in range	642.63	1190.14	3	1061.69
4	Brittleness (mm)	is in range	2.00	4.35	3	3.45
5	Toughness (g. sec)	is in range	654.87	1267.36	3	1148.87
6	Crispness	maximize	9.00	20.00	3	18.60
7	Ice cream holding time (min)	maximize	17.00	35.00	3	31.60
8	Overall acceptability	maximize	5.48	8.50	3	8.18

Table 4.27: Predicted and observed values of Responses of waffle cone prepared from pre-mix

S. No.	Responses	Predicted value	Observed values
1	Hardness (g)	1061.69	1060.35
2	Brittleness (mm)	3.45	3.40
3	Toughness (g. sec)	1148.87	1150.68
4	Crispness	18.60	18.00
5	Ice cream holding time (min)	31.60	32.00
6	Overall acceptability	8.18	8.00
7	Desirability (%)	89.00	-

The responses of ingredients for the development of the waffle cone from apple pomace flour-based pre-mix predicted by using the Design Expert-07 software given in Table 4.27 resulted in a hardness of 1061.69 g, brittleness of 3.45 mm, a toughness of 1148.87 g.sec, crispness of 18.60, ice-cream holding time 31.60 min, and overall acceptability 8.18. The closeness of the values observed for hardness (1060.35 g), brittleness (3.40 mm), toughness (1150.68 g sec), crispness (18.00), ice-cream holding time (32.00 min) and overall acceptability (8.00) approved the response surface methodology (RSM) model validation (Table 4.27). The desirability score for the waffle cone with apple pomace flour-based pre-mix was 0.89 formed within the acceptable limits.

4.6 OPTIMIZATION OF INGREDIENTS FOR THE DEVELOPMENT OF GLUTEN-FREE APPLE POMACE WAFFLE CONE FROM PRE-MIX THROUGH RESPONSE SURFACE METHODOLOGY

To estimate the effect of responses and their interaction with varying independent components, the analytical data on physical and functional attributes were obtained from the

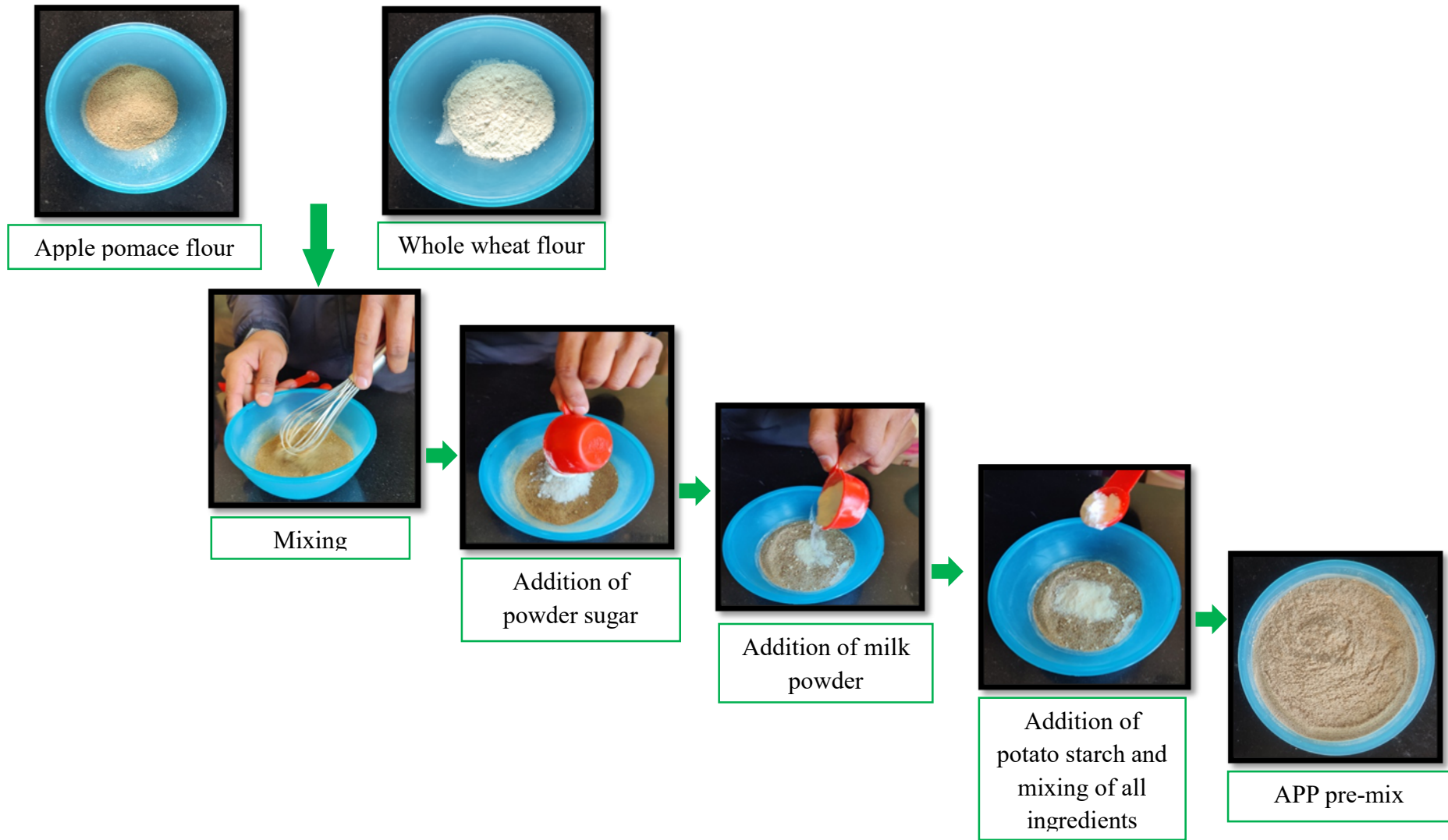


Plate 3- Flow chart for the preparation of apple pomace waffle cone pre-mix (apple pomace flour with whole wheat flour)

central composite design (CCD) which was fitted to first and second-order, linear, and quadratic model types. Analysis of variance (ANOVA) was used to study the experimental data to assess the effects of independent variables *i.e.*, milk powder (g) and potato starch (g) on dependent variables *i.e.*, hardness (g), brittleness (mm), toughness (g.sec), crispness, ice-cream holding time (min) and overall acceptability (based on sensory evaluation 9-point hedonic scale) of the gluten-free waffle cone prepared from apple pomace with red rice. Using the analysis of variance, the significance of the linear, quadratic, and independent-variable interactions, as well as their lack of fit, were assessed. A capacity of a model to fit to describe the data in the experimental domain, where points were excluded from the regression, was evaluated using the lack of fit test. A successful model with a high coefficient of determination, defined as the percentage of response variation that could be attributable to the model rather than random error same was also taken into consideration during experimentation.

Table 4.28: Independent and dependent variables used for experimental design

Independent variables	Lower limit	Upper limit	Dependent variables
Milk powder (g)	7.00	13.00	Hardness (g), Brittleness (mm), Toughness (g.sec), Crispness, Ice-cream holding time (min), and Overall acceptability
Potato starch (g)	1.00	3.00	

Overall acceptability (Sensory evaluation on 9-point hedonic scale)

4.6.1 Optimization of quantity of water based on desired viscosity

Viscosity of the batter is a major parameter which is directly linked to the quality characteristics of waffle cone development such as volume, texture, sheet development etc. The viscosity of batter was maintained in the range of 4500 to 5000 mPa in waffle cone batter as optimized in the pre-trials by the addition of water according to dry ingredients (milk powder and potato starch). Table 4.29 shows the quantity of water as per designed by RSM. The quantity of water increased with increase in the concentration of milk powder as well as potato starch. This might be due to the high protein content in milk powder and starch content in potato starch. The highest quantity of water (88.00 ml) was required for the run 11 (13.00 g of milk powder and 3.00 g of potato starch). While, the minimum quantity of water was required for the run 13 (5.76 g of milk powder and 2.00 g of potato starch). The water absorption capacity of any ingredient depends upon the amount of fibre, starch and protein

present in the ingredients. Similar statement given by Chandra and Smasher (2013) for water absorption capacity of flours which depends on starch and fibre content present in flour and Kushwaha *et al.* (2023) observed that more liquid was required for preparation of jack fruit seed flour ice cream cone when higher protein and fibre present in jack fruit seed flour.

Table 4.29: Optimization of quantity of water based on desired viscosity (4500-5000 mPas)

S No	Milk powder (g)	Potato starch (g)	Quantity of water (ml)
1	10.00	2.00	80.00
2	10.00	0.59	77.00
3	10.00	2.00	80.00
4	14.24	2.00	85.00
5	10.00	2.00	80.00
6	10.00	2.00	80.00
7	13.00	1.00	83.00
8	10.00	3.41	86.00
9	7.00	3.00	78.00
10	10.00	2.00	80.00
11	13.00	3.00	88.00
12	7.00	1.00	74.00
13	5.76	2.00	70.00

4.6.2 Effect of independent variables on the different responses

The perusal of data in Table 4.30 revealed the effect on different dependent variables for the preparation of gluten-free waffle cones from apple pomace flour based on different concentrations of ingredients such as milk powder (MP) and potato starch (PS). It was observed that the hardness (g) of the waffle cone ranged between 620.00 and 1185.21 (g). The maximum brittleness of the gluten-free waffle cone was observed in treatment T₈ *i.e.*, 4.50 mm and minimum in treatment T₂ (1.80 mm), Whereas, the maximum toughness of the gluten-free waffle cone was found in treatment T₁₁ (1260.00 g.sec) and minimum in treatment T₂ (670.20 g.sec) respectively. However, the maximum crispness was recorded in treatment T₁₁ with a value of (19.00) and a minimum of (7.00) in treatment T₂. The ice-cream holding time of the gluten-free waffle cone was found minimum (15.00 min) in treatment T₂ and a maximum of (34.00 min) in treatment T₈. The overall acceptability of the gluten-free waffle cone was found to be (8.50), which was found maximum in treatment T₆ and the minimum (5.54) was recorded in treatment T₂. The data were analyzed to observe the effect of independent variables on these responses.

Table 4.30: Effect of independent variables on the different responses

Sn	Independent variables		Dependent variables					
	MP (g)	PS (g)	Hardness (g)	Brittleness (mm)	Toughness (g.sec)	Crispness	Ice cream holding time (min)	Overall acceptability
1	10.00	2.00	990.15	3.20	1021.00	16.00	29	8.00
2	10.00	0.59	620.00	1.80	670.20	7.00	15	5.54
3	10.00	2.00	1012.20	3.34	1047.00	17.00	30	8.20
4	14.24	2.00	1042.14	3.50	1145.54	18.00	30	7.75
5	10.00	2.00	1050.24	3.70	1090.24	17.00	30	7.95
6	10.00	2.00	990.27	3.47	1105.92	17.00	31	8.50
7	13.00	1.00	690.75	2.14	890.58	9.00	17	5.24
8	10.00	3.41	1100.25	4.50	1121.21	18.00	34	6.50
9	7.00	3.00	820.54	3.00	990.46	13.00	26	5.89
10	10.00	2.00	1024.68	3.54	1125.63	18.00	32	8.10
11	13.00	3.00	1185.21	3.97	1260.00	19.00	34	7.80
12	7.00	1.00	650.58	2.10	770.20	11.00	19	5.75
13	5.76	2.00	740.75	2.40	792.51	13.00	21	5.90

MP- Milk powder, PS- Potato starch

Overall acceptability (Sensory evaluation on 9-point hedonic scale)

a) Hardness

The correlation between independent variables (milk powder and potato starch) with the hardness of gluten-free apple pomace waffle cone prepared from pre-mix is mentioned in Eqⁿ 4.6 (a).

$$\text{Hardness} = + 1013.56 + 104.53 A + 168.82 B + 82.36 AB - 70.44 A^2 - 86.57 B^2 \dots 4.6 (a)$$

$$R^2 = 0.9867$$

Equation 4.6 (a) displays the regression coefficient from the stepwise regression fitting model and the analysis of variance. The determination coefficient (R^2) value demonstrated that the model was fitted explained 98.67 per cent of the variability in hardness of gluten-free waffle cones. The hardness of gluten-free waffle cones was found significantly affected by independent variables. It has been noticed that the gluten-free waffle cone prepared from Run 2 (10.00 g of milk powder and 0.59 g of potato starch) had the lowest hardness of 620.00 g and Run 11 (13.00 g of milk powder and 3.00 g of potato starch) had the highest hardness of 1185.21 g.

First-order analysis showed that the R-square value is 98.67 per cent, and P- values (0.0001) less than 0.05 indicate model values are significant. In second-order analysis, from

the derived equation it was revealed that the first independent variables and interaction of milk powder with potato starch had a positive quadratic effect on the hardness of gluten-free waffle cones. This might be possible because of the high protein content in milk powder and starch content in potato which leads to high gelatinization contributing to increased hardness. Similar results were observed by Silva *et al.* (2022) in gluten free ice cream basket (Figure 4.22).

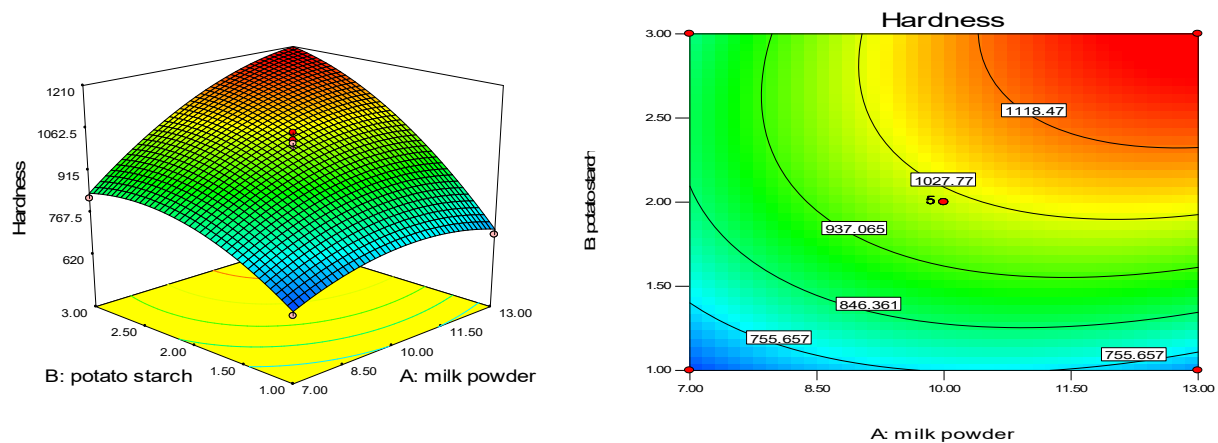


Figure (4.22)- Three-dimensional response surface and two-dimensional contour plots for hardness of gluten-free waffle cone prepared from pre-mix

b) Brittleness

The correlation between independent variables (milk powder and potato starch) with the brittleness of gluten-free apple pomace waffle cone prepared from pre-mix is mentioned in eqⁿ 4.6 (b).

$$\text{Brittleness} = + 3.45 + 0.32 A + 0.82 B + 0.23 AB - 0.31 A^2 - 0.21 B^2 \dots 4.6 (b)$$

$$R^2 = 0.9412$$

The regression coefficient from the stepwise regression fitting model and the analysis of variance are shown in Equation 4.6 (b). The model was properly fitted as a value of 94.12 per cent was obtained for the determination coefficient (R^2). The brittleness of gluten-free waffle cones was found significantly affected by independent variables. Run 8 (10.00 g of milk powder and 3.41 g of potato starch) waffle cone was observed the highest brittleness of gluten-free waffle cones *i.e.*, 4.50 mm and Run 2 (10.00 g of milk powder and 0.59 g of potato starch) recorded the lowest brittleness of gluten-free waffle cones *i.e.*, 1.80 mm.

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 94.12 per cent, according to first-order analysis, and P-values

(0.0001) less than 0.05 suggest that model results are significant. In second-order analysis, from the derived equation it was revealed that the independent variables and interaction (milk powder and potato starch) had a positive quadratic effect. The positive effect contributed may be due to the high concentration of sugar which had a significant effect of gelatinization characteristics of starch. The results were in accordance to Kigozi *et al.* (2016) in sorghum ice cream cone (Figure 4.23).

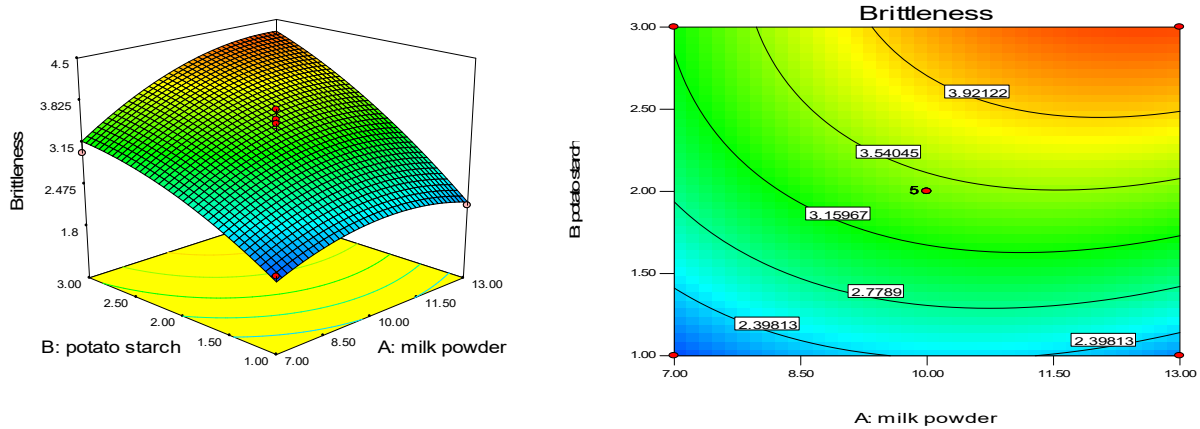


Figure (4.23)- Three-dimensional response surface and two-dimensional contour plots for brittleness of gluten-free waffle cone prepared from pre-mix

c) Toughness

The correlation between independent variables (milk powder and potato starch) with the toughness of gluten-free waffle cone prepared from pre-mix is mentioned in eqⁿ 4.6 (c).

$$\text{Toughness} = + 1077.89 + 112.10 A + 154.58 B + 39.13 AB - 42.54 A^2 - 79.56 B^2 \dots 4.6 (c)$$

$$R^2 = 0.9624$$

Equation 4.6 (c) displays both the variance analysis and the regression coefficient from the stepwise regression fitting model. The determination coefficient (R^2) value demonstrated the appropriate fit of the model with a 96.24 per cent value. It was discovered that independent factors considerably impacted the toughness of gluten-free waffle cones. Run 2 (10.00 g of milk powder and 0.59 g of potato starch) was recorded the lowest toughness of the waffle cone with a value of 670.20 (g.sec) and Run 11 (13.00 g of milk powder and 3.00 g of potato starch) observed the toughness of the waffle cone *i.e.*, 1260.00 (g.sec).

Response surface analysis with CCD employed first-order and second-order statistical models. R-square values of 96.24 per cent, according to first-order analysis, and P-values

(0.0001) less than 0.05 suggested that model results are significant. In second-order analysis, from the derived equation it was observed that the independent variables and the interaction between milk powder and potato starch had a positive quadratic effect, on the toughness of gluten-free waffle cones due to the high protein and starch content in milk powder and potato starch, respectively. The results were similar to Silva *et al.* (2022) Figure (4.24).

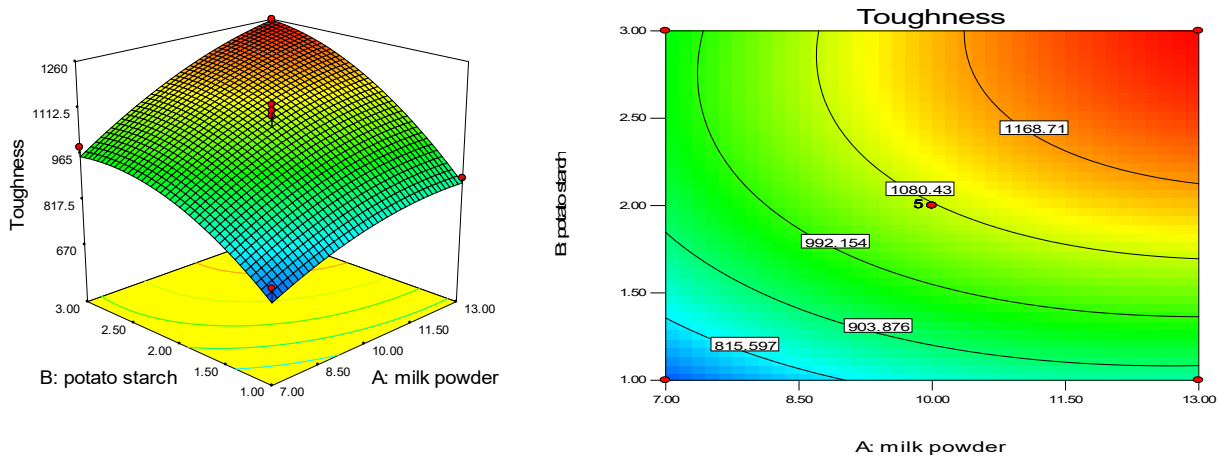


Figure (4.24)- Three-dimensional response surface and two-dimensional contour plot for toughness of gluten-free waffle cone prepared from pre-mix

d) Crispness

The correlation between independent variables (milk powder and potato starch) with the crispness of gluten-free apple pomace waffle cone prepared from pre-mix is mentioned in eqⁿ 4.6 (d).

$$\text{Crispness} = + 17.00 + 1.38 A + 3.45 B + 2.00 AB - 1.00 A^2 - 2.51 B^2 \dots 4.6 (d)$$

$$R^2 = 0.9625$$

The determination coefficient (R^2) value demonstrated the model's appropriate fit. The determination coefficient (R^2) result indicated that the model was correctly fitted with a value of 96.25 per cent. Independent variables were found to have a significant influence on the crispness of the gluten-free waffle cone. Run 11 (10.00 g of milk powder and 3.00 g of potato starch) was reflected the highest crispness of gluten-free waffle cones *i.e.*, 19.00 and Run 2 (10.00 g of milk powder and 0.59 g of potato starch) reflected the lowest crispness of waffle cones *i.e.*, 7.00.

R-square values of 96.25 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results are significant. In second-order analysis,

from the derived equation it was observed that the independent variables and interaction of milk powder with potato starch had a positive quadratic effect on the crispness of gluten-free waffle cones. This may be due to high fibre in apple pomace and protein in milk powder which lead to high water absorption capacity contributing to harder and crispier final product. The results were in accordance to Kushwaha *et al.* (2023) Figure (4.25).

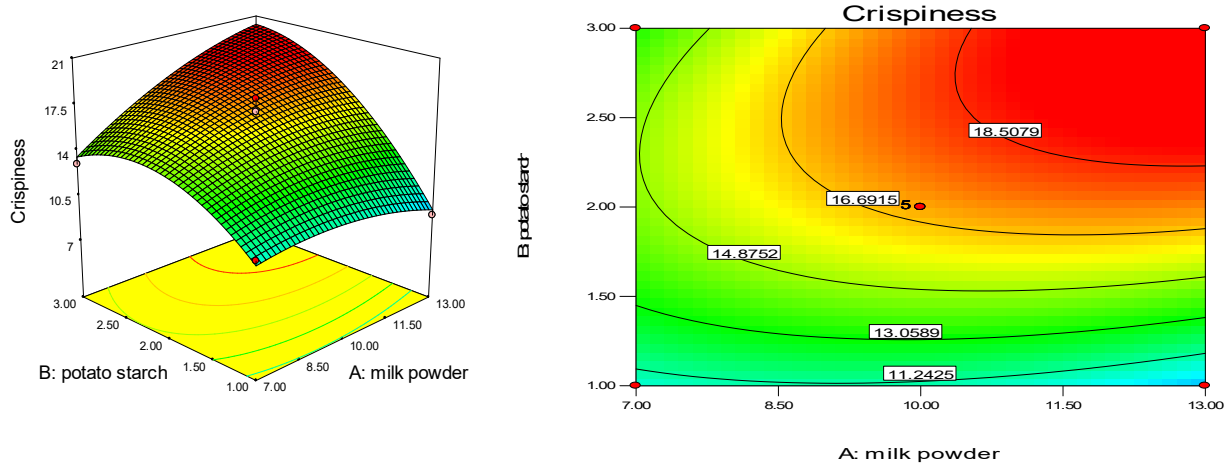


Figure (4.25)- Three-dimensional response surface and two-dimensional contour plots for crispness of gluten-free waffle cone prepared from pre-mix

e) Ice cream holding time

The correlation between independent variables (milk powder and potato starch) with the ice-cream holding time of gluten-free waffle cone prepared from pre-mix is mentioned in eqⁿ 4.6 (e).

$$\text{Icecream holding time} = + 30.40 + 2.34 A + 6.37 B + 2.50 AB - 2.70 A^2 - 3.22 B^2 \dots 4.6 (e)$$

$$R^2 = 0.9730$$

The determination coefficient (R^2) result indicated that the model was correctly fitted with a value of 97.30 per cent. It was observed that the independent factors considerably impacted the ice cream holding time. Run 8 (10.00 g of milk powder and 3.41 g of potato starch) was found the highest ice-cream holding time in gluten-free waffle cones *i.e.*, 34.00 (min) and Run 2 (10.00 g of milk powder and 0.59 g of potato starch) waffle cone recorded the minimum ice-cream holding time in gluten-free waffle cone for the value of 15.00 (min).

R-square values of 97.30 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggested that model results were significant. In second-order

analysis, from the derived equation it was revealed that the independent variables and interaction (milk powder with potato starch) had a positive quadratic effect on the ice-cream holding time of gluten-free waffle cone. The positive effect can be explained due to the high protein and starch content which increased the binding strength of the waffle cones. The results were similar to Mhatre *et al.* (2022) in comparative study of ice cream cone prepared from composite flour (Figure 4.26).

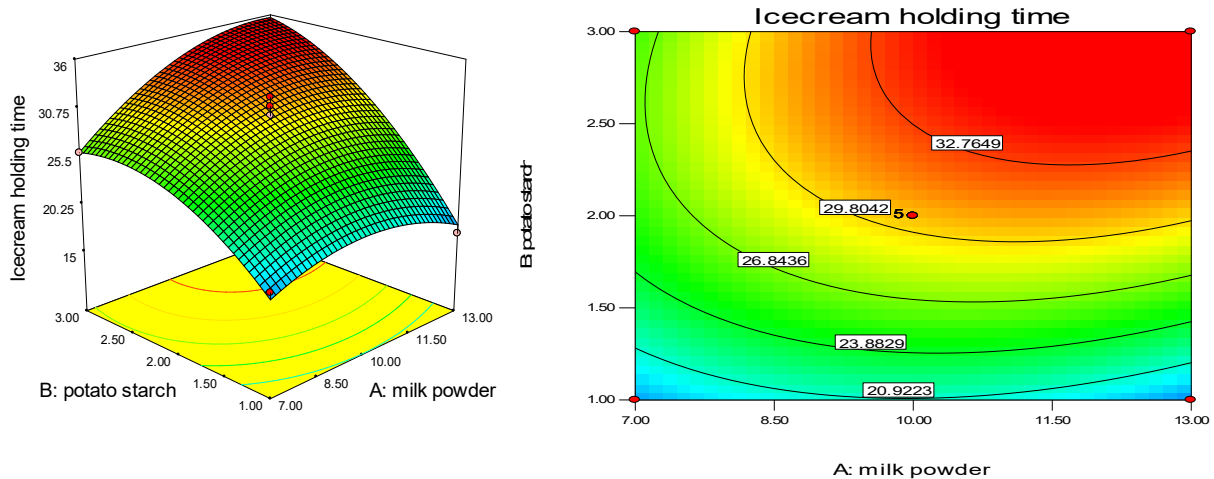


Figure (4.26)- Three-dimensional response surface and two-dimensional contour plots for ice cream holding time of gluten-free waffle cone prepared from pre-mix

f) Overall acceptability (9-point hedonic scale)

The correlation between independent variables (milk powder and potato starch) with the overall acceptability of apple pomace flour-based gluten-free waffle cone prepared from pre-mix is mentioned in eqⁿ 4.6 (f).

$$\text{Overall acceptability} = + 8.15 + 0.50 A + 0.51 B + 0.61 AB - 0.72 A^2 - 1.13 B^2 \dots 4.6 (f)$$

$$R^2 = 0.9589$$

The determination coefficient (R^2) result indicated that the model was correctly fitted having a value of 95.89 per cent. Independent variables were found to have a significant influence on the overall acceptability of gluten-free waffle cones. Run 6 (10.00 g of milk powder and 2.00 g of potato starch) was observed the maximum overall acceptability in gluten-free waffle cones *i.e.*, 8.50 and Run 2 (10.00 g of milk powder and 0.59 g of potato starch) recorded minimum overall acceptability in gluten-free waffle cones *i.e.*, 5.54.

R-square values of 95.89 per cent, according to first-order analysis, and P-values (0.0001) less than 0.05 suggest that model results were found to be significant. In second-

order analysis, from the derived equation it was obtained that the independent variables and interaction between the milk powder and potato starch) had a positive quadratic effect on the overall acceptability of gluten-free waffle cones. This might be due to caramelization as well as the fruity flavour provided to the waffle cones by apple pomace. Similar results were also given by Negi (2018) in apple pomace supplemented muffins Figure (4.27).

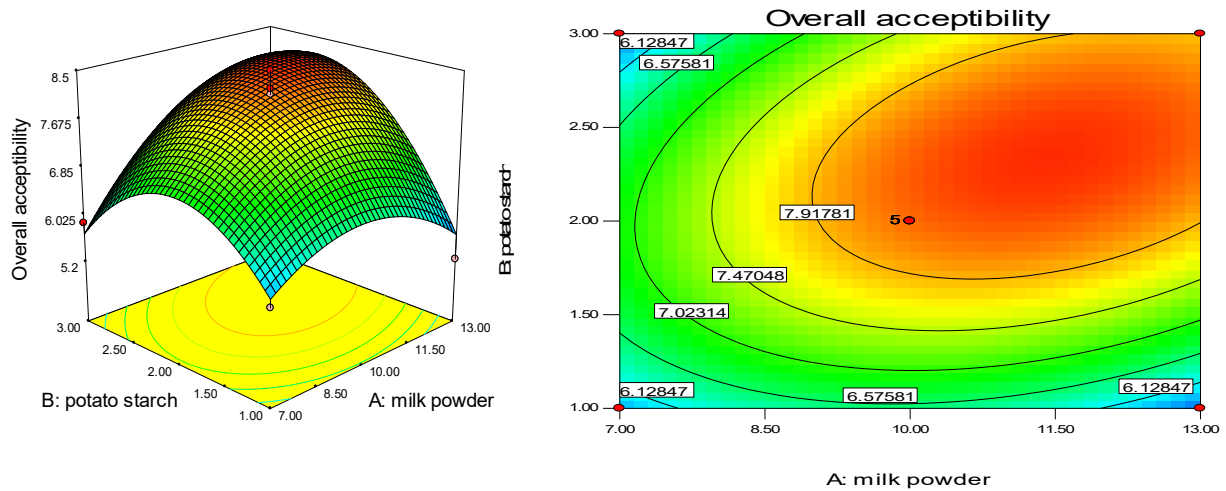


Figure (4.27)- Three-dimensional response surface and two-dimensional contour plots for overall acceptability of gluten-free waffle cones prepared from pre-mix

4.6.3 Optimization of ingredients for gluten-free apple pomace waffle cone through desirability

The RSM results indicated the output of independent variables (milk powder and potato starch) on dependent variables (hardness, brittleness, toughness, crispness, ice-cream holding, and overall acceptability) of the gluten-free apple pomace waffle cone prepared from pre-mix. Response surface plots were taken into consideration for optimization since the best result came from interactions between the various responses. The optimization process was based on desirability is a multiple-response approach. The optimization approach considers each variable's priorities and desires, and the scores of each dependent variable were converted into scores for desirability, ranged from zero for undesirable to 1.0 for high desirable. The geometric mean of the individual desirability was used to calculate the overall desirability of the outcomes at various levels of the response variable. The predicted values were recorded by setting optimum goals for independent and dependent variables to be in range, maximum, minimum, or target, varying accordingly before final optimization as depicted in Table 4.31.

Table 4.31: Optimization of ingredients through desirability

S. No.	Factor of responses	Goal	Lower limit	Upper limit	Importance	Predicted value
1	A: Milk powder (g)	equal to >	7.00	13.00	3	10.00
2	B: Potato starch (g)	target	1.00	3.00	3	2.00
3	Hardness (g)	is in range	620.00	1185.21	3	1013.56
4	Brittleness (mm)	is in range	1.80	4.50	3	3.45
5	Toughness (g. sec)	is in range	670.20	1260.00	3	1077.89
6	Crispness	maximize	7.00	19.00	3	17.00
7	Ice cream holding time (min)	maximize	15.00	34.00	3	30.40
8	Overall acceptability	maximize	5.24	8.50	3	8.15

Table 4.32: Predicted and observed values of Responses of gluten-free waffle cones prepared from pre-mix

S. No.	Responses	Predicted value	Observed values
1	Hardness (g)	1013.56	1012.20
2	Brittleness (mm)	3.45	3.34
3	Toughness (g. sec)	1077.89	1047.00
4	Crispness	17.00	17.00
5	Ice cream holding time (min)	30.40	30.00
6	Overall acceptability	8.15	8.20
7	Desirability (%)	90.00	-

The responses of ingredients for the development of gluten-free apple pomace waffle cone predicted by using the Design Expert-07 software given in Table 4.32 resulted in hardness of 1013.56 g, brittleness of 3.45 mm, a toughness of 1077.89 g.sec, crispness of 17.00, ice-cream holding time 30.40 min and overall acceptability 8.15. The closeness of observed values with predicted values for hardness (1012.20 g), brittleness (3.34 mm), toughness (1047.00 g.sec), crispness (17.00), ice-cream holding time (30.00 min) and overall acceptability (8.20) approved validation the response surface methodology (RSM) model (Table 4.32). The desirability score 90.00 per cent for the preparation of gluten-free apple pomace waffle cones was within the acceptable limits.

4.7 QUALITY CHARACTERISTICS OF WAFFLE CONE PRE-MIX

4.7.1 Physical and functional quality of waffle cone prepared from pre-mix

Data presented in Table (4.33) shows the physical and functional quality of waffle cones prepared from market waffle cone pre-mix, apple pomace and gluten-free apple

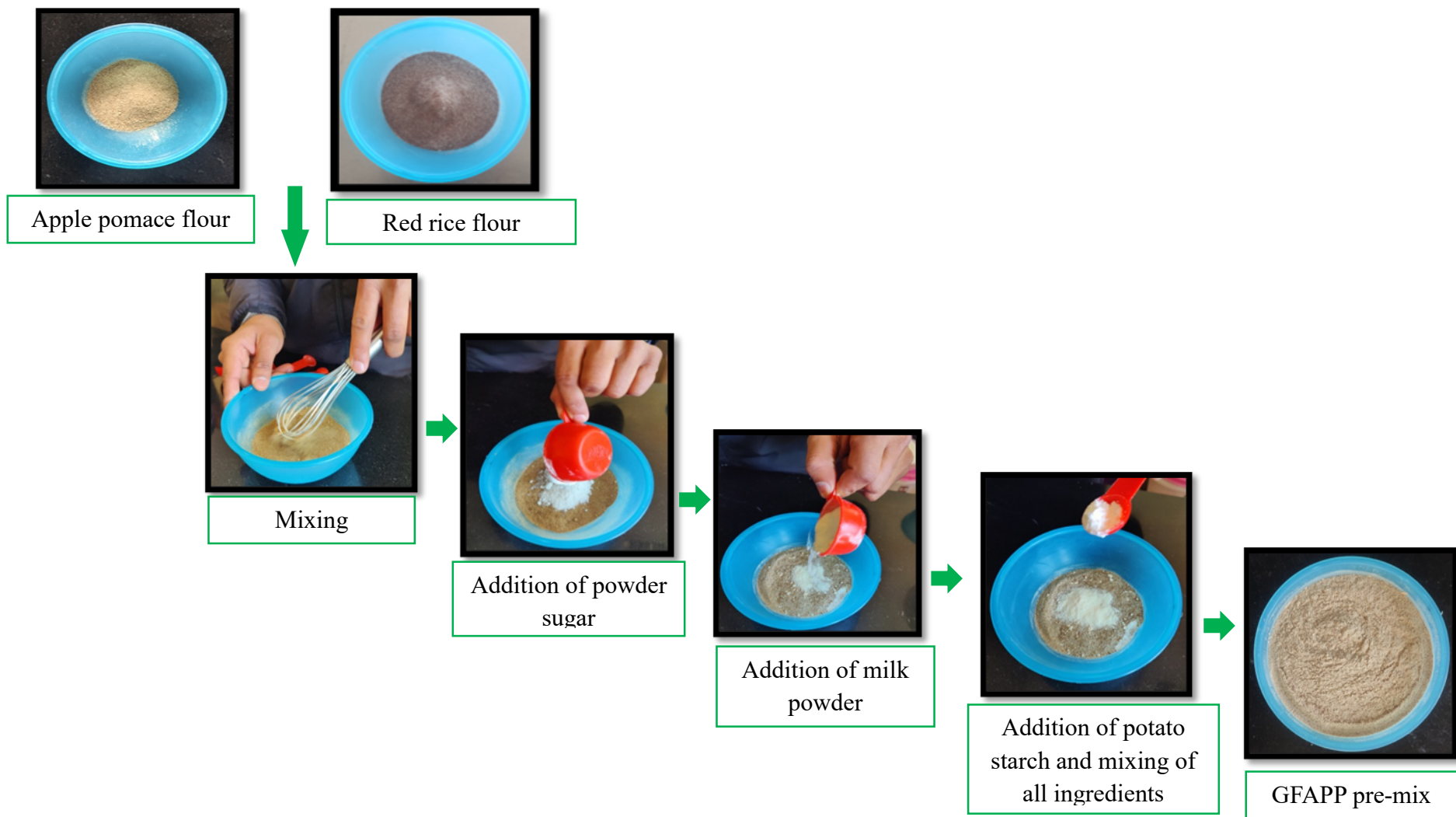


Plate 4- Flow chart for the preparation of gluten-free apple pomace waffle cone pre-mix (apple pomace flour with red rice flour)

pomace waffle cone pre-mix. The weight of the cone and ice cream holding time were observed significantly higher in the waffle cone prepared from market waffle cone pre-mix 10.50 g and 35.00 min followed from the waffle cone prepared by apple pomace waffle cone pre-mix (10.18 g and 32.00 min) and gluten-free apple pomace waffle cone pre-mix (10.11 g and 30.00 min), respectively. However, difference in the thickness of the waffle cone prepared from different pre-mixes was found non-significant. Although the functional properties *i.e.*, baking loss was observed at par in waffle cones prepared from apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix (66.06 % and 66.30 %) however, it was significantly higher than waffle cones prepared from market waffle cone pre-mix.

Table 4.33: Physical and functional quality of waffle cone prepared from pre-mix

Physical and functional quality	Mean ± SD			CD
	Market waffle cone pre-mix	Apple pomace waffle cone pre-mix	Gluten-free apple pomace waffle cone pre-mix	
Weight (g)	10.50 ^a ± 0.05	10.18 ^b ± 0.05	10.11 ^b ± 0.04	0.18
Thickness (mm)	2.60 ^a ± 0.01	2.58 ^a ± 0.01	2.57 ^a ± 0.01	NS
Ice cream holding time (min)	35.00 ^a ± 0.16	32.00 ^b ± 0.15	30.00 ^c ± 0.11	0.60
Baking loss (%)	65.00 ^b ± 0.19	66.06 ^a ± 0.20	66.30 ^a ± 0.18	0.62

4.7.2 Texture quality of waffle cone prepared for pre-mix

Table (4.34) shows the textural quality of waffle cones prepared from pre-mixes *i.e.*, market, apple pomace and gluten-free apple pomace waffle cone pre-mix. Waffle cone prepared from market waffle cone pre-mix was observed significantly higher values for hardness 1090.50 g followed by apple pomace waffle cone pre-mix 1060.35 g and then gluten-free apple pomace waffle cone pre-mix 1012.20 g. The brittleness of the waffle cone prepared from apple pomace waffle cone pre-mix (3.40 mm) was found at par with waffle cone prepared from gluten-free apple pomace waffle cone pre-mix (3.34 mm) and was found significantly higher than the waffle cone prepared from market waffle cone pre-mix (3.21 mm). The toughness and crispness were observed significantly higher in waffle cones prepared from apple pomace waffle cone pre-mix (1150.68 g sec and 18.00) as compared to gluten-free apple pomace waffle cone pre-mix (1047.00 g sec and 17.00) and market waffle cone pre-mix (1018.24 g sec and 12.00). The high fibre content of apple pomace increased the texture of the waffle cones to reflected the increased crispness, similar results were

reported by Dom *et al.* (2020) in sweet potato peel flour supplemented ice cream cone and Kushwaha *et al.* (2023) in jack fruit seed flour-based ice cream cone.

Table 4.34: Texture quality of waffle cone prepared from pre-mix

Texture quality	Mean ± SD			
	Market waffle cone pre-mix	Apple pomace waffle cone pre-mix	Gluten-free apple pomace waffle cone pre-mix	CD
Hardness (g)	1090.50 ^a ± 2.67	1060.35 ^b ± 2.80	1012.20 ^c ± 2.69	9.73
Brittleness (mm)	3.21 ^a ± 0.02	3.40 ^b ± 0.03	3.34 ^b ± 0.02	0.06
Toughness (g. sec)	1018.24 ^c ± 2.70	1150.68 ^a ± 2.94	1047.00 ^b ± 2.73	10.22
Crispness	12.00 ^c ± 0.06	18.00 ^a ± 0.11	17.00 ^b ± 0.10	0.10

4.7.3 Sensory quality of waffle cone prepared from pre-mix

The data appended in Table 4.35 shows the sensory quality of waffle cones prepared from market, apple pomace and gluten-free apple pomace waffle cone pre-mix. The waffle cone prepared from gluten-free apple pomace waffle cone pre-mix scored higher for texture (8.30), taste (8.20), colour (8.10) and overall acceptability (8.20) followed by apple pomace waffle cone pre-mix scored for texture (8.20), taste (8.10), colour (8.00) and overall acceptability (8.00) and market waffle cone pre-mix scored for texture (7.90), taste (7.50), colour (8.00) and overall acceptability (7.80). The waffle cone prepared by apple pomace-based pre-mix was given the highest sensory scores owing to the fruity flavor, aroma and brownish-red colour of apple pomace flour. A similar result given by Alongi *et al.* (2019) in biscuit prepared with apple pomace supplementation.

Table 4.35: Sensory quality of waffle cone prepared from pre-mix

Sensory quality	Mean ± SD			
	Market waffle cone pre-mix	Apple pomace waffle cone pre-mix	Gluten-free apple pomace waffle cone pre-mix	CD
Texture	7.90 ^b ± 0.03	8.20 ^a ± 0.05	8.30 ^a ± 0.06	0.11
Taste	7.50 ^c ± 0.03	8.10 ^b ± 0.05	8.20 ^a ± 0.05	0.05
Colour	7.20 ^b ± 0.04	8.00 ^a ± 0.04	8.10 ^a ± 0.04	0.13
Overall Acceptability	7.50 ^c ± 0.02	8.00 ^b ± 0.04	8.20 ^a ± 0.05	0.04

4.7.4 Colour quality of waffle cone pre-mix

Data presented in Table (4.36) and Fig 4.28 (a), (b) and (c) regarding colour quality of waffle cone pre-mixes. The L* value of market waffle cone pre-mix was recorded higher

74.78 followed by 64.32 in apple pomace waffle cone pre-mix and 61.60 in gluten-free apple pomace waffle cone pre-mix reflects the lightness of the pre-mix due to dark colour of apple pomace flour. Whereas, the a^* (redness-greenness) and b^* (yellowness-blueness) in the gluten-free apple pomace waffle cone pre-mix was observed significantly higher 2.39 and 26.78 than apple pomace waffle cone pre-mix 1.68 and 25.24 and market waffle cone pre-mix 1.95 and 7.32. While the hue angle (h^0) was recorded significantly higher (86.19) in apple pomace waffle cone pre-mix followed by (84.88) gluten-free apple pomace waffle cone pre-mix and (75.08) market waffle cone pre-mix. The intensity of the colour as chroma was observed significantly higher in gluten-free apple pomace waffle cone pre-mix than apple pomace waffle cone pre-mix. The colour difference from market waffle cone pre-mix to apple pomace waffle cone pre-mix was recorded 20.75 and gluten-free apple pomace waffle cone pre-mix as 23.45.

Table 4.36: Colour quality of waffle cone pre-mix

Colour quality	Mean \pm SD			CD
	Market waffle cone pre-mix	Apple pomace waffle cone pre-mix	Gluten-free apple pomace waffle cone pre-mix	
L* (lightness)	74.78 ^c \pm 0.21	64.32 ^a \pm 0.18	61.60 ^b \pm 0.19	0.33
a* (redness-greenness)	1.95 ^b \pm 0.01	1.68 ^c \pm 0.01	2.39 ^a \pm 0.01	0.13
b* (yellowness- blueness)	7.32 ^c \pm 0.02	25.24 ^b \pm 0.10	26.72 ^a \pm 0.11	0.23
Hue angle (h^0)	75.08 ^c \pm 0.22	86.19 ^a \pm 0.23	84.88 ^b \pm 0.22	0.66
Chroma (c)	-	17.92 ^b \pm 0.06	19.40 ^a \pm 0.08	0.07
ΔE	-	20.75 ^b \pm 0.09	23.45 ^a \pm 0.11	0.08

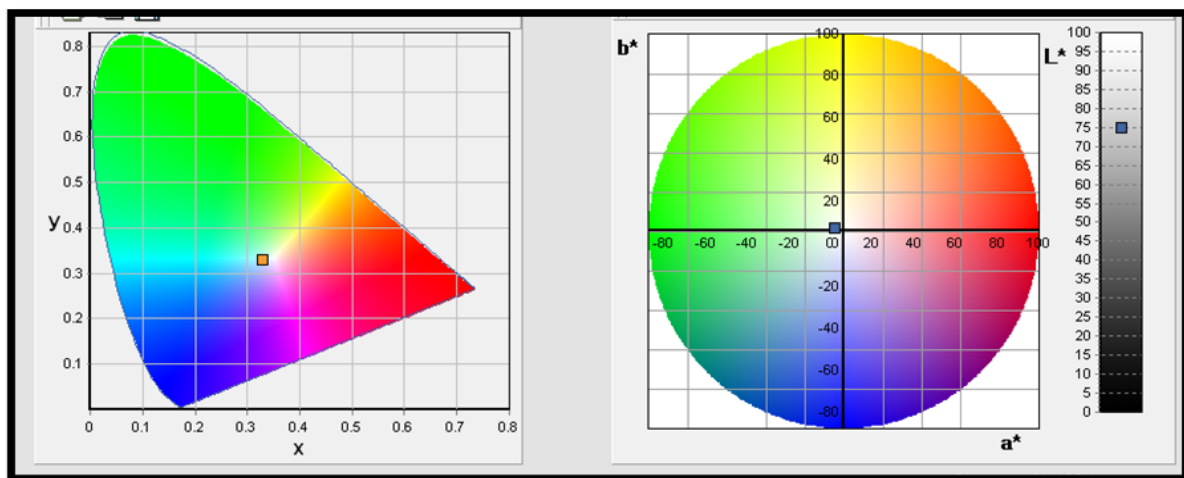


Figure 4.28 (a) CIE readings of market waffle cone pre-mix

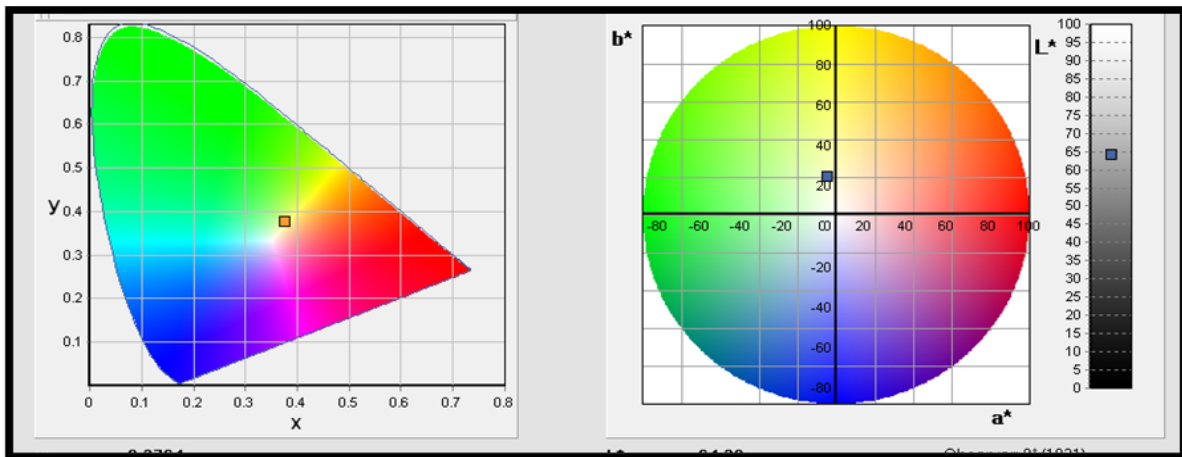


Figure 4.28 (b) CIE readings of apple pomace waffle cone pre-mix

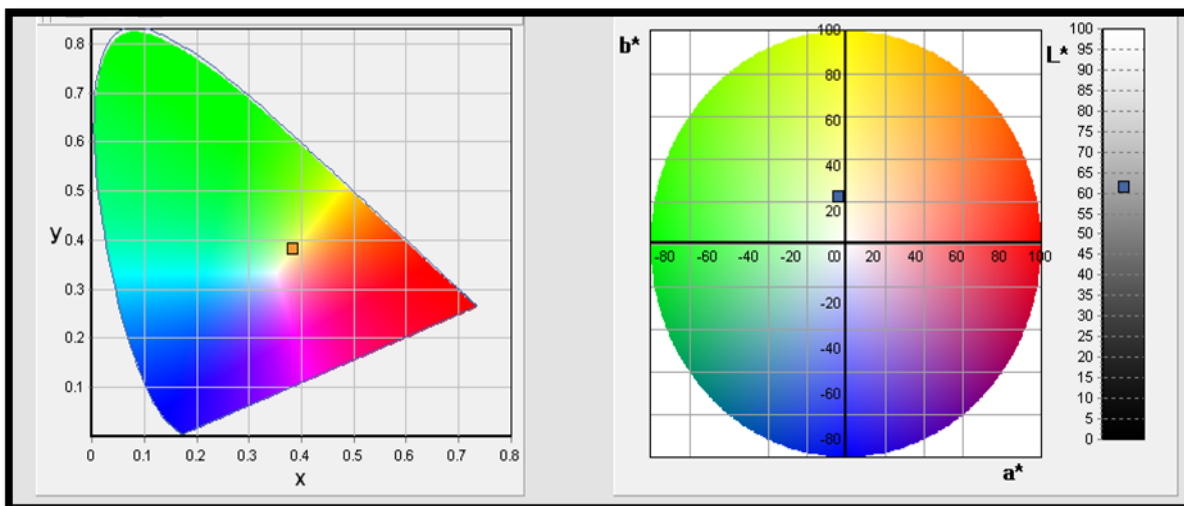


Figure 4.28 (c) CIE readings of gluten-free apple pomace waffle cone pre-mix

4.7.5 Chemical quality of waffle cone pre-mix

Data in Table (4.37) shows the chemical quality of waffle cone pre-mixes. The moisture content, ash content, crude fat, crude fibre, dietary fibre, protein content, total phenol, antioxidant activity and anthocyanin content were recorded higher in apple pomace-based waffle cone pre-mix (apple pomace and gluten-free apple pomace waffle cone pre-mix) due to nutritional profiles of apple pomace flour and red rice flour. Whereas among these apple pomace-based waffle cone pre-mixes the moisture content, ash content, crude fat, total phenol, antioxidant activity and anthocyanin content were found significantly higher in gluten-free apple pomace waffle cone pre-mix (8.65 %, 2.34 %, 7.42 %, 256.37 mg GAE/100g, 80.42 % and 7.26 mg/100g), respectively. The higher content of crude fibre, dietary fibre and crude protein were recorded in apple pomace pre-mix (7.01 %, 19.41 % and

9.15 %), respectively than gluten-free apple pomace waffle cone pre-mix and market waffle cone pre-mix may be due to concentration of apple pomace flour and whole wheat flour. The carbohydrate and energy values were observed statistically significant higher in market waffle cone pre-mix (76.45 % and 390.14 Kcal/100g) followed by gluten-free apple pomace pre-mix (66.41 % and 384.62 Kcal/100g) and apple pomace pre-mix (65.98 % and 381.90 Kcal/100g). The difference between nutritional composition may be due to the composition and quantity of ingredients. A similar result was found by Negi *et al.* (2021) in muffin pre-mix using apple pomace.

Table 4.37: Chemical characteristics of waffle cone pre-mix

Characteristics	Mean \pm SD			C.D.
	Market pre-mix	Apple pomace pre-mix	Gluten-free apple pomace pre-mix	
Moisture content (%)	8.11 ^c \pm 0.05	8.40 ^b \pm 0.05	8.65 ^a \pm 0.06	0.04
Ash content (%)	1.32 ^c \pm 0.01	2.28 ^b \pm 0.02	2.34 ^a \pm 0.02	0.05
Crude fat (%)	5.50 ^c \pm 0.02	7.18 ^b \pm 0.03	7.42 ^a \pm 0.03	0.08
Crude fibre (%)	2.62 ^c \pm 0.01	7.01 ^a \pm 0.03	6.65 ^b \pm 0.03	0.12
Total dietary fibre (%)	11.32 ^c \pm 0.05	19.41 ^a \pm 0.10	19.11 ^b \pm 0.10	0.11
Crude protein (%)	6.00 ^c \pm 0.03	9.15 ^a \pm 0.04	8.53 ^b \pm 0.04	0.07
Carbohydrate (%)	76.45 ^a \pm 0.28	65.98 ^c \pm 0.24	66.41 ^b \pm 0.18	0.12
Energy Value (Kcal/100g)	390.14 ^a \pm 2.12	381.90 ^c \pm 2.10	384.62 ^b \pm 2.02	2.95
Water activity	0.45 ^c \pm 0.00	0.46 ^b \pm 0.00	0.47 ^a \pm 0.01	0.01
Total phenol content (mg GAE/100g)	4.03 ^c \pm 0.02	205.16 ^b \pm 0.98	256.37 ^a \pm 1.24	2.11
Antioxidant activity (%)	9.93 ^c \pm 0.03	70.16 ^b \pm 0.26	80.42 ^a \pm 0.41	0.79
Anthocyanin content (mg/100g)	NF	5.79 ^b \pm 0.03	7.26 ^a \pm 0.03	0.04

4.7.6 Mineral composition of waffle cone pre-mix

Table 4.38 represents the data on the mineral composition of waffle cone pre-mixes which includes phosphorous, potassium, sodium, calcium, sulphur, magnesium, iron, zinc and manganese indicating that the apple pomace utilized for the development of waffle cone pre-mix (apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix) due to higher amount of mineral content present in apple pomace flour. Among all three pre-mixes minerals like phosphorous, potassium, calcium, magnesium, iron and zinc content were found significantly higher in gluten-free apple pomace waffle cone pre-mix (2178.00 ppm, 4350.00 ppm, 11150.00 ppm, 1315.00 ppm, 78.00 ppm, 10.00 ppm and 18.80 ppm), respectively as compared to apple pomace waffle cone pre-mix and market waffle cone pre-

mix may be due to the presence of abundant mineral source like apple pomace as well as red rice flour. The higher amount of sodium (3260.00 ppm) and sulphur (1489.50 ppm) were found in market waffle cone pre-mix than apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix. Minerals are required for normal growth, cellular activity and oxygen transport (Fe) as well as the regulation of blood pressure and strengthening of bones (Ca). Except for Magnesium, all mineral content of apple pomace flour-based waffle cone pre-mix was lower than the FAO/WHO recommended dietary requirement for food.

Table 4.38: Mineral composition of waffle cone pre-mix

Mineral (ppm)	Mean ± SD			C.D.
	Market pre-mix	Apple pomace pre-mix	Gluten-free apple pomace pre-mix	
Phosphorus	977.50 ^c ± 3.15	1910.20 ^b ± 3.92	2178.00 ^a ± 3.99	13.77
Potassium	1525.00 ^c ± 3.80	4325.00 ^b ± 4.44	4350.00 ^a ± 5.02	18.32
Sodium	3260.00 ^a ± 4.23	2092.50 ^c ± 4.10	2682.50 ^b ± 4.02	16.07
Calcium	7325.00 ^c ± 6.98	9900.00 ^b ± 11.32	11150.00 ^a ± 12.30	26.83
Sulphur	1489.50 ^a ± 3.72	1165.00 ^c ± 3.26	1271.00 ^b ± 3.50	14.17
Magnesium	600.00 ^c ± 2.12	1285.00 ^b ± 3.52	1315.00 ^a ± 3.64	13.41
Iron	28.40 ^c ± 0.14	53.00 ^b ± 0.21	78.00 ^a ± 0.27	1.78
Copper	9.20 ^c ± 0.07	9.70 ^b ± 0.07	10.00 ^a ± 0.05	0.10
Zinc	13.70 ^c ± 0.09	17.00 ^b ± 0.09	18.80 ^a ± 0.11	0.34
Manganese	6.00 ^b ± 0.03	8.90 ^a ± 0.07	6.14 ^b ± 0.04	2.18

4.8 STORAGE STUDY OF STANDARDIZED PRODUCTS

4.8.1 Moisture content (%) of waffle cone

The moisture content of products is one of the most important parameter to monitor the freshness of product during storage as loss and gain of moisture is a serious problem in bakery products that can result in change in textural properties of the product and promotes the chemical and microbiological spoilage in low and intermediate moisture products. Table 4.39 shows that the moisture content value of the waffle cone increased with the storage period in three-waffle cone sample stored in the low-density polyethylene (LDPE) and aluminium laminated pouch (ALP) at a temperature of 38°C and relative humidity of 90 per cent. According to Kathalsar *et al.* (2020), an increase in moisture content is due to the absorption of moisture from the surrounding environment. The present study data shows that

based on higher regression (R^2) a higher increase in moisture content was observed in LDPE pouches as compared to aluminium pouches value was observed to increase from 6.81 to 7.10 per cent in market waffle cone, 7.25 to 7.64 per cent in apple pomace waffle cone and 7.12 to 7.64 per cent in gluten-free apple pomace waffle cone. While in case of aluminium pouches the moisture content from 6.81 to 7.05 per cent in the market, 7.25 to 7.59 per cent in apple pomace waffle cone and 7.12 to 7.45 per cent in gluten-free apple pomace waffle cone, respectively. A similar trend in increasing moisture content in both packaging materials in biscuits has been reported by Kathalsar *et al.* (2020).

Table 4.39: Reaction orders for moisture content of waffle cone during storage

Waffle cones stored in LDPE									
Days	Zero order (A)			First order (ln A)			Second order (1/A)		
	MC	APC	GF APC	MC	APC	GF APC	MC	APC	GF APC
0	6.81	7.25	7.12	1.918392	1.981001	1.962908	0.146843	0.137931	0.140449
7	6.91	7.38	7.25	1.93297	1.998774	1.981001	0.144718	0.135501	0.137931
14	7.00	7.52	7.39	1.94591	2.017566	2.000128	0.142857	0.132979	0.135318
21	7.10	7.64	7.52	1.960095	2.033398	2.017566	0.140845	0.13089	0.132979
R²	0.9996	0.9992	0.9998	0.9995	0.9989	0.9997	0.9994	0.9985	0.9995
Waffle cone stored in ALP									
0	6.81	7.25	7.12	1.918392	1.981001	1.962908	0.146843	0.137931	0.140449
7	6.89	7.36	7.23	1.930071	1.99606	1.978239	0.145138	0.13587	0.138313
14	6.98	7.48	7.35	1.943049	2.012233	1.9947	0.143266	0.13369	0.136054
21	7.05	7.59	7.45	1.953028	2.026832	2.008214	0.141844	0.131752	0.134228
R²	0.9979	0.9997	0.9989	0.9976	0.9996	0.9986	0.9973	0.9995	0.9982

4.8.2 Kinetics of quality decrease rate of waffle cone against moisture content (%)

The choice of the reaction order kinetics for the increase in moisture content of waffle cone stored in LDPE (Low-density polyethylene) and ALP (Aluminium laminated pouch) is done by comparing the R^2 value of each linear regression equation to determine the order of reaction. The chosen reaction order is a reaction order with a larger R^2 value. Table 4.40 and fig 4.29 (a and b) show that the increasing rate of moisture content of waffle cone based on zero order reaction. This is shown from the fact that value of R^2 zero order > R^2 first order >

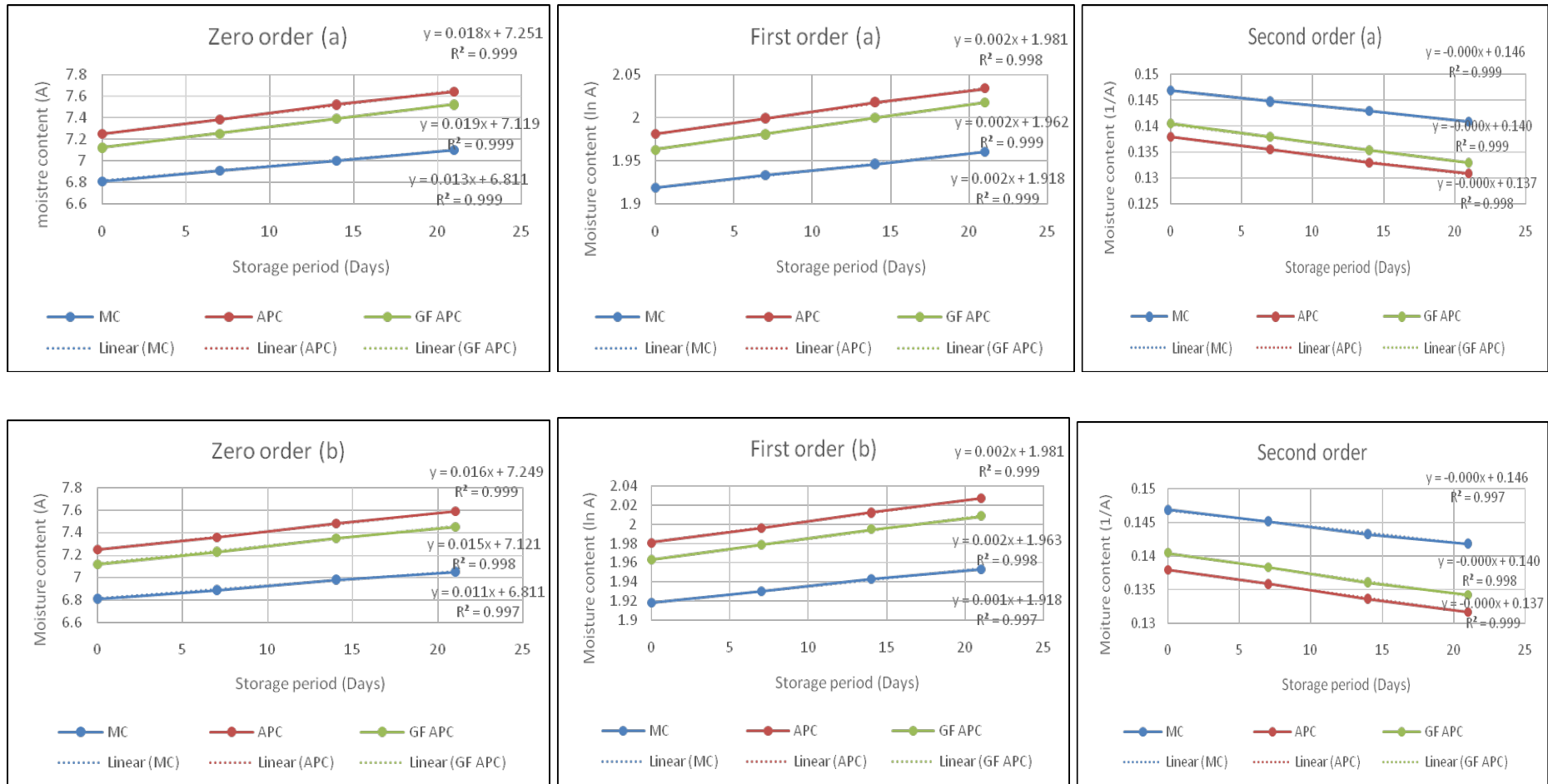


Fig. 4.29 Linear regression equation graph for moisture content of waffle cone stored in LDPE (a) and ALP (b)

R² second order at 38 °C and 90 per cent relative humidity. Similar trend in free fatty acid value in apple brownies during storage was reported by Pulungan *et al.* (2018).

Table 4.40: Linear regression equation for moisture content parameter of waffle cone

Waffle cone stored in LDPE			
Products	MC	APC	GF APC
Zero order	Y= 0.013x + 6.811	Y= 0.018x + 7.251	Y= 0.019x + 7.199
First order	Y= 0.002x + 1.9186	Y= 0.0025x + 1.9813	Y= 0.0026x + 1.9629
Second order	Y= -0.0003x + 0.1468	Y= -0.0003x + 0.1379	Y= -0.0004x + 0.1404
R² Zero order	0.9996	0.9992	0.9998
R² First order	0.9995	0.9989	0.9997
R² Second order	0.9994	0.9985	0.9995
Waffle cone stored in LDPE			
Zero order	Y= 0.0116x + 6.811	Y= 0.0163x + 7.249	Y= 0.0159x + 7.121
First order	Y= 0.0017x + 1.9186	Y= 0.0022x + 1.981	Y= 0.0022x + 1.9632
Second order	Y= -0.0002x + 0.147	Y= -0.0003x + 0.1379	Y= -0.0003x + 0.1404
R² Zero order	0.9979	0.9997	0.9989
R² First order	0.9976	0.9996	0.9986
R² Second order	0.9973	0.9995	0.9982

4.8.3 Free fatty acid (mg/g) of waffle cone

Free fatty acid (FFA) is one of the most important parameter used to determine the quality of products. Waffle cones were monitored for both oxidative and hydrolytic rancidity during storage. In oxidative rancidity, lipid oxidation of unsaturated fatty acids into hydroperoxides takes place later which forms aldehydes and ketones whereas, in hydrolytic rancidity, triglycerides of fats are converted into free fatty acid and glycerol, resulting in a distinct soapy flavor in food product cone. Table 4.41 shows an increase in free fatty acid content in both packaging materials *i.e.*, low-density polyethylene and aluminium laminated pouches during storage periods based on higher regression (R²) in waffle cone. The increase in free fatty acid content was higher in low-density polyethylene and recorded to be 0.12 to 0.97 mg/g in market waffle cones, 0.41 to 1.69 mg/g in apple pomace waffle cones and 0.35 to 1.66 mg/g in gluten-free waffle cone. Comparatively a lower increase of free fatty acid in aluminium pouches was observed 0.12 to 0.88 mg/g in market waffle cone, 0.41 to 1.54 mg/g in apple pomace waffle cone and 0.35 to 1.49 mg/g in gluten-free apple pomace waffle cone. Similar findings were observed by Kumar *et al.* (2014), Bhangar *et al.* (2008) and Pulungan *et al.* (2018) in oryzanol-fortified biscuits, cookies and apple brownies, respectively.

Table 4.41: Reaction orders for free fatty acid of waffle cone during storage

Waffle cone stored in LDPE									
Days	Zero order (A)			First order (ln A)			Second order (1/A)		
	MC	APC	GF APC	MC	APC	GF APC	MC	APC	GF APC
0	0.12	0.41	0.35	-2.12026	-0.8916	-1.04982	8.333333	2.439024	2.857143
7	0.39	0.84	0.76	-0.94161	-0.17435	-0.27444	2.564103	1.190476	1.315789
14	0.65	1.26	1.23	-0.43078	0.231112	0.207014	1.538462	0.793651	0.813008
21	0.97	1.69	1.66	-0.03046	0.524729	0.506818	1.030928	0.591716	0.60241
R ²	0.9978	1	0.9994	0.9323	0.9585	0.9987	0.7709	0.8565	0.8487
Waffle cone stored in ALP									
0	0.12	0.41	0.35	-2.12026	-0.8916	-1.04982	8.333333	2.439024	2.857143
7	0.28	0.79	0.66	-1.27297	-0.23572	-0.41552	3.571429	1.265823	1.515152
14	0.57	1.17	1.14	-0.56212	0.157004	0.131028	1.754386	0.854701	0.877193
21	0.88	1.54	1.49	-0.12783	0.431782	0.398776	1.136364	0.649351	0.671141
R ²	0.9815	1	0.9936	0.9809	0.9622	0.9713	0.8604	0.8700	0.8881

4.8.4 Kinetics of quality decrease rate of waffle cone against free fatty acid (mg/g)

The free fatty acid content was observed to increase with the increase in storage time due to the oxidation of products in both packaging materials. The oxidation reaction of the waffle cone is caused by the content of oxygen with a fat-containing waffle cone. Fat is derived from butter and milk in a composition of waffle cones. Table 4.42 and Fig. 4.30 (a and b) showed an increase in free fatty acid content in all waffle cone samples in similar storage conditions (38 °C and 90 % ERH). The chosen reaction order is a reaction order with the larger R² value. The increase in free fatty acid content of waffle cone was based on zero order rate of reaction. This is shown from the value of R² zero order > R² first order > R² second order in both low-density polyethylene and aluminium laminated packaging materials.

Table 4.42: Linear regression equation for free fatty acid parameter of waffle cone

Waffle cone stored in LDPE			
Products	MC	APC	GF APC
Zero order	Y= 0.0401x + 0.111	Y= 0.0609x + 0.411	Y= 0.062x + 0.34
First order	Y= 0.0969x - 1.8978	Y= 0.665x - 0.7757	Y= 0.0736x - 0.9257
Second order	Y= -0.3276x + 6.8066	Y= -0.0848x + 2.1445	Y= -0.1038x + 2.4871
R ² Zero order	0.9978	1	0.9994
R ² First order	0.9323	0.9585	0.9587
R ² Second order	0.7709	0.8565	0.8487
Waffle cone stored in ALE			
Zero order	Y= 0.0367x + 0.077	Y= 0.0539x + 0.412	Y= 0.557x + 0.325
First order	Y= 0.0955x - 2.024	Y= 0.0623x - 0.7891	Y= 0.0699x - 0.9677
Second order	Y= -0.3344x + 7.2101	Y= -0.0826x + 2.1692	Y= -0.1028x + 2.5596
R ² Zero order	0.9815	1	0.9936
R ² First order	0.9809	0.9622	0.9713
R ² Second order	0.8604	0.87	0.8881

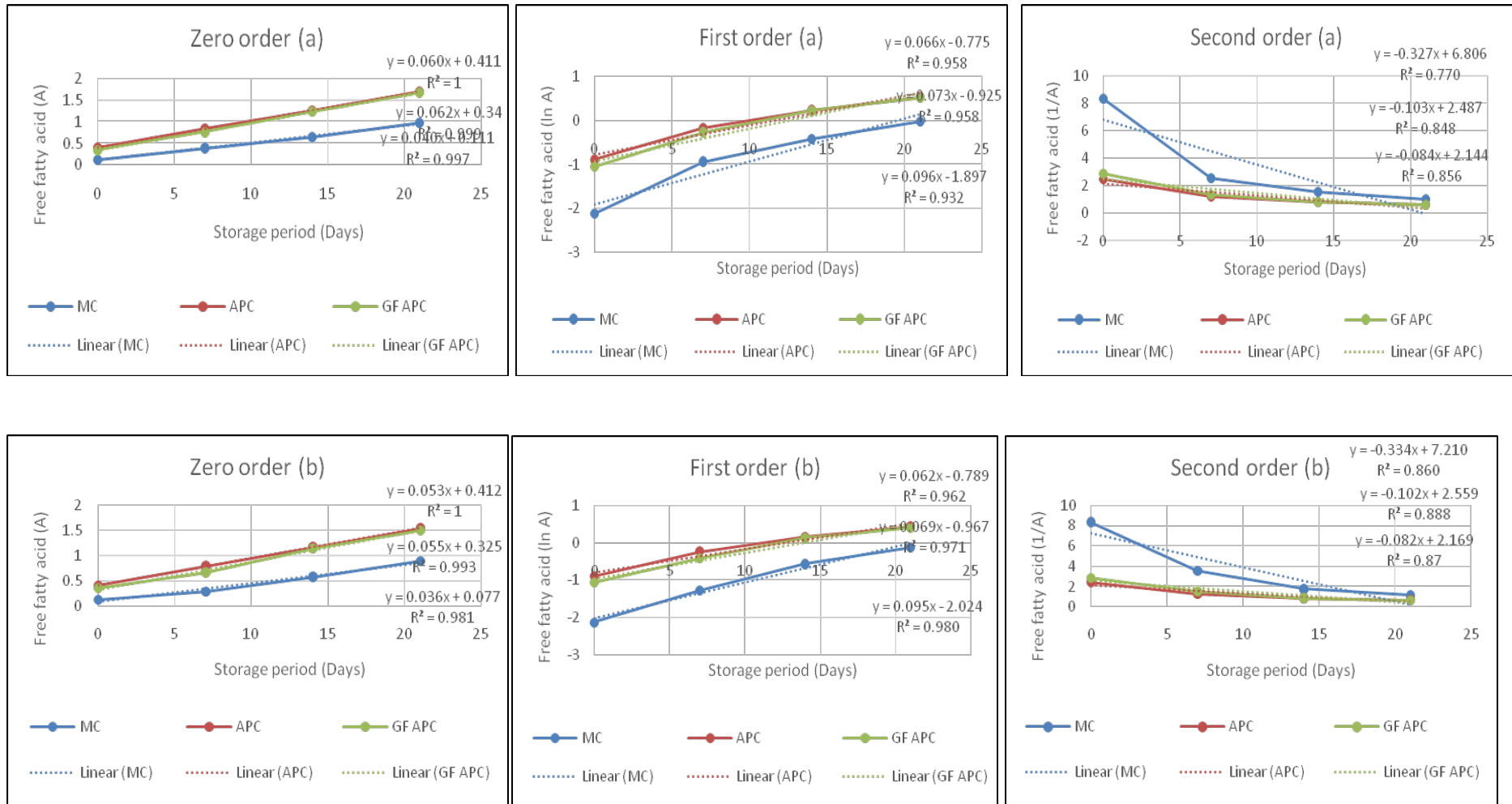


Fig. 4.30: Linear regression equation graph for free fatty acid content of waffle cone packed in LDPE (a) and ALP (b)

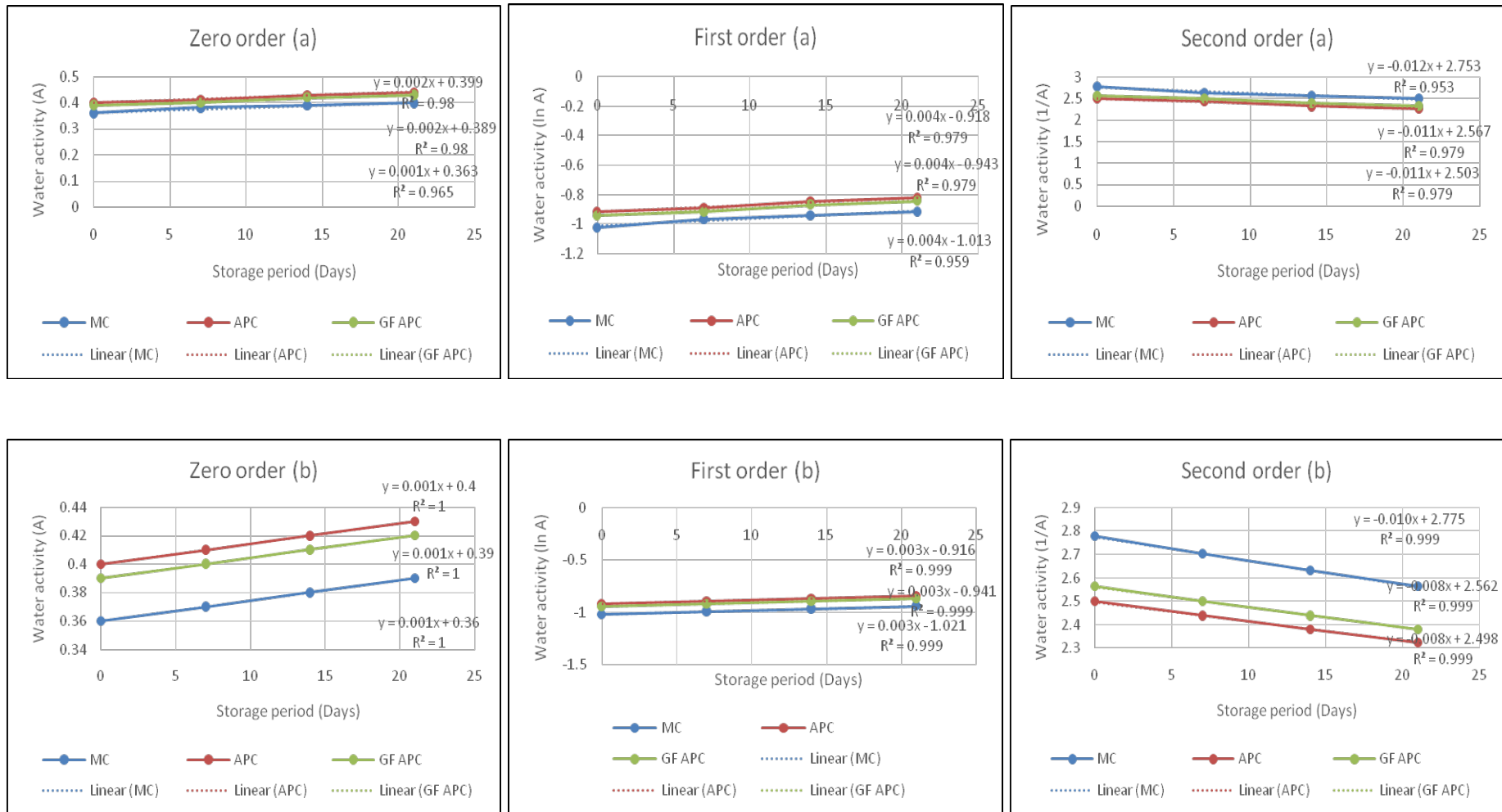


Fig. 4.31: Linear regression equation graph for water activity of waffle cone packed in LDPE (a) and ALP (b)

4.8.5 Water activity of waffle cone

The increased water content in food leads to deterioration reactions that are mediated by the water activity of products. As a result, intermediate moisture content food such as waffle cone become moist, lose aroma, and allow growth of micro-organisms causing damage and is no longer acceptable by consumers. The water activity of the waffle cone was increased with the storage period in both packaging materials *viz.*, low-density polyethylene and aluminium laminated pouches due to the permeability of water vapor from the surrounding environment. Table 4.43 shows the data based on higher regression (R^2), a higher increase in water activity in low-density polyethylene was observed in market waffle cone where, it increased from 0.36 to 0.40, 0.40 to 0.44 in apple pomace waffle cone and 0.39 to 0.43 in gluten-free waffle cone. A comparatively lower increase in water activity was observed in aluminium laminated pouches where, water activity increased from 0.36 to 0.39 in market waffle cone, 0.40 to 0.43 in apple pomace waffle cone and 0.39 to 0.42 in gluten-free waffle cone. Piga *et al.* (2005) and Mushtaq (2015) have found a similar increasing trend of water activity in wheat and mushroom cookies during storage.

Table 4.43: Reaction orders for water activity of waffle cone during storage

Waffle cone stored in LDPE									
Days	Zero order (A)			First order (ln A)			Second order (1/A)		
	MC	APC	GF APC	MC	APC	GF APC	MC	APC	GF APC
0	0.36	0.40	0.39	-1.02165	-0.91629	-0.94161	2.777778	2.50000	2.564103
7	0.38	0.41	0.4	-0.96758	-0.8916	-0.91629	2.631579	2.439024	2.50000
14	0.39	0.43	0.42	-0.94161	-0.84397	-0.8675	2.564103	2.325581	2.380952
21	0.40	0.44	0.43	-0.91629	-0.82098	-0.84397	2.5	2.272727	2.325581
R^2	0.9657	0.98	0.98	0.9599	0.9799	0.9799	0.9537	0.9797	0.9797
Waffle cone stored in ALP									
0	0.36	0.40	0.39	-1.02165	-0.91629	-0.94161	2.777778	2.50000	2.564103
7	0.37	0.41	0.4	-0.99425	-0.8916	-0.91629	2.702703	2.439024	2.50000
14	0.38	0.42	0.41	-0.96758	-0.8675	-0.8916	2.631579	2.380952	2.439024
21	0.39	0.43	0.42	-0.94161	-0.84397	-0.8675	2.564103	2.325581	2.380952
R^2	1	1	1	0.9999	0.9999	0.9999	0.9994	0.9995	0.9995

4.8.6 Kinetics of quality decrease rate of waffle cone against water activity

The water activity is directly proportional to the water content present in the food products. The more will be the water present, the higher will be water activity. Table 4.44 and Fig 4.31 (a and b) show the reaction order of kinetics that there is an increase in the water activity in low-density polyethylene and aluminium laminated pouches under similar storage

conditions (38°C and 90 % ERH). The determination of the reaction order kinetics for the increasing water activity content is done by comparing the value of R^2 in each linear regression equation on order reaction of zero, first order and second order. The chosen reaction order is a reaction order with a larger R^2 value. It is shown from the table 4.44 that value of R^2 of zero order > R^2 first order > R^2 second order in both low-density polyethylene and aluminium laminated packaging materials under similar temperature (38°C) and equilibrium relative humidity (90 %) condition.

Table 4.44: Linear regression equation for water activity parameter of waffle cone

Waffle cone stored in LDPE			
Products	MC	APC	GF APC
Zero order	Y= 0.0019x + 0.363	Y=0.002x X +0.399	Y= 0.00x + 0.389
First order	Y= 0.0049x -1.0131	Y= 0.0048x - 0.9182	Y= 0.0049x - 0.9436
Second order	Y= -0.0129x + 2.7535	Y= -0.0114x + 2.5036	Y= -0.0119x + 2.5679
R² Zero order	0.9657	0.98	0.98
R² First order	0.9599	0.9799	0.9799
R² Second order	0.9537	0.9797	0.9797
Waffle cone stored in ALE			
Zero order	Y= 0.0014x + 0.36	Y= 0.0014x + 0.40	Y= 0.0014x + 0.39
First order	Y= 0.0038x -1.0213	Y= 0.0034x - 0.916	Y= 0.0035x - 0.9413
Second order	Y= -0.0102x + 2.7759	Y= -0.0083x + 2.4986	Y= -0.0087x + 2.5626
R² Zero order	1	1	1
R² First order	0.9999	0.9999	0.9999
R² Second order	0.9994	0.9995	0.9995

4.8.7 Moisture content (%) of waffle cone pre-mix

The data illustrated in Table 4.45 shows the moisture content of the market, apple pomace and gluten-free apple pomace waffle cone pre-mix during storage. All three-waffle cone pre-mix samples were stored in low-density polyethylene (LDPE) and aluminium laminated pouch (ALP) at the same temperatures (38°C) and relative humidity (90 %) condition. The moisture content value of waffle cone pre-mix increased with the increase in time of storage. Minimum changes in moisture content of pre-mix packed in aluminium laminated pouches were observed as compared to LDPE pouches. This may be due to the impervious nature of aluminium laminated packaging to air and vapour (Sharma and Riar,

2020). The increased moisture content recorded to be higher in the LDPE pouches. The increase in moisture based on linear regression (R^2) recorded as 8.11 to 8.42 per cent in market pre-mix, 8.40 to 8.73 per cent in apple pomace pre-mix and 8.65 to 8.96 per cent in gluten-free apple pomace pre-mix. In case of ALP pouches the moisture content increased from 8.11 to 8.35 per cent in market waffle cone pre-mix, 8.40 to 8.68 per cent in apple pomace waffle cone pre-mix and 8.65 to 8.90 per cent in gluten-free apple pomace waffle cone pre-mix. Similar trend in increasing moisture content in apple pomace-incorporated muffin pre-mix has been reported by Negi (2018).

Table 4.45 Reaction orders for moisture content of waffle cone pre-mix during storage

Waffle cone stored in LDPE									
Days	Zero order (A)			First order (ln A)			Second order (1/A)		
	MP	APP	GF APP	MP	APP	GF APP	MP	APP	GF APP
0	8.11	8.40	8.65	2.093098	2.128232	2.157559	0.123305	0.119048	0.115607
7	8.21	8.52	8.76	2.105353	2.142416	2.170196	0.121803	0.117371	0.114155
14	8.33	8.62	8.87	2.119863	2.154085	2.182675	0.120048	0.116009	0.11274
21	8.42	8.73	8.96	2.13061	2.166765	2.19277	0.118765	0.114548	0.111607
R^2	0.9973	0.9988	0.9978	0.9971	0.9985	0.9973	0.9968	0.9982	0.9968
Waffle cone stored in ALP									
0	8.11	8.4	8.65	2.093098	2.128232	2.157559	0.123305	0.119048	0.115607
7	8.19	8.5	8.74	2.102914	2.140066	2.16791	0.1221	0.117647	0.114416
14	8.28	8.59	8.83	2.113843	2.150599	2.178155	0.120773	0.116414	0.11325
21	8.35	8.68	8.9	2.122262	2.161022	2.186051	0.11976	0.115207	0.11236
R^2	0.9979	0.9993	0.9966	0.9976	0.999	0.9962	0.9974	0.9987	0.9957

4.8.8 Kinetics of quality decrease rate of waffle cone pre-mix against moisture content

The determination of the reaction order kinetics from increased moisture content is done by comparing the value of R^2 in each linear regression equation at the same 38°C temperature and 90 per cent relative humidity on zero, first order and second order reaction. The chosen reaction order is a larger R^2 value. Table 4.46 and Fig. 4.32 (a and b) shows the moisture content rate of waffle cone based zero-order reaction. It is shown that the value of R^2 of zero order > R^2 of first order > R^2 of second order at temperature 38°C and 90 per cent relative humidity in both low-density polyethylene and aluminium laminated packaging materials.

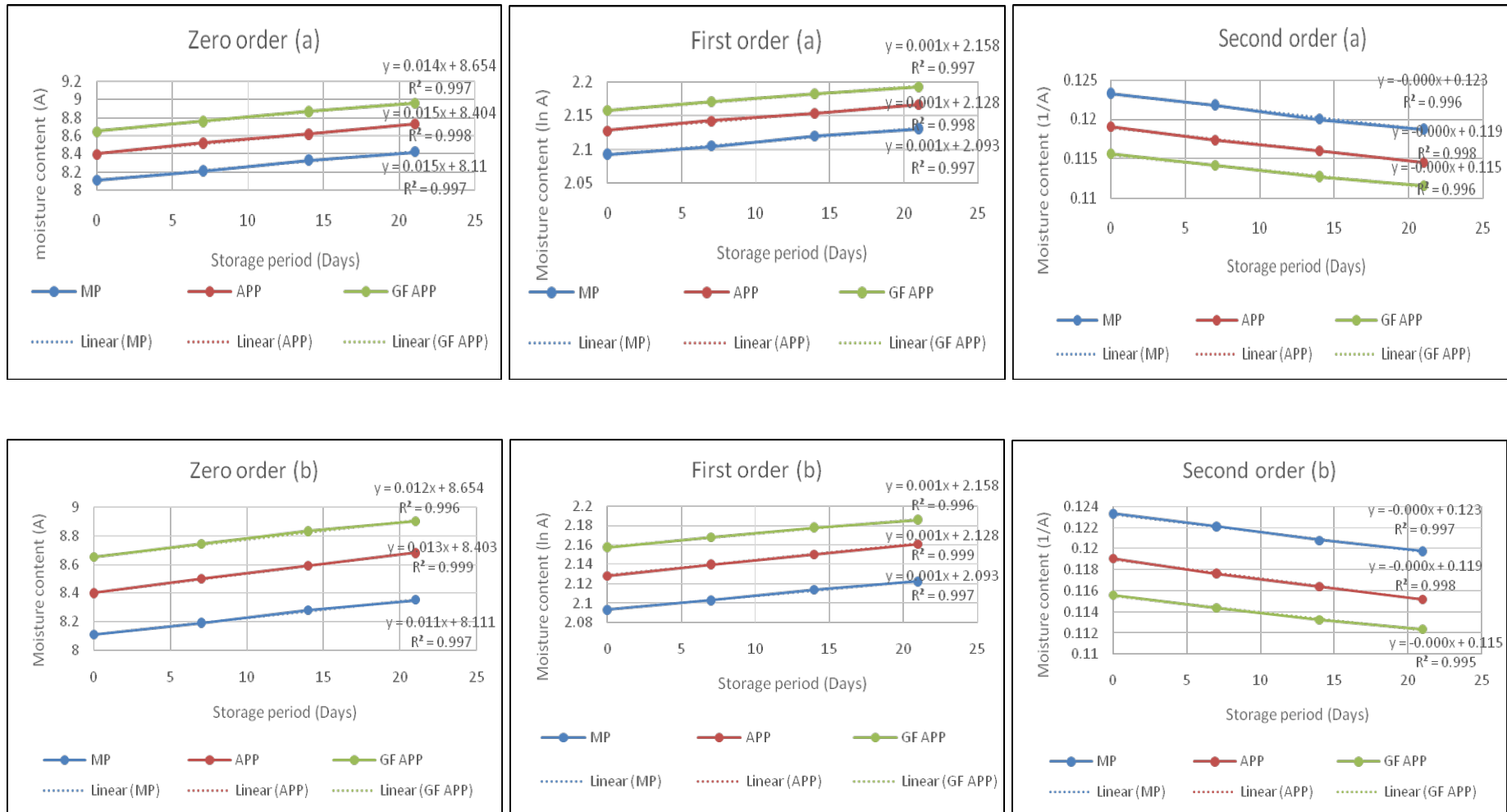


Fig. 4.32: Linear regression equation graph for moisture content of waffle cone pre-mix packed in LDPE (a) and ALP (b)

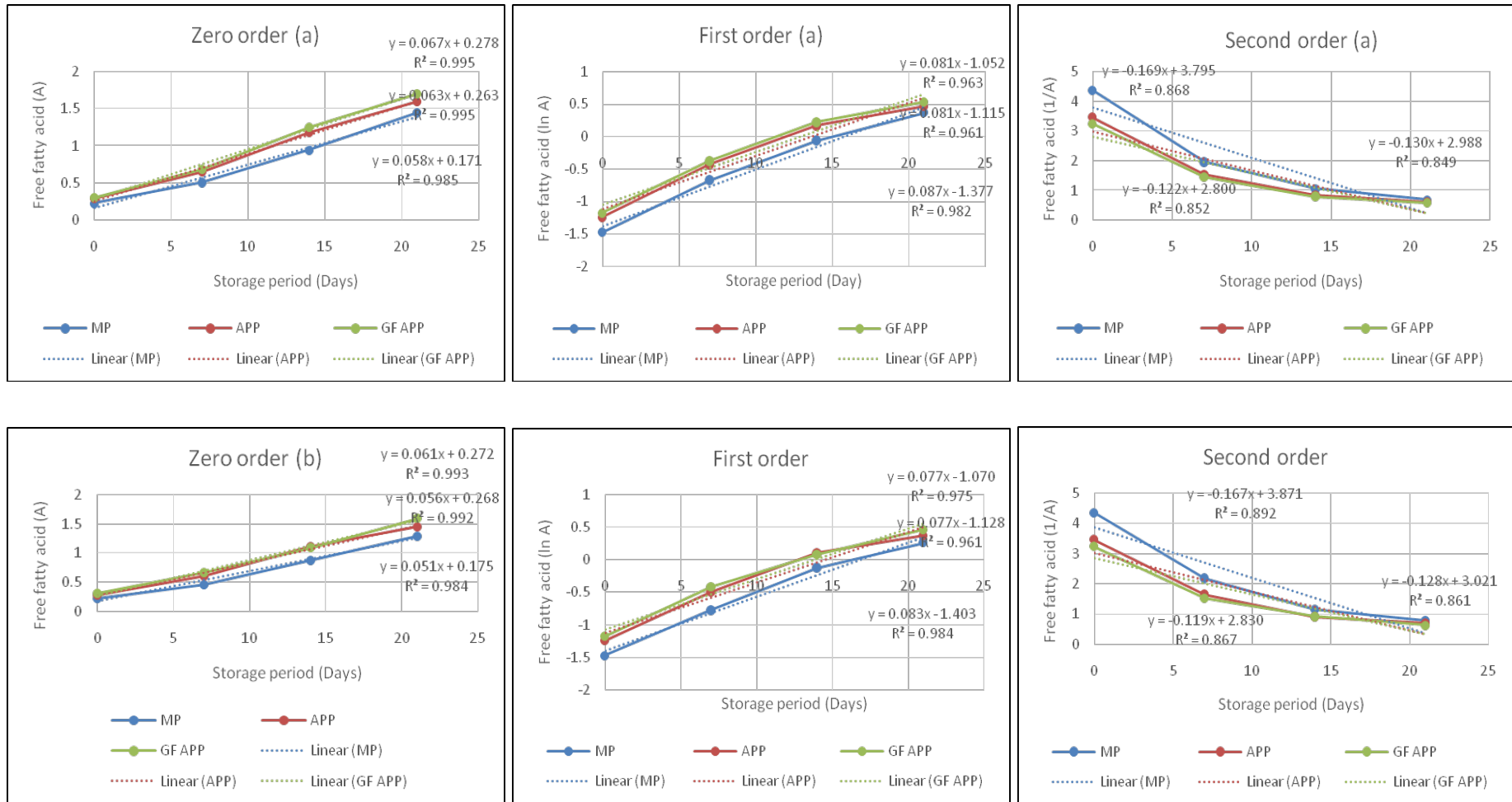


Fig. 4.33 Linear regression equation graph for free fatty acid content of waffle cone pre-mix packed in LDPE (a) and ALP (b)

Table 4.46: Linear regression equation for moisture parameter of waffle cone pre-mix

Waffle cone stored in LDPE			
Products	MP	APP	GF APP
Zero order	$Y= 0.015x + 8.11$	$Y= 0.015x + 8.404$	$Y= 0.014x + 8.654$
First order	$Y= 0.008x + 2.0923$	$Y= 0.0018x + 2.1288$	$Y= 0.0017x + 2.1581$
Second order	$Y= -0.002x + 0.1233$	$Y= -0.0002x + 0.119$	$Y= -0.0002x + 0.1155$
R ² Zero order	0.9973	0.9988	0.9978
R ² First order	0.9971	0.9985	0.9973
R ² Second order	0.9968	0.9982	0.9968
Waffle cone stored in ALE			
Zero order	$Y= 0.106x + 8.111$	$Y= 0.0133x + 8.403$	$Y= 0.012x + 8.654$
First order	$Y= 0.0014x + 2.0933$	$Y= 0.0016x + 2.1286$	$Y= 0.0014x + 2.1581$
Second order	$Y= -0.0002x + 0.1233$	$Y= -0.0002x + 0.119$	$Y= -0.0002x + 0.1155$
R ² Zero order	0.9979	0.9993	0.9966
R ² First order	0.9976	0.999	0.9962
R ² Second order	0.9974	0.9987	0.9957

4.8.9 Free fatty acid (mg/g) waffle cone pre-mix

The Table 4.47 indicate a general increasing trend of free fatty acid market, apple pomace and gluten-free apple pomace waffle cone pre-mixes at 38°C temperature and 90 per cent relative humidity over the entire storage period. Based on higher regression (R²) data shows a higher increase in free fatty acids was observed in waffle cone pre-mix packed in LDPE pouches from 0.23 to 1.44 mg/g in market pre-mix, 0.29 to 1.59 mg/g in apple pomace pre-mix and 0.31 to 1.70 mg/g in gluten-free apple pomace pre-mix followed by waffle cone pre-mix packed in aluminium laminated pouches from 0.23 to 1.29 mg/g, 0.29 to 1.45 mg/g and 0.31 to 1.59 mg/g in market, apple pomace and gluten-free apple pomace waffle cone pre-mix, respectively.

Table 4.47: Reaction orders for free fatty acid of waffle cone pre-mix during storage

Waffle cone stored in LDPE									
Days	Zero order (A)			First order (ln A)			Second order (1/A)		
	MP	APP	GF APP	MP	APP	GF APP	MP	APP	GF APP
0	0.23	0.29	0.31	-1.46968	-1.23787	-1.17118	4.347826	3.448276	3.225806
7	0.51	0.65	0.69	-0.67334	-0.43078	-0.37106	1.960784	1.538462	1.449275
14	0.94	1.18	1.25	-0.06188	0.165514	0.223144	1.06383	0.847458	0.8
21	1.44	1.59	1.70	0.364643	0.463734	0.530628	0.694444	0.628931	0.588235
R ²	0.9857	0.9951	0.9952	0.982	0.9615	0.9638	0.8685	0.8492	0.8522
Waffle cone stored in ALP									
0	0.23	0.29	0.31	-1.46968	-1.23787	-1.17118	4.347826	3.448276	3.225806
7	0.46	0.61	0.66	-0.77653	-0.4943	-0.41552	2.173913	1.639344	1.515152
14	0.88	1.11	1.09	-0.12783	0.10436	0.086178	1.136364	0.900901	0.917431
21	1.29	1.45	1.59	0.254642	0.371564	0.463734	0.775194	0.689655	0.628931
R ²	0.9847	0.9926	0.9939	0.9846	0.9618	0.9756	0.8925	0.8615	0.8674

The effect of packaging material on the free fatty acid content of waffle cone pre-mix may be due to oxidation of the product. Similar, results were observed by Negi (2018) where muffin pre-mix supplemented by apple pomace and Thakur (2021) where Kodo millet flour supplemented muffin pre-mix was stored.

4.8.10 Kinetics of quality decrease rate of waffle cone pre-mix against free fatty acid (mg/g)

The oxidation reaction in waffle cone pre-mix is caused by the oxygen present inside package and migrated from outside. Fat is derived from milk powder which is a minor ingredient of the waffle cone pre-mix. Table 4.48 and Fig. 4.33 (a and b) showed the increase of free fatty acid content in waffle cone pre-mix. The chosen reaction order has a larger R^2 value where the increased rate of free fatty acid of waffle cone pre-mixes based on zero order rate of reaction. This shows the value of R^2 zero order $>$ R^2 first order $>$ R^2 second order on similar storage conditions (38°C and 90 % ERH) in both low-density polyethylene and aluminium laminated packaging materials.

Table 4.48: Linear regression equation for free fatty acid parameter of waffle cone pre-mix

Waffle cone stored in LDPE			
Products	MP	APP	GF APP
First order	Y= 0.0873x - 1.3772	Y= 0.0814x - 1.115	Y= 0.0814x - 1.0521
Second order	Y= -0.1694x + 3.7953	Y= -0.1307x + 2.9881	Y= -0.1223x + 2.8001
R² Zero order	0.9857	0.9951	0.9952
R² First order	0.982	0.9615	0.9638
R² Second order	0.8685	0.8492	0.8522
Waffle cone stored in ALP			
Zero order	Y= 0.0514x + 0.175	Y= 0.0569x + 0.268	Y= 0.061x + 0.272
First order	Y= 0.0832x - 1.4031	Y= 0.0775x - 1.1281	Y= 0.0772x - 1.0702
Second order	Y= -0.16179x + 3.8716	Y= -0.1288x + 3.0217	Y= -0.1198x + 2.8301
R² Zero order	0.9847	0.9926	0.9939
R² First order	0.9846	0.9618	0.9756
R² Second order	0.8925	0.8615	0.8674

4.8.11 Water activity waffle cone pre-mix

Perusal of data in Table 4.49 shows the effect of storage conditions and packaging materials on the water activity of waffle cone pre-mix. The general increasing trend in the water activity of all type of waffle cone pre-mix have been recorded during entire storage period of 21 days at 38°C temperature and 90 per cent relative humidity.

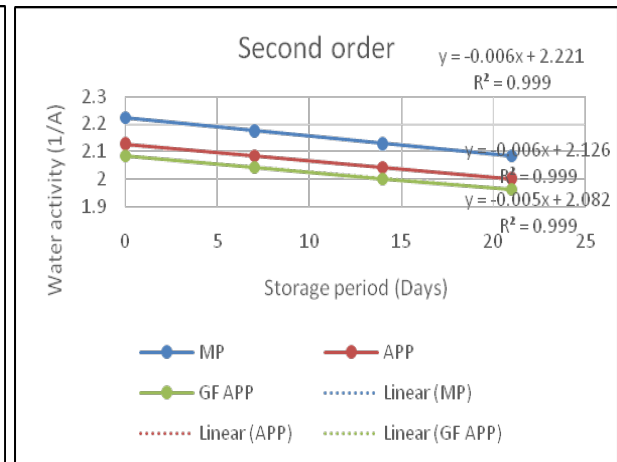
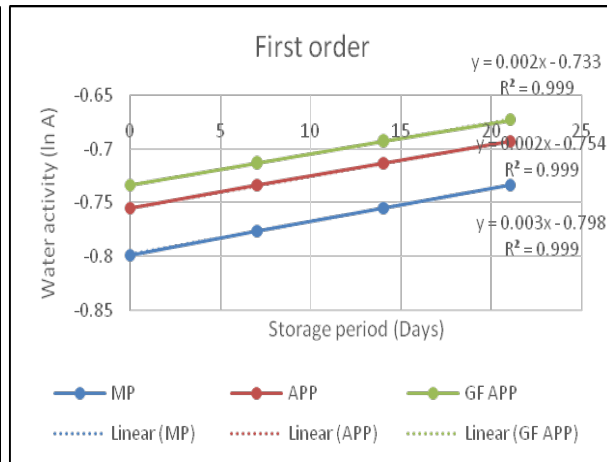
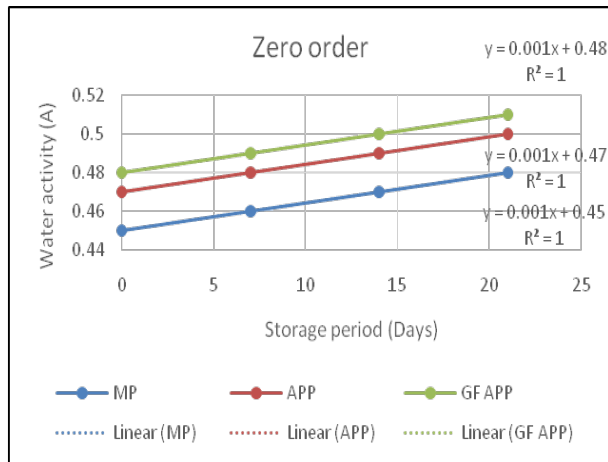
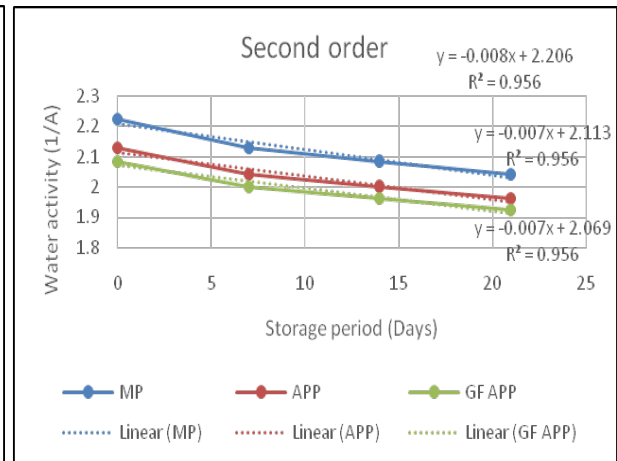
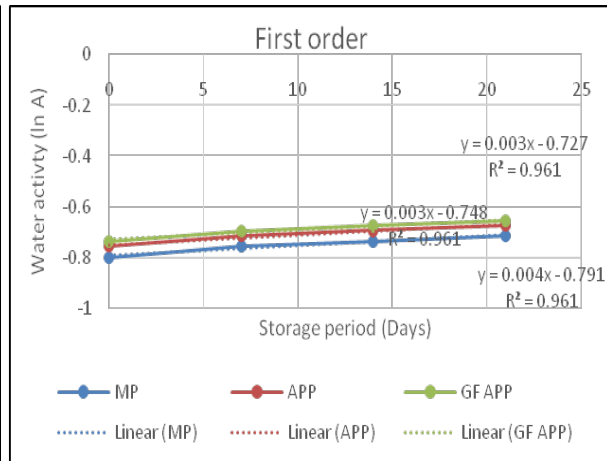
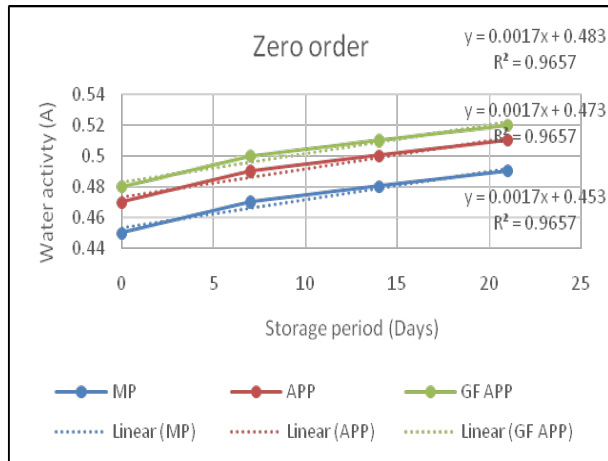


Fig. 4.34 Linear regression equation graph for water activity of waffle cone pre-mix packed in LDPE (a) and ALP (b)

The data shows that based on higher regression (R^2) the increase of storage period with higher increase in water activity was observed in waffle cone pre-mix packed in LDPE pouches with increase from 0.45 to 0.49 in market pre-mix, 0.47 to 0.51 in apple pomace pre-mix and 0.48 to 0.52 in gluten-free apple pomace pre-mix and a minimum increase in the water activity were noted in waffle cone pre-mix packed in aluminium laminated pouches from 0.45 to 0.48, 0.47 to 0.50 and 0.48 to 0.51 in market, apple pomace and gluten-free apple pomace waffle cone pre-mix, respectively. However, the increase in water activity is due to an increase in moisture content and high water absorption capacity of non-starch polysaccharides in apple pomace flour. Results were agreed well with Sharma *et al.* (2018) and Thakur (2021).

Table 4.49: Reaction orders for water activity of waffle cone pre-mix during storage

Waffle cone stored in LDPE									
Days	Zero order (A)			First order (ln A)			Second order (1/A)		
	MP	APP	GF APP	MP	APP	GF APP	MP	APP	GF APP
0	0.45	0.47	0.48	-0.79851	-0.75502	-0.73397	2.222222	2.12766	2.083333
7	0.47	0.49	0.5	-0.75502	-0.71335	-0.69315	2.12766	2.040816	2.00000
14	0.48	0.50	0.51	-0.73397	-0.69315	-0.67334	2.083333	2.00000	1.960784
21	0.49	0.51	0.52	-0.71335	-0.67334	-0.65393	2.040816	1.960784	1.923077
R ²	0.9657	0.9657	0.9657	0.9611	0.9613	0.9613	0.9561	0.9566	0.9567
Waffle cone stored in ALP									
0	0.45	0.47	0.48	-0.79851	-0.75502	-0.73397	2.222222	2.12766	2.083333
7	0.46	0.48	0.49	-0.77653	-0.73397	-0.71335	2.173913	2.083333	2.040816
14	0.47	0.49	0.50	-0.75502	-0.71335	-0.69315	2.12766	2.040816	2.00000
21	0.48	0.50	0.51	-0.73397	-0.69315	-0.67334	2.083333	2.00000	1.960784
R ²	1	1	1	0.9999	0.9999	0.9999	0.9996	0.9997	0.9997

4.8.12 Kinetics of quality decrease rate of waffle cone pre-mix against water activity

The water activity of market, apple pomace and gluten-free waffle cone pre-mix showed in Table 4.50 and Fig. 4.34 (a and b). The reaction order of kinetics showed that there is an increase in the water activity with the storage time in both the packaging materials (LDPE and ALP) in similar storage condition (38°C and 90 % ERH). The determination of the reaction order kinetics from increasing water activity content is done by comparing the value of R^2 in each linear regression equation on zero order reaction. The chosen reaction order is a reaction order with a larger R^2 value. It is shown from the value that R^2 of zero order > R^2 first order > R^2 second order at temperature 38°C and 90 per cent equilibrium relative humidity for 21 days.

Table 4.50: Linear regression equation for water activity parameter of waffle cone pre-mix

Waffle cone stored in LDPE			
Products	MP	APP	GF APP
Zero order	$Y = 0.0017x + 0.453$	$Y = 0.0017x + 0.473$	$Y = 0.0017x + 0.483$
First order	$Y = 0.004x - 0.7917$	$Y = 0.0038x - 0.7485$	$Y = 0.0037x - 0.7276$
Second order	$Y = -0.0084x + 2.2068$	$Y = -0.0077x + 2.1135$	$Y = -0.0074x + 2.0698$
R² Zero order	0.9657	0.9657	0.9657
R² First order	0.9611	0.9613	0.9613
R² Second order	0.9561	0.9566	0.9567
Waffle cone stored in ALE			
Zero order	$Y = 0.0014x + 0.45$	$Y = 0.0014x + 0.47$	$Y = 0.0015x + 0.48$
First order	$Y = 0.0031x - 0.7983$	$Y = 0.0029x - 0.7548$	$Y = 0.0029x - 0.7338$
Second order	$Y = -0.0066x + 2.2212$	$Y = -0.0061x + 2.1268$	$Y = -0.0058x + 2.0825$
R² Zero order	1	1	1
R² First order	0.9999	0.9999	0.9999
R² Second order	0.9996	0.9997	0.9997

4.9 PREDICTION OF SHELF LIFE OF WAFFLE CONE AND WAFFLE CONE PRE-MIX

4.9.1 Prediction of shelf life of waffle cone

4.9.1.1 Prediction of shelf life of waffle cone (according to moisture content)

The data presented in Table 4.51 shows the rate of reaction (k) and predicted shelf life of waffle cone in using Arrhenius graph plot Fig 4.35 (T₁, T₂, T₃, T₄, T₅ and T₆) with moisture content as the quality factor. The predicted shelf life of market, apple pomace and gluten-free apple pomace waffle cone was 342, 227 and 229 days in low density polyethylene pouches and 404, 260 and 275 days in aluminium laminated pouches, respectively at 38°C temperature and 90 per cent relative humidity.

Table 4.51 Predicted shelf life of waffle cone

Waffle cone stored in LDPE			
Treatments	Temperature (°C)	Rate constant (k)	Shelf life (Days)
T ₁ (Market cone)	38°C	0.0137	342
T ₂ (Apple pomace waffle cone)	38°C	0.0187	227
T ₃ (Gluten-free apple pomace cone)	38°C	0.0191	229
Waffle cone stored in ALP			
T ₄ (Market cone)	38°C	0.0116	404
T ₅ (Apple pomace waffle cone)	38°C	0.0163	260
T ₆ (Gluten-free apple pomace cone)	38°C	0.0159	275

4.9.1.2 Prediction of shelf life of waffle cone (according to free fatty acid content)

Data presented in Table 4.52 shows the rate of reaction (k) and shelf life (t_s) of the waffle cone based on by Arrhenius graph plot Fig 4.36 (T_1 , T_2 , T_3 , T_4 , T_5 and T_6) according to the free fatty acid content as quality factor. The shelf life of waffle cones were estimated 371, 239 and 232 days in low density polyethylene pouches and 405, 270 and 263 days in aluminium laminated pouches of market waffle cone, apple pomace waffle cone and gluten-free apple pomace waffle cone, respectively.

Table 4.52 Predicted shelf life of waffle cone

Waffle cone stored in LDPE			
Treatments	Temperature (°C)	Rate constant (k)	Shelf life (Days)
T ₁ (Market cone)	38°C	0.0401	371
T ₂ (Apple pomace waffle cone)	38°C	0.0609	239
T ₃ (Gluten-free apple pomace cone)	38°C	0.0629	232
Waffle cone stored in ALP			
T ₄ (Market cone)	38°C	0.0367	405
T ₅ (Apple pomace waffle cone)	38°C	0.0539	270
T ₆ (Gluten-free apple pomace cone)	38°C	0.0557	263

4.9.1.2 Prediction of shelf life of waffle cone (according to water activity)

Perusal of data presented in Table 4.53 shows the rate of reaction (k) and shelf life (t_s) of the waffle cone by Arrhenius graph plot Fig 4.37 (T_1 , T_2 , T_3 , T_4 , T_5 and T_6) based on the water activity as quality factor. The shelf life of market waffle cone, apple pomace waffle cone and gluten-free apple pomace waffle cone was estimated 231, 200 and 205 days in low density polyethylene pouches and 314, 285 and 292 days, in aluminium laminated pouches, respectively.

Table 4.53 Predicted shelf life of waffle cone

Waffle cone stored in LDPE			
Treatments	Temperature (°C)	Rate constant (k)	Shelf life (Days)
T ₁ (Market cone)	38°C	0.0019	231
T ₂ (Apple pomace waffle cone)	38°C	0.0020	200
T ₃ (Gluten-free apple pomace cone)	38°C	0.0020	205
Waffle cone stored in ALP			
T ₄ (Market cone)	38°C	0.0014	314
T ₅ (Apple pomace waffle cone)	38°C	0.0014	285
T ₆ (Gluten-free apple pomace cone)	38°C	0.0014	292

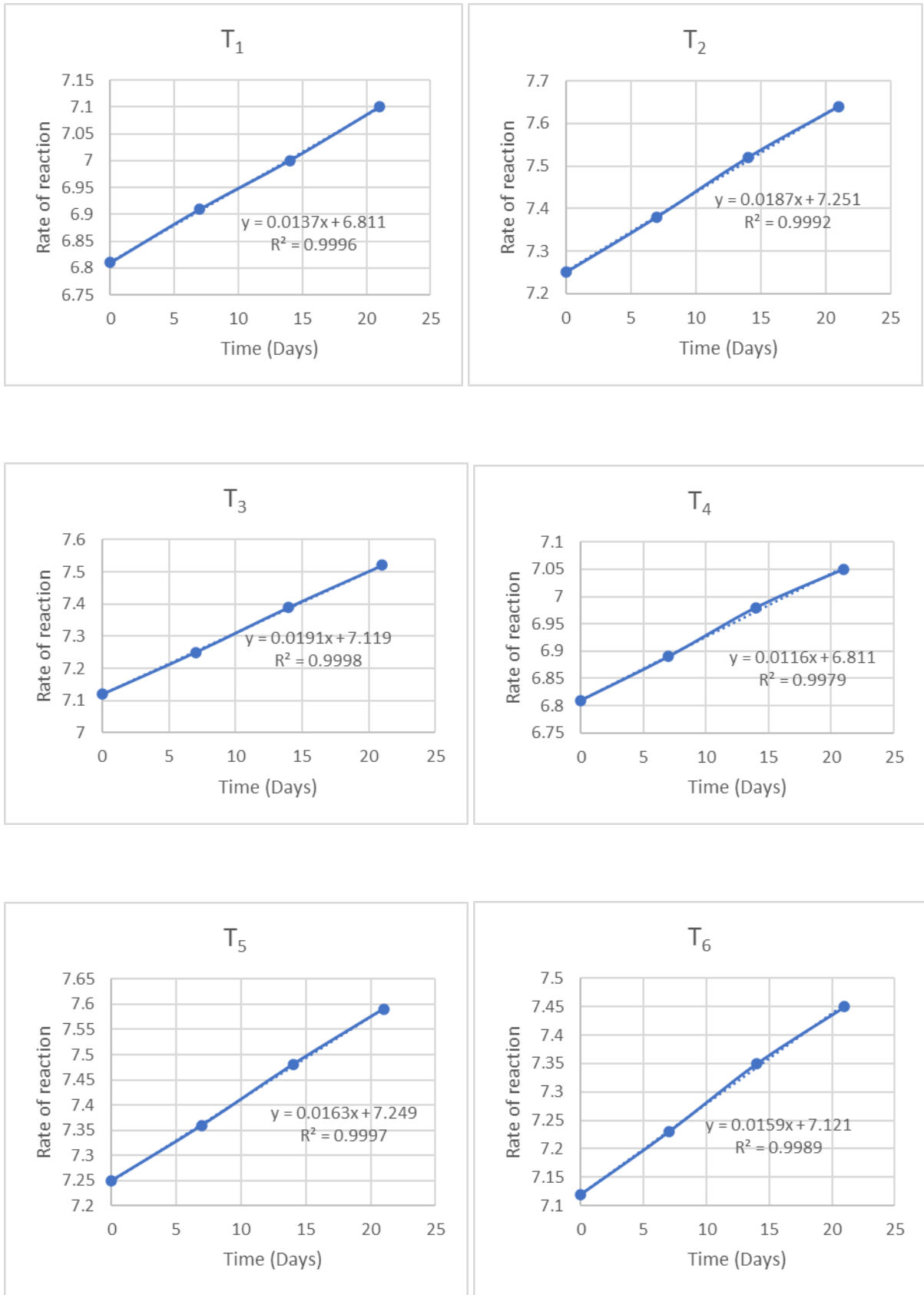


Fig. 4.35 Arrhenius plot of rate constant for moisture (%) in waffle cone versus time (days)

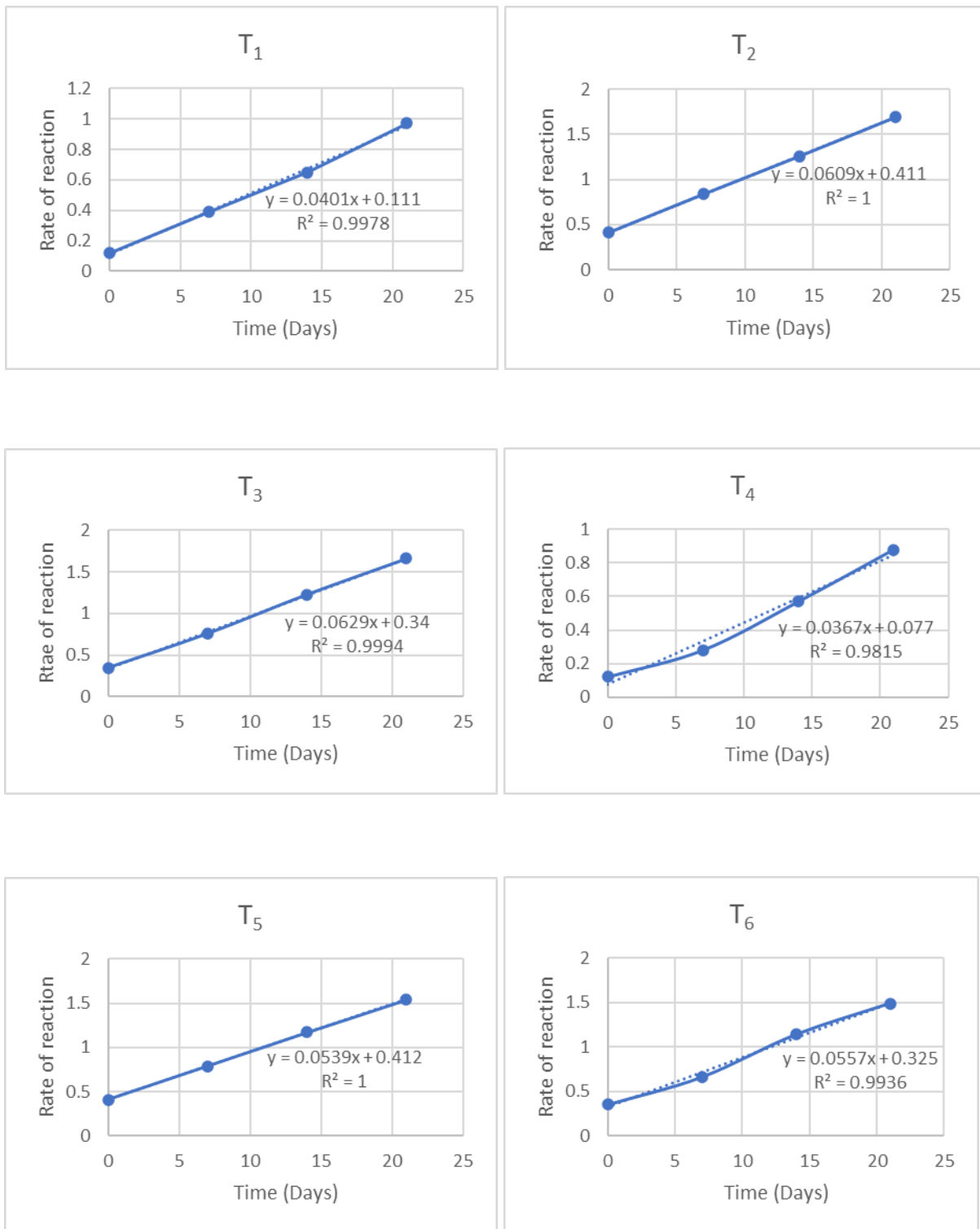


Fig. 4.36 Arrhenius plot of rate constant for free fatty acid (mg/g) in waffle cone versus time (days)

4.9.2 Prediction of shelf life of waffle cone pre-mix

4.9.2.1 Prediction of shelf life of waffle cone pre-mix (according to moisture content)

The data presented in Table 4.54 reveals the rate of reaction (k) and predicted shelf life of waffle cone pre-mixes stored at 38°C temperature and 90 per cent relative humidity using Arrhenius graph plot Fig 4.38 (T₁, T₂, T₃, T₄, T₅ and T₆) with moisture content as the quality factor. The predicted shelf life of market, apple pomace and gluten-free apple pomace waffle cone pre-mix was 226, 198 and 191 days in low density polyethylene pouches and 292, 233 and 237 days, in aluminium laminated pouches, respectively.

Table 4.54 Predicted shelf life of waffle cone pre-mix

Waffle cone stored in LDPE			
Treatments	Temperature (°C)	Rate constant (k)	Shelf life (Days)
T ₁ (Market waffle cone pre-mix)	38°C	0.0150	226
T ₂ (Apple pomace waffle cone pre-mix)	38°C	0.0156	198
T ₃ (Gluten-free apple pomace cone pre-mix)	38°C	0.0149	191
Waffle cone stored in ALP			
T ₄ (Market waffle cone pre-mix)	38°C	0.0116	292
T ₅ (Apple pomace waffle cone pre-mix)	38°C	0.0133	233
T ₆ (Gluten-free apple pomace cone pre-mix)	38°C	0.0120	237

4.9.2.2 Prediction of shelf life of waffle cone pre-mix (according to free fatty acid content)

Data in the Table 4.55 elucidate the rate of reaction (k) and predicted shelf life of waffle cone pre-mixes stored at 38°C temperature and 90 per cent relative humidity based on Arrhenius graph plot Fig 4.39 (T₁, T₂, T₃, T₄, T₅ and T₆). The predicted self-life of waffle cone pre-mix packed in LDPE pouches was 254, 232 and 217 days and aluminium laminated pouches was 287, 258 and 240 days of market waffle cone pre-mix, apple pomace waffle cone pre-mix and gluten-free waffle cone pre-mix, respectively. The overall effect of treatment (T), storage period (S) and packaging material (P) (S×P×T) was found to be significant.

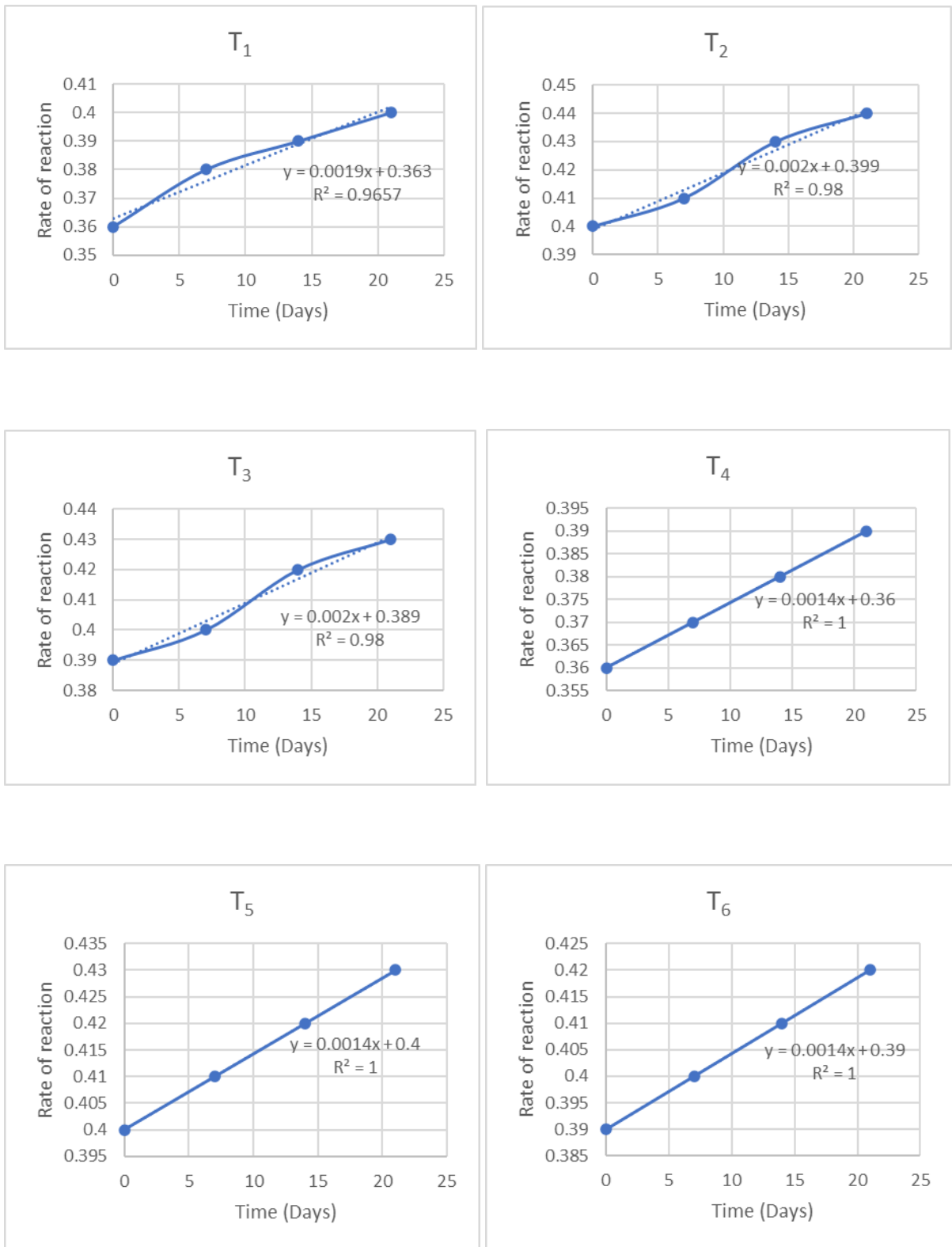


Fig. 4.37 Arrhenius plot of rate constant for water activity in waffle cone versus time (days)

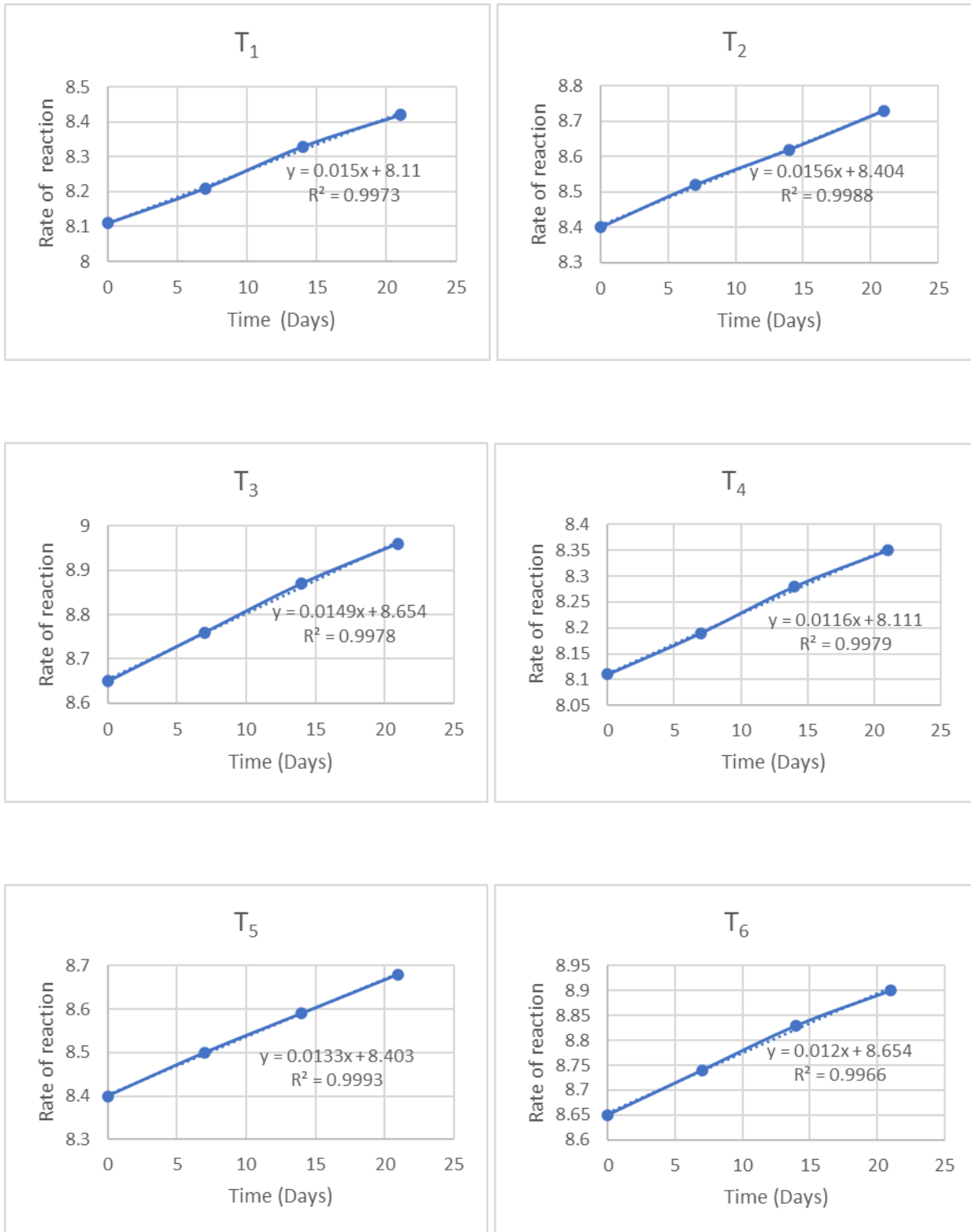


Fig. 4.38 Arrhenius plot of rate constant for moisture (%) in waffle cone pre-mix versus time (days)

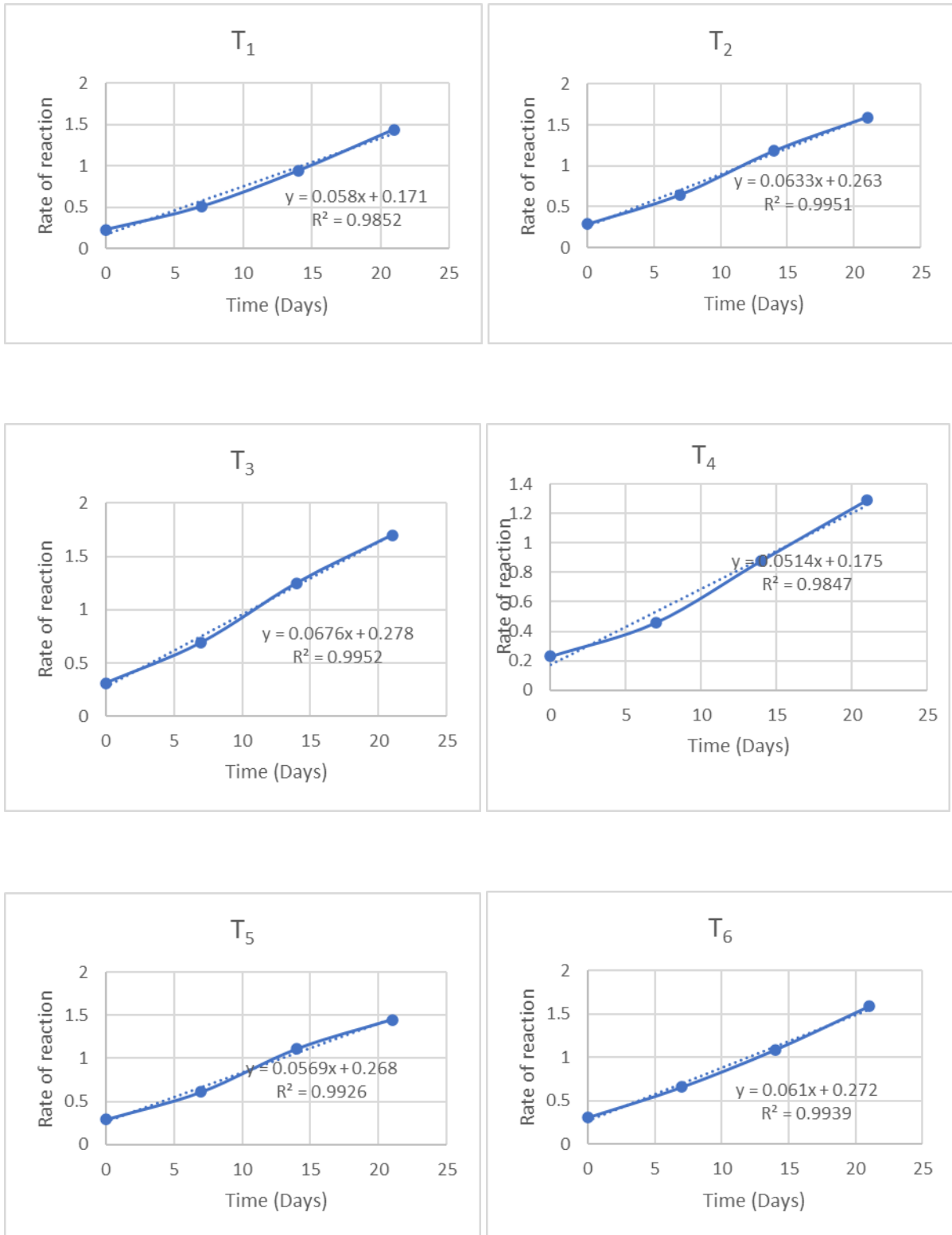


Fig. 4.39 Arrhenius plot of rate constant for free fatty acid (mg/g) in waffle cone pre-mix versus time (days)

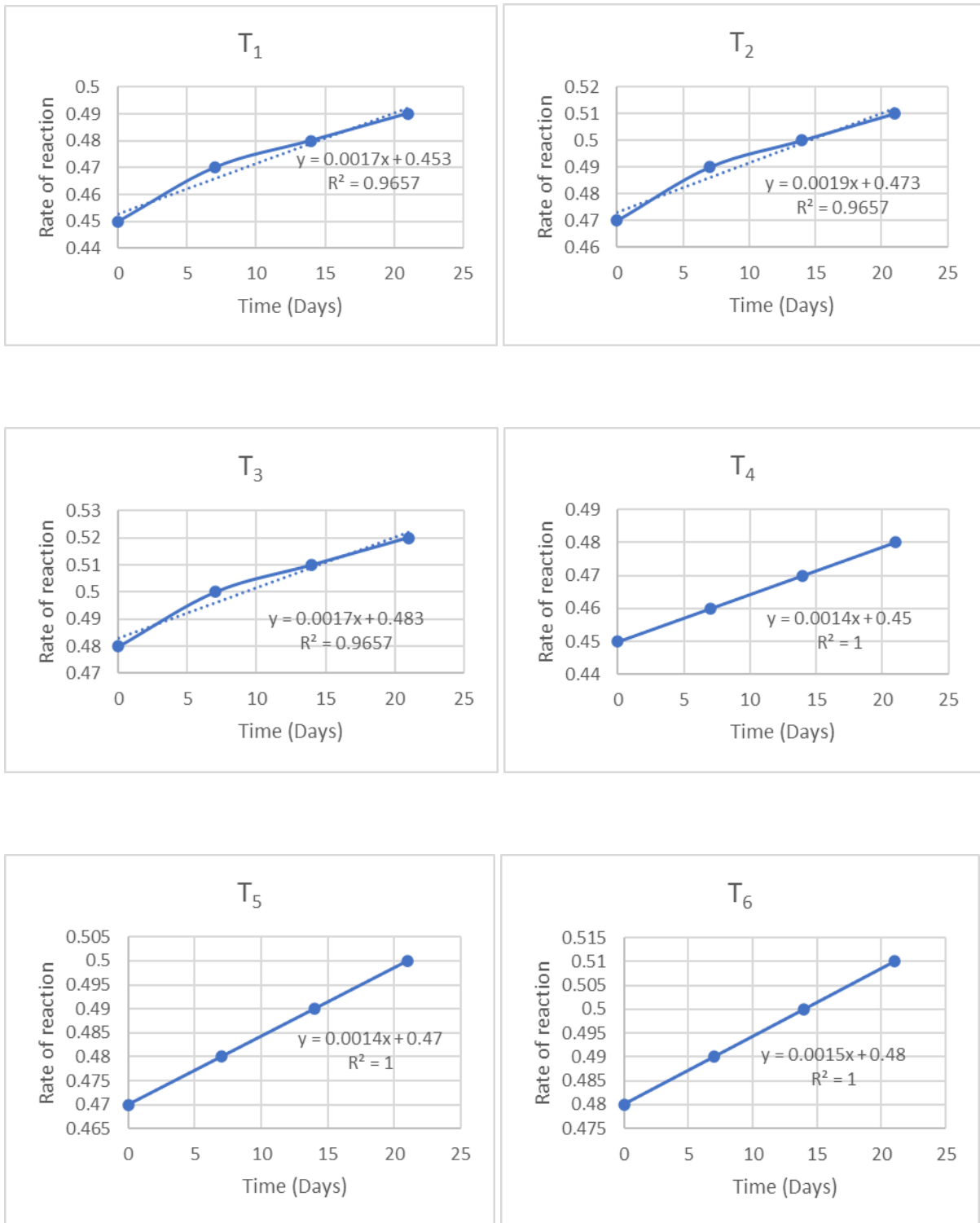


Fig. 4.39 Arrhenius plot of rate constant for water activity in waffle cone pre-mix versus time (days)

Table 4.55 Predicted shelf life of waffle cone pre-mix

Waffle cone stored in LDPE			
Treatments	Temperature (°C)	Rate constant (k)	Shelf life (Days)
T ₁ (Market waffle cone pre-mix)	38°C	0.0580	254
T ₂ (Apple pomace waffle cone pre-mix)	38°C	0.0633	232
T ₃ (Gluten-free apple pomace cone pre-mix)	38°C	0.0676	217
Waffle cone stored in ALP			
T ₄ (Market waffle cone pre-mix)	38°C	0.0514	287
T ₅ (Apple pomace waffle cone pre-mix)	38°C	0.0569	258
T ₆ (Gluten-free apple pomace cone pre-mix)	38°C	0.0610	240

4.9.2.3 Prediction of shelf life of waffle cone pre-mix (according to water activity)

Data given in Table 4.56 presented the rate of reaction (k) and predicted shelf life of waffle cone pre-mixes by using Arrhenius graph plot Fig 4.40 (T₁, T₂, T₃, T₄, T₅ and T₆). Predicted self-life of market, apple pomace and gluten-free apple pomace waffle cone pre-mix packed in LDPE pouches was found 205, 194 while 188 days and aluminium laminated pouches packed pre-mix was 250, 235 and 213 days, respectively.

Table 4.56 Predicted shelf life of waffle cone pre-mix

Waffle cone stored in LDPE			
Treatments	Temperature (°C)	Rate constant (k)	Shelf life (Days)
T ₁ (Market waffle cone pre-mix)	38°C	0.0017	205
T ₂ (Apple pomace waffle cone pre-mix)	38°C	0.0017	194
T ₃ (Gluten-free apple pomace cone pre-mix)	38°C	0.0017	188
Waffle cone stored in ALP			
T ₄ (Market waffle cone pre-mix)	38°C	0.0014	250
T ₅ (Apple pomace waffle cone pre-mix)	38°C	0.0014	235
T ₆ (Gluten-free apple pomace cone pre-mix)	38°C	0.0015	213

4.10 COST OF PRODUCTION FOR THE DEVELOPED PRODUCT

Data in Table (4.57) show the cost for the production of waffle cone prepared from apple pomace flour-based. The cost of production of apple pomace waffle cone was Rs 2.60/ piece and gluten-free apple pomace waffle cone was Rs 2.75/ piece, respectively. the products are packed in low density polyethylene pouch and aluminium laminated pouch.

Table 4.57 Cost of production of waffle cone

Particular	Rate (Rs.)	Apple pomace waffle cone		Gluten-free apple pomace waffle cone	
		Quantity (g)	Amount (Rs.)	Quantity (g)	Amount (Rs.)
Apple pomace flour	10/ Kg	20.00	0.20	20.00	0.20
Whole wheat flour	35/ Kg	8.00	0.28	-	-
Red rice flour	150/ kg	-	-	8.00	1.20
Sugar powder	50/ Kg	10.00	0.50	10.00	0.50
Butter	200/ Kg	10.00	2.00	10.00	2.00
Banana	60/ Kg	15.00	0.90	15.00	0.90
Milk	50/lit	85.00	4.25	80.00	4.00
Total cost of ingredients	-	-	8.13	-	8.80
Processing cost @ 20 %		-	1.62		1.76
Packaging material (Polyethylene & Aluminium laminated pouches)	1/ Piece	1 piece	1.00	1 piece	1.00
Total Cost	-	-	10.75	-	11.56
Profit cost @ 20 %			2.15		2.11
Total cost (5 cone)			12.90		13.67

Data presented in Table (4.57) show the cost for the production of waffle cone pre-mix prepared from apple pomace flour-based. The cost of production of apple pomace waffle cone pre-mix was Rs 215.00 per kg and gluten-free apple pomace waffle cone pre-mix was Rs 230.00s per kg, respectively packed in low density polyethylene pouch and aluminium laminated pouch.

Table 4.58 Cost of production of waffle cone pre-mix

Particular	Rate (Rs.)	Apple pomace waffle cone pre-mix		Gluten-free apple pomace waffle cone pre-mix	
		Quantity (g)	Amount (Rs.)	Quantity (g)	Amount (Rs.)
Apple pomace flour	10/ Kg	40.00	0.40	40.00	0.40
Whole wheat flour	35/ Kg	16.00	0.56	-	-
Red rice flour	150/ kg	-	-	16.00	2.40
Sugar powder	50/ Kg	20.00	1.00	20.00	1.00
Milk powder	400/ Kg	20.00	8.00	20.00	8.00
Potato starch	800/ Kg	4.00	3.20	4.00	3.20
Total cost of ingredients	-	-	13.96	-	15.00
Processing cost @ 20 %		-	2.79		3.00
Packaging material (Polyethylene & Aluminium laminated pouches)	1/ Piece	1 piece	1.00	1 piece	1.00
Total Cost	-	-	17.75	-	19.00
Profit cost @ 20 %			3.55		3.80
Total cost (100 g)			21.30		22.80

4.11 MICROBIAL QUALITY

Microbiological quality was determined by total plate count (TPC) for market waffle cone, apple pomace waffle cone, gluten-free apple pomace waffle cone, market waffle cone pre-mix, apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix CFU (Colony forming unit) per gram was observed satisfactory and within the permissible limits, during the storage period of 21 days at 38°C temperature and 90 per cent relative humidity thus reflecting good product storage stability. The microbial stability of the market waffle cone, apple pomace waffle cone and gluten-free waffle cone was due to low moisture content and high processing temperature which reduce the chance of contamination. Apple pomace flour and red rice flour also possesses good antimicrobial properties. The total microbial count of these products stored at accelerated condition were observed and found within acceptable limits during storage period.

Chapter-5

SUMMARY AND CONCLUSION

The present investigation “**Development and evaluation of apple pomace waffle cone**” was conducted in the Department of Food Science and Technology, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The main objective of the study was to develop value added products from apple pomace flour, in combination with wheat flour and red rice flour and to evaluate the quality of the products during storage. The raw material for the study (fresh apple pomace) was collected from the commercial unit, Department of Food Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan and other raw materials (whole wheat flour, red rice flour, milk, sugar powder, butter, banana, milk powder and potato starch) were procured from the local market, Solan, Himachal Pradesh. Further, the raw material was evaluated on the basis of various physico-chemical characteristics. The developed products like apple pomace waffle cone, gluten-free apple pomace waffle cone, apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix were packed in Low-Density Polyethylene (LDPE) and Aluminium Laminated Pouches (ALP) and were kept for accelerated storage under 38°C temperature and 90.00 per cent relative humidity. The quality of the products was evaluated on the basis of various physico-chemical changes such as moisture content, free fatty acid and water activity during the storage periods of 0, 7, 14 and 21 days. The cost of production was also estimated according to the economic feasibility of the products. The results observed in the present study have been summarized and briefly concluded as under:

- ❖ The physical properties of the flours (apple pomace flour, whole wheat flour and red rice flour) *viz.*, bulk density, tapped density, Carr’s index and Hausner ratio were recorded as 0.684 g/cm³, 0.773 g/cm³, 11.514 per cent and 1.130 in apple pomace flour. Whereas, in whole wheat flour, it was recorded as 0.625 g/cm³, 0.819 g/cm³, 23.680 per cent and 1.310, respectively and in red rice flour the observations recorded were 0.581 g/cm³, 0.832 g/cm³, 30.168 per cent and 1.432, respectively.
- ❖ The nutritional composition such as moisture content, ash content, crude fat, crude fibre, total dietary fibre crude protein, carbohydrate, total sugar, reducing sugar, starch content and pectin content in apple pomace flour recorded as 8.23, 2.06, 2.39, 20.68, 43.26, 3.12, 63.52, 25.29, 12.73, 13.28 and 13.58 per cent, respectively. The energy value and water activity were found to be 290.24 Kcal/100g and 0.48,

respectively. Likewise, total phenols, antioxidant activity, anthocyanin content and ascorbic acid were recorded as 451.14 mg GAE/100g, 85.37 per cent, 14.42 mg/100g and 12.21 mg/100g, respectively. Whereas, in whole wheat flour the moisture content, ash content, crude fat, crude fibre, total dietary fibre crude protein, carbohydrate, total sugar, reducing sugar and starch content were recorded as 10.52, 1.42, 1.83, 4.48, 11.95, 12.95, 68.82, 3.14, 0.59 and 57.14 per cent, respectively. Energy value and water activity were found to be 340.55 Kcal/100g and 0.51, respectively. However, total phenols and antioxidant activity were found 31.45 mg GAE/100g and 12.18 per cent, respectively. Similarly in red rice flour moisture content, ash content, crude fat, crude fibre, total dietary fibre crude protein, carbohydrate, total sugar, reducing sugar and starch content recorded as 11.02, 1.55, 1.95, 2.60, 10.12, 8.32, 74.56, 2.10, 0.37 and 65.04 per cent, respectively. Energy value and water activity were found to be 349.26 Kcal/100g and 0.53, respectively. Whereas, total phenols, antioxidant activity and anthocyanin content were found 394.26 mg GAE/100g, 64.32 per cent and 9.34 mg/100g, respectively.

- ❖ The mineral composition of flours *viz.*, phosphorus, potassium, sodium, calcium sulphur, magnesium, iron, copper, zinc and manganese were observed to be 6357.00, 8975.00, 1115.00, 1315.00, 1444.70, 1645.00, 97.00, 2 4.00, 23.70 and 47.80 ppm, respectively in apple pomace flour, while, it was recorded as 2750.20, 3500.00, 527.50, 2775.00, 1326.50, 2605.00, 43.10, 10.90, 34.60 and 26.20 ppm in whole wheat flour and in red rice flour it was recorded as 4090.00, 3800.00, 667.50, 3225.00, 1369.20, 4075.00, 64.50, 12.70, 39.90 and 12.20 ppm, respectively.
- ❖ The colour characteristics *i.e.*, L*, a*, b* and h° were recorded as 48.35, 2.64, 29.99 and 84.96 in apple pomace flour, 79.29, -0.08, 15.00 and -89.69 in whole wheat flour and 50.99, 2.10, 17.55 and 83.17 in red rice flour, respectively.
- ❖ The functional properties of flours *i.e.*, water absorption capacity, water solubility index and oil absorption capacity were recorded as 3.23 g/g, 3.11 g/g and 2.70 g/g in apple pomace flour, whereas 1.17 g/g, 1.08 g/g and 1.02 g/g were recorded in whole wheat flour and 1.53 g/g, 1.44 g/g, and 1.39 g/g were recorded in red rice flour, respectively.
- ❖ The optimization of ingredients for the development of the apple pomace waffle cone (apple pomace flour with whole wheat flour) and gluten-free apple pomace waffle cone (apple pomace flour with red rice flour) and their pre-mixes was done by using

Response Surface Methodology. To estimate the effect of responses and their interaction with varying independent components, the analytical data on physical and functional attributes were obtained from the central composite design (CCD) which was fitted to first and second-order, linear and quadratic model types. Analysis of variance (ANOVA) was used to study the experimental data to assess the effects in the case of apple pomace waffle cone (apple pomace flour (g), whole wheat flour (g) and sugar powder (g)) and gluten-free apple pomace waffle cone (apple pomace flour (g), red rice flour (g) and sugar powder (g)) on hardness (g), brittleness (mm), toughness (g.sec), crispiness, ice cream holding time (min) and overall acceptability (sensory evaluation based on 9-point Hedonic scale).

- ❖ The responses of ingredients for the development of the apple pomace waffle cone from apple pomace flour with whole wheat flour were predicted by using the Design expert-07 software which resulted in hardness (933.90 g), brittleness (4.66 mm), toughness (1045.03 g.sec), crispiness (16.68), ice cream holding time (31.03 min) and overall acceptability (8.34). The closeness of the actual values to that of predicted values of hardness (921.66 g), brittleness (4.53 mm), toughness (1036.82 g.sec), crispiness (17.00), ice cream holding time (31.00 min) and overall acceptability (8.24) approved validation for the response surface methodology (RSM) model.
- ❖ The responses of ingredients for the development of gluten-free apple pomace waffle cone from apple pomace flour with red rice flour were predicted by using the Design expert-07 software which resulted in hardness as (1328.45 g), brittleness (4.75 mm), toughness (1078.40 g.sec), crispiness (17.35), ice cream holding time (29.34 min) and overall acceptability (8.00). The closeness of the actual values to that of the predicted value of hardness (1336.27 g), brittleness (4.76 mm), toughness (1089.62 g.sec), crispiness (18.00), ice cream holding time (29.00 min) and overall acceptability (7.92) approved validation for the response surface methodology (RSM) model.
- ❖ The sensory evaluation of the apple pomace waffle cone and gluten-free apple pomace waffle cone prepared from apple pomace flour mixed with whole wheat flour and apple pomace flour with red rice flour, respectively were evaluated by the panellists which showed the effect of ingredients present in waffle cones on sensory parameters like texture, taste, colour and overall acceptability.
- ❖ The recipe standardized for waffle cone involves as apple pomace flour (13.00 %), whole wheat flour (5.00 %), powder sugar (7.00 %), butter (7.00 %), banana

(10.00 %) and milk (58.00 %) in apple pomace waffle cone and apple pomace flour (14.00 %), red rice flour (5.00%), powder sugar (7.00 %), butter (7.00 %), banana (10.00 %) and milk (57.00 %) in gluten-free apple pomace waffle cone.

- ❖ The standardized recipes (apple pomace waffle cone and gluten-free apple pomace waffle cone) based on RSM having responses (hardness, brittleness, toughness, crispiness, ice cream holding time and overall acceptability) were further utilized for the preparation of pre-mix (apple pomace waffle cone and gluten-free apple pomace waffle cone) and apple pomace waffle cone or gluten-free apple pomace waffle cone from pre-mix. Whereas for the preparation of waffle cone pre-mix wet ingredients *i.e.*, milk and banana were replaced by dry ingredients *i.e.*, milk powder and potato starch, respectively.
- ❖ Quality characteristics of developed waffle cones *i.e.*, weight, thickness and ice cream holding time (ICHT) were found to be 8.00 g, 2.50 mm, and 34.00 min in market waffle cone, respectively whereas, 10.20 g, 2.57 mm and 31.00 min in apple pomace waffle cone and 10.02 g, 2.51 mm and 29.00 min in gluten-free apple pomace waffle cone, respectively. The baking loss was observed at 66.00 and 66.60 per cent in apple pomace waffle cone and gluten-free apple pomace waffle cone, respectively.
- ❖ The physico-chemical composition of market waffle cones *i.e.*, moisture content, ash content, crude fat, crude fibre, total dietary fibre, crude protein and carbohydrate were recorded as 6.81, 1.20, 1.62, 1.24, 9.54, 6.45 and 82.68 per cent, respectively. Energy value and water activity were found to be 370.82 Kcal/100g and 0.36, respectively. Similarly, total phenols and antioxidant activity were recorded as 2.50 mg GAE/100g and 6.74 per cent, respectively. Whereas, waffle cone prepared from apple pomace with whole wheat flour had moisture content, ash content, crude fat, crude fibre, total dietary fibre crude protein and carbohydrate as 7.25, 2.42, 11.54, 7.13, 16.22, 8.75 and 62.91 per cent, respectively. The energy value and water activity were recorded at 406.92 Kcal/100g and 0.40, respectively. Total phenol, antioxidant activity and anthocyanin content were found to be 180.12 mg GAE/100g, 62.13 per cent and 3.81 mg/100g, respectively. Further, the moisture content, ash content, crude fat, crude fibre, dietary fibre, crude protein and carbohydrate were observed as 7.12, 2.31, 10.58, 6.73, 15.97, 7.88 and 65.38 per cent in waffle cone prepared from apple pomace with red rice flour, respectively. Energy value and water activity were recorded as 409.90 Kcal/100g and 0.39, respectively. Whereas, total phenol,

antioxidant activity and anthocyanin content were found to be 225.36 mg GAE/100g, 70.42 per cent and 5.04 mg/100g, respectively.

- ❖ The mineral composition such as phosphorus, potassium, sodium, calcium sulphur, magnesium, iron, copper, zinc and manganese were observed as 983.00, 1425.00, 3400.00, 7950.00, 2484.00, 1375.00, 39.00, 11.40, 20.00 and 6.20 ppm in the market waffle cone. Whereas, 1863.70, 6125.00, 3617.50, 17575.00, 1595.70, 2940.00, 44.70, 10.40, 22.90 and 6.90 ppm in apple pomace waffle cone and 1633.20, 5350.00, 3212.76, 16275.60, 1408.40, 1835.40, 49.30, 9.42, 22.26 and 6.60 ppm in gluten-free apple pomace waffle cone, respectively.
- ❖ Texture profile analysis (TPA) of waffle cones revealed the hardness, brittleness, toughness and crispiness as 1244.73 g, 3.73 mm, 1151.09 g.sec and 15.00, respectively in market waffle cone. Whereas, 921.66 g, 4.53 mm, 1036.82 g.sec and 17.00 in apple pomace waffle cone and 1362.27 g, 4.76 mm, 1089.62 g.sec and 18.00, respectively in gluten-free apple pomace waffle cone, respectively.
- ❖ The colour characteristics of all three waffle cone were recorded as L*, a*, b* and hue angle values 54.43, 3.51, 26.66 and 82.49 in the market waffle cone. Whereas 24.14, 6.49, 37.08 and 80.07 observed in apple pomace waffle cone and 17.15, 7.94, 28.37 and 79.91 were recorded in gluten-free apple pomace waffle cone, respectively. The ΔE and C* (Chroma) value noticed was 10.83 and 32.17 in the apple pomace waffle cone and 13.56 and 13.66, respectively in the gluten-free waffle cone.
- ❖ The effect of storage on quality characteristics of waffle cones (market waffle cone, apple pomace waffle cone and gluten-free apple pomace waffle cone) revealed that moisture content, free fatty acid and water activity increased during a storage period of 21 days at 38°C temperature and 90.00 per cent relative humidity. However, both the samples (ALP-packed and LDPE-packed waffle cone) were acceptable throughout the storage period.
- ❖ The shelf life was predicted by using the Arrhenius plot. Moisture content was used as a quality factor and the shelf life of market waffle cone, apple pomace waffle cone and gluten-free apple pomace waffle cone were predicted as 342, 227 and 229 days in Low-density polyethylene pouches (LDPE) and 404, 260 and 275 in Aluminium laminated pouches (ALP), respectively. With free fatty acid as a quality factor the shelf life of market waffle cone, apple pomace waffle cone and gluten-free apple pomace waffle cone was predicted as 371, 239 and 232 days, in LDPE packaging

material and 405, 270 and 263 in ALP pouches, respectively. Likewise, water activity when used as a quality factor the shelf life of market waffle cone, apple pomace waffle cone, and gluten-free apple pomace waffle cone was predicted as 231, 200 and 205 days, in LDPE packaging material, and 314, 285 and 292 in ALP packaging material, respectively.

- ❖ The responses of ingredients for the development of waffle cone from apple pomace waffle cone pre-mix predicted by using the Design Expert-07 software resulted in hardness (1061.69 g), brittleness (3.45 mm), toughness (1148.37 g.sec), crispiness (18.60), ice cream holding time (31.60 min) and overall acceptability (8.18). The closeness of the predicted values to the actual values of hardness (1060.35 g), brittleness (3.40 mm), toughness (1150.68 g.sec), crispiness (18.00), ice cream holding time (32.00 min) and overall acceptability (8.00) approved validation for the response surface methodology (RSM) model.
- ❖ The responses of ingredients for the development of gluten-free apple pomace waffle cone from its pre-mix were predicted by using the Design Expert-07 software resulting in hardness (1013.56 g), brittleness (3.45 mm), toughness (1077.89 g.sec), crispiness (17.00), ice cream holding time (30.40 min) and overall acceptability (8.15). The closeness of the predicted values to that of actual values of hardness (1012.20 g), brittleness (3.34 mm), toughness (1047.00 g.sec), crispiness (17.00), ice cream holding time (30.00 min) and overall acceptability (8.20) approved validation for the response surface methodology (RSM) model.
- ❖ The sensory quality of the apple pomace waffle cone prepared from apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone from gluten-free apple pomace waffle cone was evaluated by the panellist following the 9-point Hedonic scale which showed the effect of ingredients present in waffle cones on basis of sensory parameters like texture, taste, colour, overall acceptability.
- ❖ The recipe standardized for waffle cone pre-mix through RSM concludes as apple pomace flour (14.00 %), whole wheat flour (5.50 %), powder sugar (7.00 %), butter (7.00 %), milk powder (7.00 %), potato starch (1.50 %), and water (58.00 %) in apple pomace waffle cone pre-mix and apple pomace flour (15.00 %), red rice flour (5.50%), powder sugar (7.00 %), butter (7.00 %), milk powder (7.00 %), potato starch (1.50 %), and water (57.00 %) in gluten-free apple pomace waffle cone pre-mix.

- ❖ The standardized recipe based on RSM having responses (hardness, brittleness, toughness, crispiness, ice cream holding time and overall acceptability) was further utilized for the preparation of apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix.
- ❖ Quality characteristics of waffle cones *i.e.*, weight, thickness, ice cream holding time and baking loss were found to be 10.50 g, 2.60 mm, 35.00 min and 65.00 per cent in waffle cone prepared from market pre-mix. Whereas, 10.18 g, 2.68 mm, 32.00 min and 66.06 per cent in apple pomace waffle cone pre-mix and 10.11 g, 2.57 mm, 30.00 min and 66.30 per cent in gluten-free apple pomace waffle cone pre-mix, respectively.
- ❖ The chemical composition such as moisture content (8.11 %), ash content (1.32 %), crude fat (5.50 %), crude fibre (2.62 %), total dietary fibre (11.32 %), crude protein (6.00 %), carbohydrate content (76.45 %) energy value (390.14 Kcal/100g), water activity (0.45), total phenols (4.03 mg GAE/100g) and antioxidant activity (9.93 %) were recorded in market waffle cone pre-mix. Whereas, in apple pomace waffle cone pre-mix moisture content (8.40 %) ash content (2.28 %), crude fat (7.18 %), crude fibre (7.01 %), total dietary fibre (19.41 %), crude protein (9.15 %), carbohydrate content (65.98 %) energy value (381.90 Kcal/100g), water activity (0.46), total phenols (205.16 mg GAE/100g), antioxidant activity (70.16 %) and anthocyanin content (5.79 mg/100g) were recorded. The moisture content (8.65 %) ash content (2.34 %), crude fat (7.42 %), crude fibre (6.65 %), total dietary fibre (19.11 %), crude protein (8.53 %), carbohydrate content (66.41 %) energy value (384.62 Kcal/100g), water activity (0.47), total phenols (256.37 mg GAE/100g), antioxidant activity (80.42 %) and anthocyanin content (7.26 mg/100g) was recorded in gluten-free apple pomace waffle cone pre-mix.
- ❖ Mineral composition *viz.*, phosphorus, potassium, sodium, calcium sulphur, magnesium, iron, copper, zinc and manganese observed as 977.50, 1525.00, 3260.00, 7325.00, 1489.50, 600.00, 28.40, 9.20, 13.70 and 6.00 ppm in market waffle cone pre-mix. However, 1910.20, 4325.00, 2092.50, 9900.00, 1165.00, 1285.00, 53.00, 9.70, 17.00 and 8.90 ppm recorded in apple pomace waffle cone pre-mix and 2178.00, 4350.00, 2682.50, 11150.00, 1271.00, 1315.00, 78.00, 10.00, 18.80 and 6.14 ppm recorded in gluten-free apple pomace waffle cone pre-mix, respectively.
- ❖ Texture profile analysis (TPA) of market waffle cone prepared from pre-mix was analysed on the basis of hardness, brittleness, toughness and crispiness which were

recorded as 990.50 g, 3.21 mm, 1018.24 g.sec and 12.00, respectively whereas, it was recorded as 1060.35 g, 3.40 mm, 1150.68 g.sec, and 18.00, respectively in apple pomace waffle cone and 1012.20 g, 3.34 mm, 1047.00 g.sec and 17.00, respectively in gluten-free apple pomace waffle cone.

- ❖ Colour characteristics of waffle cone pre-mix were recorded for L*, a*, b* and hue angle values as 74.78, 1.95, 7.32, and 75.08 in market waffle cone pre-mix. Whereas 64.32, 1.68, 25.24 and 86.19 observed in apple pomace waffle cone pre-mix and 61.60, 2.39, 26.78 and 84.88 in gluten-free apple pomace waffle cone pre-mix, respectively. The ΔE and C* (Chroma) value was observed as 17.92 and 20.75 in apple pomace waffle cone pre-mix and 19.40 and 23.45 in gluten-free apple pomace waffle cone pre-mix.
- ❖ The effect of storage on quality characteristics of waffle cones pre-mix (market waffle cone pre-mix, apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix) revealed that moisture content, free fatty acid and water activity increased during the storage period of 21 days at 38°C temperature and 90.00 per cent relative humidity. The study revealed that, both the samples (ALP-packed and LDPE-packed pre-mix) were acceptable throughout the storage period.
- ❖ The shelf life was predicted by using the Arrhenius plot. Moisture content was used as a quality factor and the shelf life of waffle cone pre-mix, apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix were 226, 198 and 191 days in LDPE packaging material and 292, 233 and 237 in ALP packaging material, respectively. Whereas, free fatty acid was used as a quality factor and the shelf life of market waffle cone pre-mix, apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix were 254, 232 and 217 days, in LDPE packaging material, and 287, 258 and 240 in ALP packaging material, respectively. Likewise, water activity was used as a quality factor and the shelf life of market waffle cone pre-mix, apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix were 205, 194 and 188 days, in LDPE packaging material, and 250, 235 and 213 in ALP packaging material, respectively.
- ❖ Microbiological quality was determined by total plate count (TPC) for waffle cones and waffle cone pre-mix. CFU (Colony forming unit) per gram was observed satisfactory and within the permissible limits, during the storage period thus, reflecting good product storage stability.

- ❖ The cost of production for waffle cones was estimated at Rs. 2.60 per cone (apple pomace waffle cone) and Rs. 2.75 per cone (gluten-free apple pomace waffle cone). Likewise, the cost of production of waffle cone pre-mix was Rs. 215.00 per kg (apple pomace waffle cone pre-mix) and Rs. 230.00 per kg (gluten-free apple pomace waffle cone pre-mix), respectively.

CONCLUSION

The present investigation was on “Development and evaluation of apple pomace waffle cone”. Apple pomace is one of the most valuable by-product of apple as it is a good source of various nutritional compounds and provides excellent health benefits. However, it has not been utilized for the development of the product on the commercial scale. So, to exploit its nutritional and functional properties apple pomace-based products such as apple pomace waffle cone, gluten-free apple pomace waffle cone, apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix were developed and the storage stability of developed products was evaluated. Apple pomace flour-based waffle cone and waffle cone pre-mix developed were observed with higher nutritional content than market waffle cone and waffle cone pre-mix. These products (waffle cone and waffle cone pre-mix) were stored at accelerated storage conditions at 38°C temperature and 90.00 per cent relative humidity in low density polyethylene (LDPE) and aluminium laminated pouches (ALP) for 21 days and was acceptable throughout the storage period. Nowadays, consumers are demanding healthy food items which have excellent sensory quality as well as health benefits at the same time. As many people are allergic to gluten, so gluten-free apple pomace waffle cone is a better alternative for people having celiac disease. Apple pomace is a good source of dietary fibre, minerals as well as phytochemicals such as antioxidant activity, polyphenols, anthocyanin and ascorbic acid which can be utilized along with cereals flour to improve their nutritional quality as cereals are generally higher in protein and carbohydrate content and lacks fibre and phytochemicals. Moreover, it will also lead to effective waste utilization and reduce food wastage. Therefore, it can be concluded from the above studies that apple pomace flour can be successfully utilized for the development of products with good sensory as well as health-promoting characteristics for the benefit of the general masses.

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APPENDIX – I

HEDONIC RATING TEST

EVALUATION FOR SENSORY QUALITY OF DEVELOPED PRODUCT

NAME: _____ Date: _____ PRODUCT: _____

Please evaluate the following samples as per the standard scale.

Parameters Treatments	Texture	Taste	Colour	Overall acceptability

9-point hedonic scale

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

Signature of evaluator

APPENDIX - II

ANOVA: Quality characteristics of waffle cone (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Weight (g)	Thickness (mm)	Ice cream holding time (min)	Baking loss (%)
Treatment	2	7.460667	0.007167	31.66667	7326.6
Error	12	0.001167	0.000333	0.625	0.855

ANOVA: Chemical characteristics of waffle cone (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Moisture (%)	Ash (%)	Crude fat (%)	Crude fibre (%)
Treatment	2	0.2555	2.269407	149.6747	54.08835
Error	12	0.0053	0.00554	0.016867	0.00647

ANOVA: Chemical characteristics of waffle cone (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Total dietary fibre (%)	Crude protein (%)	Carbohydrate (%)	Energy value (Kcal/100g)
Treatment	2	71.87673	6.741307	580.2032	2366.365
Error	12	0.062277	0.032763	0.449417	6.640547

ANOVA: Chemical characteristics of waffle cone (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Water activity	Total phenol (mg GAE/100g)	Antioxidant activity (%)	Anthocyanin content (mg/100g)
Treatment	2	0.002167	69382.86	5993.266	34.5255
Error	12	0.0001	9.512633	3.023883	0.000617

ANOVA: Mineral composition of waffle cone (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Phosphorus	Potassium	Sodium	Calcium
Treatment	2	1042936	31746875	205149.6	1.36E+08
Error	12	68.85833	131.6667	153.2027	381.5333

ANOVA: Mineral composition of waffle cone (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Sulphur	Magnesium	Iron	Copper
Treatment	2	1650848	3235335	133.1167	4.900667
Error	12	98.25433	54.66667	0.298333	0.225133

ANOVA: Mineral composition of waffle cone (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)	
		Zinc	Manganese
Treatment	2	11.606	0.616667
Error	12	0.116183	0.00425

ANOVA: Colour characteristics of waffle cone (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)					
		L*	a*	b*	h°	Chroma	ΔE
Treatment	2	1964.128	25.5065	156.1372	10.44114	257.1795	1303.437
Error	12	0.034243	0.0029	0.014567	0.12679	0.000833	0.002483

ANOVA: Texture characteristics of waffle cone (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Hardness (g)	Brittleness (mm)	Toughness (g.sec)	Crispiness
Treatment	2	260264.9	1.471447	16353.39	11.66667
Error	12	54.37751	0.0031	78.81227	0.026667

ANOVA: Sensory evaluation of waffle cone (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Texture	Taste	Colour	Overall acceptability
Treatment	2	0.303333	0.863333	0.156743	0.381986
Error	12	0.016322	0.011789	0.008265	0.002852

ANOVA: Quality characteristics of waffle cone prepared from pre-mix (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Weight (g)	Thickness (mm)	Ice cream holding time (min)	Baking loss (%)
Treatment	2	0.213807	0.016167	31.66667	2.409307
Error	12	0.01778	0.001383	0.191667	0.203557

ANOVA: Chemical characteristics of waffle cone pre-mix (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Moisture (%)	Ash (%)	Crude fat (%)	Crude fibre (%)
Treatment	2	0.365167	1.644027	5.503247	29.68634
Error	12	0.001267	0.001527	0.003903	0.008277

ANOVA: Chemical characteristics of waffle cone pre-mix (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Total dietary fibre (%)	Crude protein (%)	Carbohydrate (%)	Energy value (Kcal/100g)
Treatment	2	105.2101	13.94874	175.4421	88.31289
Error	12	0.00669	0.003173	0.007727	4.585847

ANOVA: Chemical characteristics of waffle cone pre-mix (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Water activity	Total phenol (mg GAE/100g)	Antioxidant activity (%)	Anthocyanin content (mg/100g)
Treatment	2	0.0005	88958.85	7252.505	73.74786
Error	12	8.33E-05	2.360543	0.33282	0.00131

ANOVA: Mineral composition of waffle cone pre-mix (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Phosphorus	Potassium	Sodium	Calcium
Treatment	2	1985705	13184375	1703885	19019792
Error	12	99.875	176.8333	136.1667	379.1667

ANOVA: Mineral composition of waffle cone pre-mix (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Sulphur	Magnesium	Iron	Copper
Treatment	2	136898.8	817791.7	3075.267	0.816667
Error	12	105.75	94.83333	1.675	0.00625

ANOVA: Mineral composition of waffle cone pre-mix (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)	
		Zinc	Manganese
Treatment	2	33.45	21.24824
Error	12	0.06215	2.517807

ANOVA: Colour characteristics of waffle cone pre-mix (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)					
		L*	a*	b*	h°	Chroma	ΔE
Treatment	2	242.1278	0.64008	584.0397	184.2255	583.064	823.1292
Error	12	0.057663	0.00892	0.028497	0.234727	0.002867	0.004167

ANOVA: Texture characteristics of waffle cone prepared from pre-mix (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Hardness (g)	Brittleness (mm)	Toughness (g.sec)	Crispiness
Treatment		6390.279	0.047167	24264.19	51.66667
Error		49.9125	0.002167	55.03955	0.00545

ANOVA: Sensory evaluation of waffle cone prepared from pre-mix (market, apple pomace and gluten-free apple pomace)

Source of variation	Degree of freedom	MSS (Mean sum of squares)			
		Texture	Taste	Colour	Overall acceptability
Treatment		0.303333	1.003333	1.703333	1.003333
Error		0.004656	0.029444	0.0004	0.034722

Anova and regression coefficients of the second order polynomial model for different response variable (apple pomace waffle cone)

Variable	Degree of freedom	F-values					
		Hardness (g)	Brittleness (mm)	Toughness (g. sec)	Crispiness	Ice cream holding time (min)	Overall acceptability
Model	9	20.51	19.57	11.80	49.14	24.78	38.32
A	1	5.99	13.88	1.26	13.28	16.53	14.30
B	1	19.41	1.46	10.19	2.17	24.51	14.74
C	1	126.75	24.46	69.76	218.70	122.36	87.12
AB	1	5.97	2.93	3.36	4.41	2.59	2.21
AC	1	1.83	9.24	1.51	1.10	2.59	6.54
BC	1	4.67	1.10	2.04	4.41	23.33	1.06
A ²	1	1.53	33.36	1.41	82.95	2.02	29.79
B ²	1	12.22	1.15	7.83	50.59	3.44	116.99
C ²	1	5.96	93.26	11.81	102.02	28.55	109.21
Lack of fit		4.73	1.25	4.48	2.40	1.95	2.06
R ²		0.94	0.94	0.91	0.97	0.95	0.97
Adequate precision		0.90	0.89	0.83	0.95	0.91	0.94
CV %		5.72	10.44	7.27	4.99	5.37	2.49

R²- coefficient of determination, CV- coefficient of variation

A- Apple pomace flour (g) at linear level, B- Whole wheat flour at linear level, C- Sugar powder at linear level, AB- Interaction between apple pomace flour (g) and whole wheat flour (g), AC- Interaction between apple pomace flour (g) and sugar powder (g), BC- Interaction between whole wheat flour (g) and sugar powder (g), A²- Apple pomace flour (g) at quadratic level
 B²- Whole wheat flour (g) at quadratic level, C²- Sugar powder(g) at quadratic level

Anova and regression coefficients of the second order polynomial model for different response variable (gluten-free apple pomace waffle cone)

Variable	Degree of freedom	F-values					
		Hardness (g)	Brittleness (mm)	Toughness (g. sec)	Crispiness	Ice cream holding time (min)	Overall acceptability
Model	9	49.82	18.66	41.87	72.42	22.20	31.16
A	1	5.12	15.73	6.70	5.30	15.30	21.00
B	1	11.11	4.39	12.04	8.75	28.65	4.01
C	1	170.45	17.49	198.82	371.90	97.71	52.08
AB	1	10.91	3.02	1.67	1.11	1.51	1.27
AC	1	3.78	15.77	1.06	4.44	2.96	3.27
BC	1	1.06	1.54	2.47	4.44	21.83	2.09
A²	1	49.26	28.34	16.47	108.59	3.63	17.55
B²	1	173.74	3.48	83.70	88.70	5.62	123.04
C²	1	64.03	79.82	78.61	108.46	2674	86.43
Lack of fit		3.88	3.49	1.63	2.38	1.21	1.80
R²		0.97	0.94	0.97	0.98	0.95	0.96
Adequate precision		0.95	0.89	0.95	0.97	0.90	0.93
CV %		5.61	11.25	4.08	4.90	5.35	2.43

R²- coefficient of determination, CV- coefficient of variation

A- Apple pomace flour (g) at linear level, B- Red rice flour at linear level, C- Sugar powder at linear level, AB- Interaction between apple pomace flour (g) and red rice flour (g), AC- Interaction between apple pomace flour (g) and sugar powder (g), BC- Interaction between red rice flour (g) and sugar powder (g), A²- Apple pomace flour (g) at quadratic level

B²- Red rice flour (g) at quadratic level, C²- Sugar powder(g) at quadratic level

ANOVA: and regression coefficients of the second order polynomial model for different response variable (apple pomace waffle cone pre-mix)

Variable	Degree of freedom	F-values					
		Hardness (g)	Brittleness (mm)	Toughness (g. sec)	Crispiness	Ice cream holding time (min)	Overall acceptability
Model	5	28.86	68.58	26.90	23.91	46.53	35.74
A	1	38.13	34.23	27.35	11.34	33.26	29.84
B	1	66.68	258.67	61.88	63.32	134.01	38.59
AB	1	9.06	3.86	10.20	4.30	6.09	9.75
A²	1	13.94	40.09	15.02	12.40	33.41	42.76
B²	1	20.29	10.59	24.41	32.70	33.52	70.18
Lack of fit		6.35	2.06	4.58	2.91	2.28	4.02
R²		0.95	0.98	0.95	0.94	0.97	0.96
Adequate precision		0.92	0.96	0.91	0.90	0.94	0.93
CV %		6.21	4.28	6.90	7.54	5.11	4.14

R²- coefficient of determination, CV- coefficient of variation

A- Milk powder (g) at linear level, B- Potato starch at linear level, AB- Interaction between milk powder (g) and potato starch (g), A²- Milk powder (g) at quadratic level, B²- Potato starch (g) at quadratic level

ANOVA: and regression coefficients of the second order polynomial model for different response variable (gluten-free apple pomace waffle cone pre-mix)

Variable	Degree of freedom	F-values					
		Hardness (g)	Brittleness (mm)	Toughness (g. sec)	Crispiness	Ice cream holding time (min)	Overall acceptability
Model	5	103.76	22.43	35.85	35.95	50.54	32.68
A	1	107.81	12.67	51.43	15.92	22.13	19.64
B	1	281.77	82.51	98.02	98.61	163.30	20.07
AB	1	32.87	3.33	2.89	16.63	12.62	14.27
A²	1	43.41	10.41	6.68	7.19	25.54	35.55
B²	1	64.99	4.82	22.98	45.24	35.99	86.30
Lack of fit		1.58	2.83	1.09	3.16	2.22	3.71
R²		0.98	0.94	0.96	0.96	0.97	0.95
Adequate precision		0.97	0.89	0.93	0.93	0.95	0.92
CV %		3.09	8.15	4.37	6.61	5.26	4.57

R²- coefficient of determination, CV- coefficient of variation

A- Milk powder (g) at linear level, B- Potato starch at linear level,

AB- Interaction between milk powder (g) and potato starch (g), A²- Milk powder (g) at quadratic level, B²- Potato starch (g) at quadratic level

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ABSTRACT

The present study entitled, “Development and evaluation of apple pomace waffle cone” was conducted in the Department of Food Science and Technology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. Apple (*Malus x domestica* Borkh) is a major temperate fruit crop in India with a production of 2437.37 MT from an area of 308.00 thousand hectares. Out of total production of apple, 70.0 per cent is freshly consumed and the remaining 30.0 per cent is used for the extraction of juice. The biomass left after the extraction of juice known as pomace goes waste. Being rich in phenolic compounds, dietary fibre and minerals, apple pomace was utilized for the development of apple pomace waffle cone in the present study. The apple pomace was collected from the commercial canning unit (Dept. of FST, Dr. YSP, UHF) followed by drying, grinding to flour (30 mesh sieve) and then further evaluated for physico-chemical and functional properties. The optimization of the recipe for waffle cone development was done by response surface methodology based on the desirability of responses *viz.* hardness, brittleness, toughness, crispness, ice cream holding time and overall acceptability (9-point Hedonic scale). The optimized recipe for apple pomace waffle cone includes apple pomace flour (13.0 %), whole wheat flour (5.0 %), sugar powder (7.0 %), butter (7.0 %), ripe banana paste (10.0 %) and milk (58.0 %) and similarly, for gluten-free apple pomace waffle cone includes apple pomace flour (14.0 %), red rice flour (5.0 %), sugar powder (7.0 %), butter (7.0 %), ripe banana paste (10.0 %) and milk (57.0 %) with the batter viscosity kept in the range of 4500 to 5000 mPas followed by baked for two minutes at 150°C temperature. The standardized products *i.e.*, apple pomace waffle cone and gluten-free apple pomace waffle cone was observed significantly higher in minerals, crude fat, crude fibre, total dietary fibre, crude protein, total phenol, antioxidant activity and anthocyanin content as compared to market available waffle cone. The above selected recipes were further utilized for the development of waffle cone pre-mixes with standardized on the basis of response surface methodology based on the similar responses used during optimization of apple pomace waffle cone. The nutritional profile of optimized apple pomace waffle cone pre-mix and gluten-free apple pomace waffle cone pre-mix were found higher than the market waffle cone pre-mix. The developed products were packed in LDPE and ALP pouches and the shelf-life studies was conducted using accelerated storage conditions *i.e.*, 38°C temperature and 90.0 per cent relative humidity for 21 days. Minimum changes were recorded during storage as acceptable for consumption and the predicted self-life of products based on Arrhenius graph plot were observed more than 6 months in both the packaging material. Hence, it is concluded that the apple pomace can be exploited for sustainable production of high-quality food with enhanced nutritional, functional as well as sensory properties which will also help to reduce the negative impact to the environment by waste generation.

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