A DISSERTATION ON

Innovative Lyophilized Yogurt Energy Bar Enriched with Barnyard Millet: An Approach to Nutrient-Rich Snacking

SUBMITTED TO THE
DEPARTMENT OF BIOENGINEERING
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DEGREE OF MASTER OF TECHNOLOGY
IN FOOD TECHNOLOGY

BY

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UNDER THE SUPERVISION OF

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DECLARATION FORM

I, **Adiba Fatima**, a student of **B.Tech. - M. Tech Dual Degree Food Technology** (V Year/ X Semester), Integral University have completed my six months dissertation work entitled **"Innovative Lyophilized Yogurt Energy Bar Enriched with Barnyard Millet: An Approach to Nutrient-Rich Snacking"** successfully from **Integral University, Lucknow** under the able guidance of **Dr. Rahul Singh, Assistant Professor & Dr. Aisha Kamal, Associate Professor, Integral University, Lucknow.**

I, hereby, affirm that the work has been done by me in all aspects. I have sincerely prepared this project report and the results reported in this study are genuine and authentic.

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Certificate that **Ms Adiba Fatima** (Enrollment Number 1800102061) has carried out the research work presented in this thesis entitled **"Innovative Lyophilized Yogurt Energy Bar Enriched with Barnyard Millet: An Approach to Nutrient-Rich Snacking"** for the award of **B.Tech. - M.Tech. Dual Degree Food Technology** from Integral University, Lucknow under our supervision. The thesis embodies results of original work and studies carried out by the student himself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution. The dissertation was a compulsory part of her **B.Tech. - M.Tech. Dual Degree Food Technology.**

I wish her good luck and bright future.

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TO WHOM IT MAY CONCERN

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Place: Lucknow Adiba Fatima

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ACRONYMS

S.No.	Acronyms	Full forms
1	TPC	Total Phenolic Content
2	TA	Titratable Acidity
3	TSS	Total Soluble Solids
4	FT-IR	Fourier Transform Infrared Spectroscopic
5	DPPH	2,2-diphenyl-1-picryl-hydrazyl-hydrate
6	FAO	Food and Agriculture Organization
7	CIE	International Commission on Illumination
8	RTE	Ready to eat
9	RDA	Recommended Dietary Allowance

ABSTRACT

Yogurt Energy Bar has gained popularity worldwide as a convenient snack choice, catering to the flavorful demand of the consumer and leading to a nutritious and active lifestyle. This research provides an overview embracing the key characteristics of the Yogurt Energy Bar enriched with Barnyard Millet and other raw materials and also analyzes various parameters that affect the shelf-life and stability of this bar. It is a hybrid product that combines the nutritional points of Yogurt and Barnyard millet along with the bar's portability and ease of consumption. The Yogurt Energy Bar was full of natural goodness and was free of any preservatives, artificial sweeteners, and no additives. Six samples are prepared for further analysis which includes: Physico-chemical analysis, phytochemical analysis, sensory analysis, color analysis, and cost analysis. The physico-chemical analysis showed the determination of Moisture content (2.33±0.05 to 4.01±0.05), Ash content (4.02±0.01 to 1.97±0.04), fat content (2.03±0.09 to 4.30±0.13), protein content (7.48±0.52 to 12.3±0.36), TSS (4.0±0.14 to 7.0±0.17), titratable acidity (0.10±0.03 to 0.20±0.07), pH (4.02±0.01 to 1.97±0.04), whereas the phytochemical analysis: Total Phenolic Content (47.00±7.5 to 64.57±9.33) and Anti-oxidant activity (84.18±2.20 to 87.76±2.49) showed the presence of bioactive compound. Color analysis of the Yogurt Energy Bar samples was done using CIE Lab showing L* value (58.32±1.46 to 77.40±1.16 and 21.26±1.18 to 34.49±0.86) a* value (3.25±0.17 to 4.86±0.22 and 2.63±0.33 to 9.24±0.58) b* (6.50±0.33 to 18.52±0.48 and 7.23±0.58 to 17.93±0.30) and cost analysis was done by comparing the Yogurt Energy Bar with the commercially available energy bars in the market Furthermore, the FT-IR analysis showed the presence of O-H, C=O, C-H, Protein and Peptide. The sensory analysis was done using 9-scale Hedonic Sensory Evaluation method for the bar. these parameters namely included color (6.1±0.35 to 8.49±0.33) Texture (6.59±0.51 to 8.34±0.22) Taste (6.9±0.90 to 8.53±0.40) Aroma (7.43±0.40 to 8.51±0.46) Overall Acceptability (6.92±0.70 to 8.46±0.08).

Keywords: Yogurt Energy Bar, Physico-chemical, Phytochemical, Sensory analysis

CHAPTER 1

INTRODUCTION

India is a country that is rich in biodiversity along with vibrant agricultural practices. Indeed, India is a country that is beautifully blessed with a diverse array of fruit crops and seeds. The population of India cannot overlook the role of fruit crops and seeds in an Indian diet, they are identified as an integral part of Indian cuisine. Due to varied climatic conditions and agricultural practices, India grows a diversified number of crops.

An energy bar is a type of bar that contains nutrients for humans. These bars are often ready-to-eat snack bars, which are portable or compact food products that may be consumed anywhere and at any time. These bars are typically made up of different nutrient composition with a combination of ingredients such as a variety of nuts, dried fruits, seeds, yogurt, and sweeteners. These are all then compressed for the final shape of a bar. Consumers' demand and healthy food desire are growing rapidly daily, so researchers are keenly interested and pushing for new product development which is healthy, ready-to-eat, and palatable at the same time **(Mridula et al, 2013).** Energy bar is a good source of protein, calcium, minerals, and vitamins which mainly provides various health benefits and is liked by a huge population around the world. This energy bar consists of a variety of ingredients which has nutritional benefits. Other materials used for making this energy bar include yogurt, vanilla essence, oats, millet, honey, dates, almonds, thickening agent – agar & gelatin, and skim milk powder.

Millets are the superfood of the year 2023 that hold the key to resolving growing gut-related ailments and metabolic problems. Superfoods are foods that promise to provide health advantages due to their high nutritional density. Pearl millet (bajra), proso millet (barri), sorghum (jawar), finger millet (ragi), barley (jo), oats (jaee), barnyard millet(samak), and foxtail millet (kangani) are examples of common millets **(Jena et al, 2023)**.

Millets are food grains with excellent nutritional value and health advantages that may be grown with little water and input. They are planted across the nation in varied agroecological locations with less pest and disease infestation and hence may be grown readily as organic crops. As a result of the Government of India's efforts, the United Nations has designated 2023 as the International Year of Millets (IYOM).

Barnyard Millet (*Echinochloa frumentacea*), which in India is also known as "Sanwa" or "Samak" has been cultivated for centuries, and was an underutilized grain that held an immense amount of nutritional diversity, and food security; and also promoted sustainability **(Maithani et al, 2023)**. Diets with various nutrient aspects can help maintain a good lifestyle, improve well-being, immunity booster, and prevent various diseases. Barnyard millet is considered to be used in a portion of functional food as a nutraceutical to prevent or treat various diseases, curb appetite, and maintain a lifestyle owing to various health benefits. It is therefore acknowledged as "Nutricereal". It has high-quality digestible proteins, is fiber-rich, has various minerals (especially Calcium & Iron), has the least calories, and is gluten-free **(Bhinda et al, 2023).**

Yogurt is a quality food that is a staple in Indian cuisine which was introduced centuries ago. It is used and consumed in a variety of ways in India. Research and tradition claim the nature of yogurt for taste, texture, and health properties associated with the consumption of yogurt. Yogurt has a variety of benefits. It claims to be a good source of protein, calcium, and probiotics. These probiotics are live bacterias that improve gut health, and the immune system. Yogurt being utilized in a product development area has gained a lot of interest from researchers. This has grabbed people's attention worldwide **(Chandan et al, 2017).**

Oats (Avena sativa L.) have garnered a lot of attention due to its high quantity of dietary fibers, phytochemicals, and nutritional value. Oats are thought to provide a number of health advantages, including hypocholesterolaemic and anticancer qualities. Oats have just been approved for use in the diets of celiac sufferers. Because of their excellent nutritional content, oat-based food products such as bread, biscuits, cookies, probiotic drinks, morning cereals, flakes, and baby food are gaining popularity. Oat research and development may aid in the treatment of different ailments known to humans **(Rasane et al, 2015).**

Dates can be eaten fresh or dried. Aside from being a good source of carbohydrates, dietary fibres, several vital vitamins and minerals, and a variety of phytochemicals such as phenolics, carotenoids, anthocyanins, and flavonoids. Even date pits are high in fiber, minerals, lipids, and protein. The phytochemicals contribute to the nutritional and sensorial aspects of dates. Dates are used in energy bar as a key ingredient to provide nutrients and a wide range of benefits, they also inhibit a chewy texture which makes it more palatable, and is sweet in taste

so it acts as a sweetener for the bar as a healthy substitute for white sugar. it is high energy providing food (314 kcal per 100g of flesh). Selenium, copper, magnesium, and potassium are very common along with other minerals in dates along with key vitamins B complex and C. It is rich in dietary fiber, and a good source of anti-oxidants (mainly carotenoids and phenolics). Dates being a rich source of fiber prevents constipation and aid in controlling blood sugar levels **(Elliott et al, 2018).**

Honey has been utilized for centuries owing to its proven nutritional and medicinal properties. Honey has been consumed in a variety of ways, including as a type of sweetener and flavoring ingredient. Honey is produced across the world. Honey's most significant nutrient is carbohydrates, which come in various forms of monosaccharides, fructose, and glucose. Honey acts as an antioxidant, anti-inflammatory, and anti-bacterial agent, and it improves the adhesion of skin grafts and the wound healing process. Honey's function in the scientific literature has been recognized, and there is compelling evidence in favor of its antioxidant and antibacterial effects, cough prevention, fertility, and wound healing properties **(Meo et al, 2017).** Honey is a great natural sweetener and a good nutritional source in energy bars. It is a good source of carbohydrates which provides instant energy in our daily life and physical activity. Honey contains anti-oxidants, anti-inflammatory, and boosts the immune system. Although it has these nutritional properties it should be consumed in moderate quantity as it is high in sugar.

Other ingredients like skim milk powder, china grass (vanilla), veg. gelatin, and vanilla essence were used in the making of the bar. These not only provided palatability but also a better shape of a bar. these made the energy bar healthier, nutrition-rich, and a diet that fulfills protein, carbohydrates, vitamins, minerals, fat, and fiber needs. These ingredients help in enhancing taste and give a good mouthfeel. Thus, the aim of this study was to develop a Yogurt Energy Bar enriched with Barnyard Millet and raw materials without adding any artificial sweetener or preservative and is gluten-free.

The main objective of this study was:

1. To prepare a fortified yogurt energy bar enriched with barnyard millet.
2. To study various physicochemical parameters of the yogurt energy bar.
3. To study the shelf-life of the yogurt energy bar.

CHAPTER 2

REVIEW OF LITERATURE

In this chapter, a review of the work related to the topic "**Innovative Lyophilized Yogurt Energy Bar Enriched with Barnyard Millet: An approach to Nutrient-Rich Snacking**" has been discussed in detail. The knowledge of this study of new product development would help to understand the researches to be performed. The review of research was carried out by various researchers related to yogurt energy providing bites, its functionality, health benefits, and processes involved. The purpose of this research was to prepare a yogurt energy bar; and study its shelf life, nutritional quality, and its physicochemical parameters.

2.1 An Overview of Energy Bar

Energy Bars have become an extremely popular staple for athletes, fitness freaks, and individuals in the working environment; it is a convenient, compact, easy and ready-to-eat, and nutritious option available in the market **(Dharshini et al, 2023).** These nutria-dense bars are in compact form providing instant energy and also curbing the appetite. These bars have a fascinating history that spans various decades. The initial appearance of these energy bars was for space missions and astronauts; they constituted an entire meal of calories and energy. The ingredients of these energy bars specialized in nutritional benefits and were health pros which made the bar achieve its motto to provide energy and to be called an "Energy Bar". High-protein bars primarily provide customers potentially good health advantages since, along with the basic diet, they are minimal in calories, allowing you to effectively control your weight through health and exercise programmes. According to domestic specialists' study, the key factors influencing the choice of energy bars made from natural raw ingredients, including in hotel and restaurant facilities. Small briquettes of compacted grain flakes, nuts, and dried fruits make up energy bars. Nutritionists advocate eating these treats as a snack between meals or as a substitute for sweets and chocolate. Previously, such bars could only be bought at sports nutrition stores, but they are now increasingly available in regular supermarkets and pharmacies **(Serhiienko et al, 2023).**

The fact that energy bars have a lengthy shelf life and handy packaging allows for snacking at any time is a plus. However, keep in mind that the maximum daily consumption of the

beneficial delicacy is 1-2 pieces. Nuts, dried fruits, and flax seeds were chosen as raw materials for the production of high-energy bars. The presence of almonds and chocolate bars Dried fruits aid in the normalization of nervous system function, the storage of energy in cells which helps preserve immunity and cardiovascular health, and aid in the restoration of strength. The compactness, lightness, and convenience of energy benefits is one of their key advantages. Energy bars are quite popular. They are as tasty as a traditional chocolate bar, thus a growing number of people are opting for them.

Nonetheless, they are almost devoid of water, which should be recalled in order to avoid dehydration, particularly during sports exercise **(Serhiienko et al, 2023).**

2.2 Types of Energy Bar

There are a variety of Energy Bars available in the market, each catering to different nutritional needs and dietary preferences. These bars are designed for the preferable nutritional task which has become a basic need for us as a human in our day-to-day life. The design is being made in consideration of the normal population, diabetic population, astronauts, children, women, gymnastics, and dieticians; and are basically categorized into few general categories which are; Nutritional/ intrinsic health value bars, cereal/snack bars, granola bars, yogurt bars, rice snack bars. The marketing motive of these bars are to focus on two factors: Health Factor & Convenience Factor **(Fahimeh Rajabi et al, 2017).** Nutritional bars are classed on the basis of compactness, convenience and availability. Protein Bars are specifically designed on the basis to provide high amount of protein, which makes it suitable for the consumer for muscle gain, weight loss and other purpose. Whereas, there are a few Meal replacement Bars that are formulated to serve as a replacement of an entire meal. This work is still undre progress and development and the aim is to provide a complete balanced meal energy through a bar. these bars typically offer a higher calorie content. Nutri-bars offers nutritious snacks for sportsmen that aid in the development of stamina and the maintenance of a healthy weight while also delivering an appropriate daily intake of all nutrients. Athletes, teenagers, and school-aged children are among the key users of these items. Supplement bars, power bars, and granola bars are all names for energy bars. They are said to be a healthy source of energy that is high in protein and includes essential minerals **(Safvi et al, 2023).** Due to the wellness-healthy image, Energy Bars have faced massive growth in market as consumers are being more

concerned and attracted towards it, and seeing this it can be presumed that in future it will have an even bigger market. This is also motivating the researchers to come up with new great innovative ideas. The nutritional demand of bars is being classified in a bigger variety and the availability is vast. To summarize, nutrition bar can be marketed as per its various consumption **(Ibrahim et al, 2013).**

2.3 Energy Bar for Astronauts

Energy bars are very specifically designed for the consumption of astronauts. In the 1960s, the first energy bar was marketed as "Space Food Sticks" **(Nudi et al, 2014).** NASA, the US Air Force, and the Pillsbury Company in collaboration created this. This design meets a unique way of formation for fulfilling the nutritional requirement and space travel challenges. Energy bars play a very crucial role in the demanding space nature where it has to provide the nutritional needs of the astronauts at their convenience, longer shelf life, balanced composition, essential macro-nutrients, and instant energy **(Serhiienko et al, 2023).** These bars are calorically dense which provides a significant compact nutrition through which the astronauts receive sufficient energy for their physical and mental performance in the space. Packaging and portability and shelf-life is the crucial part of the development of these energy bars are it has to have a longer shelf-life and sustainability. Various extensive research and development are performed to ensure the stability along with other parameters of the bars. Along with that, these bars are also to be needful according to the health monitoring and customization required for the astronauts in space **(Grover et al, 2022).**

2.4 Energy Bars for General Population

Energy Bar for the general population is also known as consumer energy bars. These bars are designed to work as a nutritional snack, meal replacement, and convenient snack for our everyday life. This leads to an active lifestyle. These bars aim for a well-balanced combination of macronutrients and essential nutrients. Whereas, wholesomeness is the main motive of these bars that can provide sustained energy. To meet the nutritional need they are designed in a variety of ways along with different flavors, textures, and a versatile combination of caters. The ingredients are energy sources. The design is made in such a way that it is convenient to carry and serves as a quick snack. **Table 2.1 (Yadav & Bhatnagar, 2016)** shows consumer awareness, understanding, and consumption habits about RTE cereal bars.

TABLE 2.1 Knowledge and consumption practices of RTE Cereal Bars

S.No	Response of consumers		Frequency		Total	Chi-square	P value
	Gender		Female (n=50)	Male (n=50)			
1	Awareness about nutri bar/ cereal bar	Yes	39	37	76	00.21	0.64^{NS}
		No	11	13	24		
2	Source of information about cereal bar	1) Advertisement	19	19	38	0.00	1.00^{NS}
		2) Friends/ relatives	27	29	56	0.16	0.68^{NS}
		3) Dietitian/ Health consellors	0	0	0	0.00	0.00
		4) Grocery stores	4	0	4	4.16	0.04*
3	Types of cereal bars available in the market	Yes	25	19	44	1.46	0.22^{NS}
		No	25	31	56		
	If yes, name the types of cereal bar	1)Energy bar	18	19	37	0.04	0.83^{NS}
		2)Protein bar	22	12	34	4.45	0.03*
		3)Diet bar	10	5	15	1.96	0.16^{NS}
4	Ever consumed cereal bar	Yes	26	21	47	1.00	0.31^{NS}
		No	24	29	53		
	If yes, specify the name of cereal bar	1)Snickers	11	14	25	0.48	0.48
		2)Horlicks Nutri bar	5	7	12	0.37	0.53^{NS}
		3)Protein bar	10	0	10	11.11	0.001*
5	Frequency of cereal bar consumption	1)Never	24	29	53		
		2)Yearly	12	10	22		
		3)Monthly	14	6	20	8.85	0.06^{NS}
		4)Weekly	0	5	5		
		5)Daily	0	0	0		
6	Reason for consuming cereal bar	1)Health benefits	23	29	52		
		2)For taste/flavor	27	21	48	4.29	0.23^{NS}
		3)Suggested by health counselor	0	0	0		
7	Willing to purchase developed RTE cereal bars if commercially available	Yes	47	45	92	0.54	0.46^{NS}
		No	3	5	8		

NS- non significant, *- significant

It was discovered that 76% of them were aware of nutri bar/ cereal bar and 24% were not; also, female customers were more knowledgeable than male consumers. There was no statistically significant difference in nutri bar/cereal bar awareness (p0.01). **McNeal (1982)** supports this claim. Friends/relatives were the most common source of knowledge on cereal bars (56%), followed by commercials (38%), and grocery shops (4%). A statistically significant difference was found between grocery shops (source of information) and male and female consumers. The main explanation might be that ladies are more likely than guys to try new things when purchasing a product.

The results of **Table 2.1** demonstrated the frequency of cereal bar intake among consumers, and it was discovered that there was a variety of consuming practices (never: 53%, yearly: 22%, monthly: 20%, weekly: 5%). According to the results from polls, 92 percent of customers would buy RTE cereal bars if they were made commercially available, while 8 percent would not. Changes in lifestyle were cited as the primary reason for opting for RTE meals, while the expanding younger population might also be cited **(Prasad and Aryasri, 2018).**

2.5 YOGURT ENERGY BAR

Yogurt Energy Bars are a specific type of bar that constitutes yogurt as a nutritive aspect as a key ingredient. This bar promotes its nutritional benefits through the yogurt along with convenience and portability. Yogurt provides a creamy texture and tangy flavor. It is also a good source of protein, carbohydrates, vitamins, minerals, calcium, and probiotics. It has potential health benefits such as a healthy gut microbiome, muscle recovery, good calorie count, better bone health. Yogurt gives a chewy texture to the energy bar and gives a better mouth feel along with its other ingredients **(Fisberg et al, 2015).** Although yogurt is a highly perishable product and has a shorter shelf-life but this manufacturing employs some processing techniques like Freeze-drying or encapsulation, to preserve the yogurt and maintain its overall quality and stability **(Carvalho et al, 2017).** Yogurt is rich in Probiotics which are beneficial bacteria that support gut health. Furthermore, the addition of probiotics to yogurt, also known as bio-yogurt, as well as the efficiency of yogurt as a probiotic carrier food **(Lourens et al, 2001).**

2.5.1 Formulation of Yogurt Energy Bar

When creating a nutritious bar, the researcher has numerous challenges: what is the type of bar that has to be made, ingredient selection, processing technique selection, need in the market, positive and negative aspects, health advantages, convenience, end product satisfaction, etc. As a result, the producer formulates the product and ingredients in such a way that has a better combination, palatability, healthy, compact, and portable. It is important to consider consumers' dietary preferences, and any potential allergies or restrictions when formulating these bars. The very first step involves defining the target audience and their nutritional need. Secondly, set certain ratios of macro-nutrients and select the base ingredients that will provide structure and binding. Choose healthy fats instead. The bar then goes under the processing

conditions and further is to be analyzed with various tests and tastes. Despite the fact that several formulations have been created to date, the researcher still undergoes new product development. Such products have scope if the consumer's need is properly targeted. These products must have maximized sensory aspects (flavor, texture, appearance, aroma, color) & functional properties. Along with the selection of ingredients, the selection of processing technique is also an important aspect for minimal nutritional losses and retention of quality. Furthermore, no difference is made as to how much nutrients are incorporated as it is all about the palatability of the consumer or both **(Ibrahim et al, 2013).**

2.5.2 Functions of Yogurt Energy Bar

Yogurt energy bars have various functions that provide numerous health benefits to consumers. The performance of this bar is defined by the ingredient selection as well as its formulation. As the yogurt energy bar is rich in protein, it is a high-protein consumption and aids in muscle recovery and weight loss. Similarly, these bars provide probiotics which benefit in improvising a healthy gut microbiome, contributing to digestion, and nutrient consumption. The combination of the nutrients in this bar helps in promoting satiety and sustained energy. They also help in maintaining blood sugar levels, providing a more stable source of energy. Along with this they also offer a pleasant taste of yogurt which is liked globally and serves as a convenient & portion-controlled bar option aiming for weight management. This also improves the eating habit. And can be consumed in all categories of an energy bar.

2.5.3 Lyophilization Technique Incorporated in the Formulation of Yogurt Energy Bar

The global market for freeze-dried yogurt snacks/bites is currently fragmented (Kulaitiene, 2021). Freeze drying is an effective way to increase the shelf life of yogurt. This process involves drying the product by sublimation at lower temperatures and pressure, preserving its nutritional, microbiological, and sensory properties, and resulting in a dry product that rehydrates quickly (Santos, 2018). Retention of the nutritional quality of the raw materials is the main motive for the selection of the Freeze-Drying technique as it minimizes the degradation of vitamins, minerals, proteins, and other losses which are very common in other drying methods. This technique involves the removal of moisture from the bars for extending its shelf-life and reducing the risk of spoilage. Lyophilization reduces the weight of the bars which also makes it easy and compact to handle and consume. It creates a shelf-stable product

with on-the-go consumption. The raw materials are first collected then prepared as a bar and later it goes under a deep-freezing condition prior to freeze drying. Deep freezing at -35 degrees Celsius, then lyophilized using a Freeze-Dryer. For 48 hours, the samples were lyophilized (Kulaitiene, 2021). The frozen bar undergoes sublimation where the frozen water present inside the bar directly forms to be gas from solid without passing the liquid phase. This process of removal of moisture also preserves the nutritional stability of the bar and its sensory attributes. As soon as lyophilization is completed the bars are typically packed in airtight packaging and moisture-resistant packaging; this packaging also helps in maintaining the longer shelf-life of the product.

2.5.4 Constituents of Yogurt Energy Bar

Generally, an energy bar is made up of some key constituents that provide various nutritive benefits and energy whereas at the same time, the ratio of these specific energy bars can vary. These bars are a source of protein, carbohydrates, fats, vitamins, and minerals. Furthermore, it also constitutes some ingredients like thickening agents, jellying agents, and softening agents. This energy bar contains yogurt, almond, barnyard millet, dates, oats, honey, thickening agent, skim milk powder, and vanilla essence and are further mixed together. It is important to label the product specifically for certain allergies or restrictions to choose this bar wisely.

2.5.4.1 Protein Source

Energy bars may contain protein as a dairy source like milk, protein, casein, or whey protein, or even as a combination of these. The amount of protein can be dependent on the type of energy bar; for example, there are some energy bars in the market that are named as Protein Bars because they provide a higher protein composition. There is a large variety of high-protein bars in the marketplace, and they generally contain protein components. Per 100 g of product, there is 20-50 g of high-quality protein **(Jovanov et al, 2021).**

2.5.4.2 Carbohydrate Source

At least one carbohydrate source is added to the energy bar. this carbohydrate source in an energy bar is an ingredient combination that is purposely added such as oats, dried fruits,

sweeteners like honey, or any other syrup. They are added purposely as they work as a quick source of instant energy for the consumer because of their carbohydrate content. Products with cereal flour, gelatinized starch, or modified dietary starch are commonly used as carbohydrate sources in an energy bar, wholegrain flour, lentils, dried fruit flour, oats, etc are also added as starch sources in the bar. regardless of the source, the functionality of these ingredients as a source is also to provide texture, thickening, crispiness, compactness, etc. these energy bars have a very limited portion of starch which is chewy, dense, and hard. The amount of starch can range from less than 1% to more than 90% by weight **(Fahime Rajabi et al, 2017).**

2.5.4.3 Fat Source

Fat source in an energy bar can be very depending on the brand or recipe of the bar. Over the next 40 years, the prevalence of obesity and diabetes grew severalfold, despite a 25% drop in the quantity of fat in the US diet. Recognising emerging evidence that the consumption of processed carbohydrates, rather than total fat, has played a key role in these epidemics, the USDA Dietary Guidelines for Americans 2015 basically dropped the maximum limit on dietary fat intake **(Ludwig et al, 2016).** The very common sources of fat like nuts, seeds, oil, or nut butter are added to the energy bar. These ingredients are added to the energy bar as a source of healthy fat to contribute to an overall ingredient profile. With this, it is also important to check the label of ingredients for any further allergies, or restrictions and also to know the source of fat.

2.5.4.4 Dietary Fiber Source

Dietary fiber is the key source if any type of energy bars. They are beneficial in any form. Dietary fiber can up from various ingredients. Some common sources are oats, whole grains, seeds, nuts, dates, figs, and some added fiber sources like chicory root, chia seed, flax seed, psyllium husk or inulin, and many others. These ingredients contribute a lot as a fiber content source to provide energy and also have various health benefits like weight loss, gut health, obesity, CVD, Cancer, digestive system, immune booster, and maintaining blood sugar level **(Krasina et al, 2021).** Dietary fiber provides metabolic advantages as well and can be used in conjunction with protein supplements in metabolic illness nutrition treatment. Dietary fiber seems a complex carbohydrate that is difficult to digest and absorb in the small intestine. Its

physicochemical characteristic can induce satiety by increasing chewing duration and intestinal luminal viscosity **(Ahn et al, 2019).**

2.6 Quality variations occurring during the storage of the bar

The main changes that an energy bar goes through during the time of storage are

- Flavor change
- Color change
- Texture change
- Nutrition loss
- Rancidity

Sensory analysis is conducted to evaluate and check the quality of a new product which is kept under storage for its shelf-life study. Physicochemical changes during storage can have a substantial influence on food product shelf life. The physicochemical parameters of the items were evaluated during the storage period to determine the shelf-life of energy bars. Moisture content, pH, titratable acidity, TSS, and water activity (aw) were discovered to fluctuate significantly during storage. Over a 90-day period, all sensory metrics, including flavor, color and appearance, body and texture, and overall acceptability, declined dramatically, chewiness reduced, and sensory parameters worsened **(Jetavat et al, 2020).**

2.6.1 Moisture Content

Yogurt is a highly perishable product; therefore, the moisture content of yogurt is higher and is more probe for an easy spoilage if not kept refrigerated or freeze-dried properly. Water is a solvent having hydrolytic reactions which is used as a medium for chemical reactions. Water in any food is present in two forms: free form or bound form. The removal of water from the food is the process of moisture removal which aims for a longer shelf-life of the energy bar. the main aim of the energy bar production is to have a moisture content below 5% which is to prevent it from microbial spoilage and maintain a dry stable product. This can be achieved through many ways like packaging or techniques like freeze-drying **(Kulaitiene et al, 2021)**

2.6.2 Sensory Aspects

Sensory aspects are the parameters that evaluate the overall consumer acceptance of the energy bar in the market. Aside from nutritional benefits, taste and aroma are important factors for customers when selecting meals.

The sensory evaluation session was conducted using a 9-point hedonic scale (a higher score implies greater quality qualities (1, detest very much, and 9, like very much) (Mamat et al., 2018). The energy bars' color, scent, look, crispiness, and taste were all evaluated. All of the qualities were rated independently by panelists based on their similarities **(Zainal et al, 2020).** The sample was packaged and assigned a three-digit code. Each attribute's mean score was provided and the result was evaluated.

2.7 Millet is "Superfood of the Year 2023"

Millets are superfoods that may hold the key to resolving growing gut-related ailments and metabolic problems. Superfoods are foods that promise to provide health advantages due to their high nutritional density. Pearl millet (bajra), proso millet (barri), sorghum (jawar), finger millet (ragi), barley (jo), oats (jaee) barnyard millet (samak), and foxtail millet (kangani) are examples of common millets. Millets, which were formerly a common food item in Indian dishes, now have little place as cereals in the current Indian diet, since rice and wheat have taken over as staple foods.

Millets, unlike rice and wheat, are an excellent source of not just calories and major nutrients, such as protein, but also micronutrients such as vitamins, such as vitamins A, B, D, E, niacin, pyridoxine, antioxidants, iron and zinc. Millet is a good energy source and vital minerals, including protein and micronutrients like vitamins A, B, D, E, niacin, pyridoxine, antioxidants, iron, and zinc. Millets have a high protein level (10-12.3 g/100 g), a low-fat content (1% to 5%), a high iron content (0.5-19.0 mg), and a high calcium content (10-410 mg). Millets are high in antioxidant polyphenols such as hydroxycinnamic acid, catechin, quercetin, luteolin, orientin, apigenin, and isoorientin **(Jena et al, 2023).** Millets are a group of small-seeded grains that are rich in nutrition and can be incorporated into an energy bar. it is rich in fiber, minerals, and anti-oxidants whereas it can add texture, chewiness, and crunchiness. Millets are gluten-free which is very healthy **(Sobana et al, 2017).**

2.8 Skim Milk Powder

Skim milk powder is made by the removal of fat from the milk and along with that the water present is also removed, which later removes a concentrated form of milk solids. The addition of skim milk powder in an energy bar can be a nutritious source of protein. Skim milk powder is commonly used in food products to enhance the nutritional value, this promotes health benefits in many ways. **(Al-hooti et al, 1997).** Skim milk powders (SMP) are utilized in a variety of products, including yogurt, soft acidified cheese, and coffee and tea whiteners. SMP is frequently used as a basic ingredient in high-value goods such as baby & medical nutritional formulations, owing to its high protein (35-40%, w/w) and calcium content, as well as its low-fat level (1.0%, w/w). Because of its low-fat content, skim milk is perfect for encapsulating nondairy vegetable oils. However, with ever-rising sustainability standards, dry blending of SMP with other components may give an alternate technique for nutritious product manufacturing **(Hailu et al, 2023).**

2.9 Thickening Agent

Food thickeners are derived from a variety of natural raw materials, including land plants, marine plants, microbes, and animal connective tissues. Popular hydrocolloids derived from various sources and being traditionally used as food thickening agents include animal-derived (gelatin, chitosan, and isinglass), fermentation-produced (xanthan, curdlan, and gellan), plant fragments (pectin, cellulose), seaweed extracts (carrageenan, agar, and alginate), seed flours (guar gum, locust bean gum, tara, and cassia tora), and tree exudates(gum arabic, tragacanth, karaya). Food thickening agents are commonly utilized to adjust rheological and textural qualities as well as to improve quality. Food thickeners' main purposes are to improve moisture binding capacity, modify structural qualities, and change flow behavior features. Modified starches and proteins, alone or in combination with exudates and seed gums, seaweed extracts, and, most recently, microbial polysaccharides, have been shown to improve product mouthfeel, handling qualities, and stability. Temperature, shear, pH, ionic strength, and other factors have an influence on the functioning of these thickening agents and must be carefully optimized by food processors during formulation. Furthermore, the type of thickener used has an effect on the product's functioning. Thickening agents are one of the most important food components in controlling the textural qualities of diverse food items. They regulate moisture

and provide food items with shape, flow, stability, and eating characteristics. In the food industry, stabilizers, emulsifiers, thickeners, and gelling agents are more commonly referred to as food hydrocolloids. These are water-soluble biopolymers made up of polysaccharides with greater molecular weight **(Himashree et al, 2022).**

2.10 Conclusion

Unlike other developed countries, India is a country with a growing concept of energy bar for the population. Many fruits and seeds are fertilized in India and these food crops have many nutritional properties and hence are used in many traditional, medical, Unani, herbal, homeopathy, and other ways since ancient times. The concept of a yogurt energy bar in new product development has been motivated by the day-to-day nutrition need in our busy lifestyles. Usage of yogurt is an emerging idea especially in a country like India, as in India yogurt is mostly preferred and traditionally accepted throughout the country and it also has huge health benefits and nutritional values. Due to the busy lifestyle, the population is preferring to Ready-to-eat foods because it curbs our diets and fulfills our needs and energy required as per RDA recommendation. Millet is titled as the superfood of the year 2023. Barnyard Millet (Samak) is rich in dietary fiber, protein, vitamins, and essential minerals like iron and magnesium. It is also gluten-free and contributes to a healthy lifestyle. As per the reviewed studies, it was observed that the utilization of lyophilization in the processing of the yogurt energy bar enriched with barnyard millet was a much-needed field of attention as the final product achieves the desired quality and nutritional values.

CHAPTER 3

MATERIAL & METHODS

This study comprises all the details related to the materials and methods used to develop a Yogurt Energy Bar enriched with Barnyard Millet and other raw materials.

3.1 Materials used

3.1.1 Raw materials

Yogurt, Barnyard Millet (samak), thickening agent (E 406, E 428), Skim Milk Powder, Vanilla Extract, Honey, Almond, Oats, and Dates.

All these raw materials were used to develop a Yogurt Energy Bar enriched with Barnyard Millet and other raw materials. These raw materials were made available from a local vendor near Integral University, Lucknow. The raw materials were all fresh and were used in a balanced amount of protein, carbohydrates, vitamins, minerals, and energy to provide a quality product and energy to the consumer.

3.1.2 Experimental Materials

Petri Dish, Spatula, Bowl, Beakers, Conical Flask, Crucibles, Test tubes, Test tube Holder, Tong, Gloves, Mixing Spatula (Silicon), Silicon Molder, Induction, Utensil, Funnel, Chemicals, Motor Pestle, Hand Sealing Machine, Para film, Butter paper. Various equipment/ instruments used in the experiments are listed in **Table 3.1.**

Table 3.1 List of equipment/instruments used

Equipment/ Instruments	Specifications	Purpose
Lyophilizer	GOLD-SIM Freeze Dryer -58°C, Ice capacity: 2 Litre	Freeze-drying the sample
Deep-freezer	Vestfrost Deep-freezer 340 BFS 345S, FIBER METAL TOP, 23-23-73	Freezing the sample prior to freeze-drying
Refrigerator	SAMSUNG 415L FROST Free Double Door 3 Star Refrigerator (Easy Clean Steel, RT42K5468SL/TL)	Storing the freeze-dried sample
Electronic Balance	MSW, 10A/VA Delhi Mettler AE 166, Capacity 100g, LC: 0.0001g	Weighing the sample

Induction	BAJAJ Majesty ICX7 Induction cooktop	Roasting the raw materials
Hot Air Oven	IFTD.6. MS Size 150mmL 900*600mm	Even drying & Moisture Estimation
Grinder	BAJAJ Rex 750W Mixer Grinder with Nutri Pro Feature	Size reduction and converting samples into smaller particles
Muffle Furnace	GMP Model Model no. KI-179	Ash estimation
Spectrophotometer	LABMAN UV/VIS spectrophotometer	Spectrophotometric Analysis
Kjeltec	FOSS KT 200 Kjeltec Labtec Line	Protein Estimation
pH meter	EUTECH Instruments pH 700	pH Determination
Refractometer		
Soxtec	FOSS CU 2046 Control Unit ST 243 Soxtec	Fat Estimation

3.2 Preliminary trials

Preliminary trials were planned according to the experiment design to achieve the final and the most suitable yogurt energy bar. the parameters, their levels, and other factors were designed accordingly. In this product development, various parameters were discussed and selected. These trials serve as a preliminary assessment to identify the potentially suitable challenge of desired product for any kind of product development. These pilot trials or feasibility studies are small-scale experiments or tests that are conducted to check the viability of a product or process and identify its fine-tune approaches and validate the concept.

In the context of the development of the Yogurt Energy Bar, different challenges came up, starting from the selection of the raw material, testing the prototype, the early version of the final product, functionality, freeze-drying of the yogurt, and the palatability of the product. These trials included the feedback of the consumers through a 9-hedonic scale sensory evaluation through which necessary adjustments and improvements were made for the product's future.

The various parameters considered for the preliminary trials are listed in **Table 3.2**

The preliminary trials were conducted under three parameters having a greater influence on the response i.e., the palatability of the yogurt energy bar. The first category of the preliminary trial included the varying composition of the yogurt layer in the bar, similarly, the second category of the preliminary trial included the varying composition of raw materials used in the barnyard millet layer of the bar. The selected composition of the yogurt energy bar was decided based on the 9-scale hedonic sensory evaluation.

The third category of the preliminary trial took place with the inclusion of lyophilization. The freeze-drying took place at a constant temperature of -54°C but at varying times. The first batch of yogurt energy bars was freeze-dried at -54°C for 4 hours which gave it a very rock-solid texture and powdery mouth feel to the sensory analyst. The second batch of yogurt energy bars was freeze-dried at the same temperature but for 3 hours and honey was added during the making of the bar; these bars were sensorily acceptable to the sensory analyst.

Thus, based on the preliminary trials and the review of the literature product weight was set as the constant parameter for the final experiment. Whereas, the composition of the yogurt energy bar and lyophilization time were set as the independent variables with three levels each.

Table 3.2: Various parameters considered for preliminary trials

S.no	Parameters	Levels	Value of levels	Response
1	Yogurt Layer Composition	4	Sugar Skim Milk Powder Agar & Gelatine Honey	Palatability
2	Barnyard Millet Layer Composition	4	Peanuts Peanut Butter Butter Honey	Palatability
3	Lyophilization Time	2	4hrs, 3hrs	Palatability & Stability

3.2.1 Constant Parameters

Selection of the constant parameters was done on behalf of the product available in the market. It is needed to be compared. Those parameters which do not affect the process directly but are

needed somewhere in the process and need to be identified to fix the values are called constant parameters. As per the preliminary trials and review of literature, two parameters were fixed as constant parameters which included, product weight (70 g), and lyophilization temperature.

3.2.1.1 Product weight

The selection of raw materials was based on the fact that they should be good enough to fulfill the need of the consumer's appetite and must be comparable enough to the market product. The decision of the selection of the ingredients was made as they all should provide nutrition and must be easy to be processed. After the set of preliminary trials, the final product weight was decided to be 70 g because it was found to be fulfilling enough for a consumer and was adequate to conduct all the experiments for analysis of responses.

3.2.1.2 Lyophilization Temperature

The lyophilization temperature was set to be constant in the instrument itself at -54°C. During and after the processing, this temperature remained constant. Thus, the overall quality of the yogurt energy bar was dependent on the lyophilization time. **Table 3.3** gives the list of constant parameters for the final product.

Table 3.3 Constant Parameters for Final Product

S. No.	Parameter	Constant
1	Product Weight	70g
2	Lyophilization Temperature	-54°C

3.2.2 Selection of Independent Variables

The variables which can be varied within a certain range during the study to see the effect on dependent variables are called Independent Variables. For this study, the independent variables considered were lyophilization time, and the composition of the yogurt energy bar. These factors affect the final product. the range and values of this product were decided on the basis of a review of the literature.

3.2.2.1 Lyophilization Time

During the preliminary trials of lyophilization, 2 levels were performed and tested. The sensory analyst checked the final product and studied it through a 9-scale hedonic sensory evaluation.

As per the review of the literature, the lyophilization time varied in the range of 4 hours and 3 hours. It was observed that the result achieved at 4 hours of time, the bar was rock-solid in texture and gave a very powdery mouth feel on chewing. But when the lyophilization time was decreased to 3 hours and honey was added, the bar comparatively became softer and chewable. It was considered to be palatable according to the analyst report of the 9-scale hedonic sensory evaluation. Therefore, the final time for lyophilization was selected to be 3 hours.

3.2.2.2 Composition of the Yogurt Energy Bar

The composition of the Yogurt Energy Bar is a parameter that leads to the variation in the nutrition of the bar. this parameter has a direct effect on the quality and quantity of the bar. In the preliminary trials, the yogurt layer of the bar was taken for sensory analysis. 4 levels of preliminary trials were performed which included: sugar, skim milk powder, agar and gelatine, and honey. Based on the final result, 4^{th} trial was approved by the sensory analyst. Similarly, the barnyard millet layer consisted of 4 level preliminary trials which included Peanuts, Peanut Butter, Butter, and Honey. The 4^{th} trial was approved by the sensory analyst. The results were based on the review of the literature and responses.

3.2.3 Dependent variable (responses)

The number of responses was selected to study the effect of independent variables on the development of Yogurt Energy Bar enriched with Barnyard Millet. Yogurt Energy Bar was analyzed for twelve responses which comprised Moisture Analysis, Ash Content Determination, pH Determination, Total Soluble Solids (TSS), Titratable Acidity, Protein Estimation, Fat Estimation, Color Analysis, DPPH Anti-oxidant activity, Total Phenolic Content (TPC), Sensory Analysis, and shelf-life analysis.

Table 3.4: Dependent Variables

S. No.	Responses
1.	Moisture Analysis
2.	Ash Content
3.	pH Determination
4.	Total Soluble Solids
5.	Titratable Acidity
6.	Protein Estimation
7.	Fat Estimation
8.	Color Analysis

9.	DPPH Anti-oxidant Activity
10.	Total Phenolic Content
11.	Sensory Analysis
12.	Shelf-life Analysis

3.3 SAMPLE PREPARATION METHOD

TABLE 3.5 Composition of the Yogurt Energy Bar prepared

S. No.	Raw Materials	Control 1(gm)	Control 2(gm)	Sample 3(gm)	Sample 4(gm)	Sample 5(gm)	Sample 6(gm)
1.	Skim Milk Powder	9	0	5	6	7	8
2.	Agar (China Grass)	0	9	4	3	2	1
3.	Yogurt	20.6	20.6	20.6	20.6	20.6	20.6
4.	Veg.gelatin	1.25	1.25	1.25	1.25	1.25	1.25
5.	Vanilla extract	4.2	4.2	4.2	4.2	4.2	4.2
6.	Honey	7.65	7.65	7.65	7.65	7.65	7.65
7.	Barnyard Millet	4.08	4.08	4.08	4.08	4.08	4.08
8.	Oats	4.08	4.08	4.08	4.08	4.08	4.08
9.	Almonds	4.16	4.16	4.16	4.16	4.16	4.16
10.	Dates	17	17	17	17	17	17

3.3.1 Preparation of Barnyard Millet Layer of the Yogurt Energy Bar

3.3.1.1 Selection of Raw Materials

The selection of raw materials was done on the basis of Millet as the superfood of the year 2023. The raw materials were collected from a local vendor near Integral University, Lucknow. Each raw materials were selected on the behalf of their nutritional composition, health benefits, physical properties like color, shape, size, texture, and taste. The packed products were selected on the behalf of their manufacturing & expiry dates. The selection of these materials was also done on the basis of their freshness and quality, shown in **Fig 1**. The list of ingredients selected for the development of yogurt energy bar are listed in **Table 3.5.**

3.3.1.2 Roasting

Barnyard Millet, Oats, and Almonds are roasted at 160°C- 175°C for 5-6 mins. Roasting enhanced the texture, taste, and aroma of these raw materials. Roasting gave a crispy texture to these raw materials which was later incorporated in the yogurt energy bar, as shown in **Fig. 2.**

3.3.1.3 Grinding

Dates and hot water were added together in the grinder for 5-10 mins. This grinding formed a slurry-like structure of the dates. The making of dates paste worked as the base structure for the bar, further in which other raw materials were added, as shown in **Fig. 3.**

3.3.1.4 Mixing

After making the dates paste and roasted raw materials, these raw materials were further mixed together and bar material was prepared. The mixing was done uniformly and each material was mixed in their decided ratios. The mixing is shown in **Fig. 4.**

3.3.1.5 Molding

These mixed combinations of raw materials were now placed into a silicon molder. The use of this silicon molder was to provide the appropriate shape to the yogurt energy bar. the barnyard millet bar layer was now kept for settling down to the shape of the bar unless the yogurt layer of the bar is poured on top of it. The process of molding is shown in **Fig. 5.**

3.3.2 Preparation of the Yogurt Layer of the Yogurt Energy Bar

3.3.2.1 Selection of the Raw Materials

The selection of these raw materials was specifically done with the incorporation of Yogurt in an energy bar. The main aim to develop a Yogurt Energy Bar is achieved. These raw materials were bought from local vendors and grocery shops near Integral University, Lucknow. Selecting yogurt for the development of a yogurt energy bar was done for its nutritional, probiotic, taste & texture purpose. Similarly, the other raw materials were also selected for the same purpose. This is shown in **Fig. 6.**

3.3.2.2 Mixing

The selected raw materials were weighed and mixed together. The mixing was done uniformly. Mixing was done for 5-6 minutes until it was properly mixed, as shown in **Fig. 7.**

3.3.2.3 Molding

Molding took place just after the mixing process. The silicon molder which contained the Barnyard Millet layer of the bar was brought. The yogurt layer was placed uniformly over the Barnyard Millet layer of the bar. this process is shown in **Fig. 8.**

3.3.2.4 Deep-freezing

As soon as the molding process of the Yogurt Energy Bar is completed it was placed inside the chamber of a Deep-freezer overnight at the temperature of -20°C to -25°C. The process of deep-freezing is done prior to freeze-drying as it is mandatory for the freeze-dried product to be first frozen at a temperature below -20°C, this was done according to the research and review of the literature **(Kulaitiene, 2021).** This is shown in **Fig. 9.**

3.3.2.5 Lyophilization

After the yogurt energy bar was frozen overnight at the temperature of -20°C to -25°C. the Yogurt Energy Bar was then placed inside the lyophilization chamber at a constant temperature of -54°C (**Kulaitiene, 2021)**. Lyophilization was done in 3 hours and the Yogurt Energy Bar was taken out of the freeze-dryer. This process is shown in **Fig. 10.**

3.3.2.6 Storage

The lyophilized Yogurt Energy Bar was then packed into zip-lock packages and placed inside the refrigerator. The temperature of the refrigerator was 3-4°C, and the Yogurt Energy Bar was stored for further analysis. The Yogurt Energy Bar is shown in **Fig. 22.**

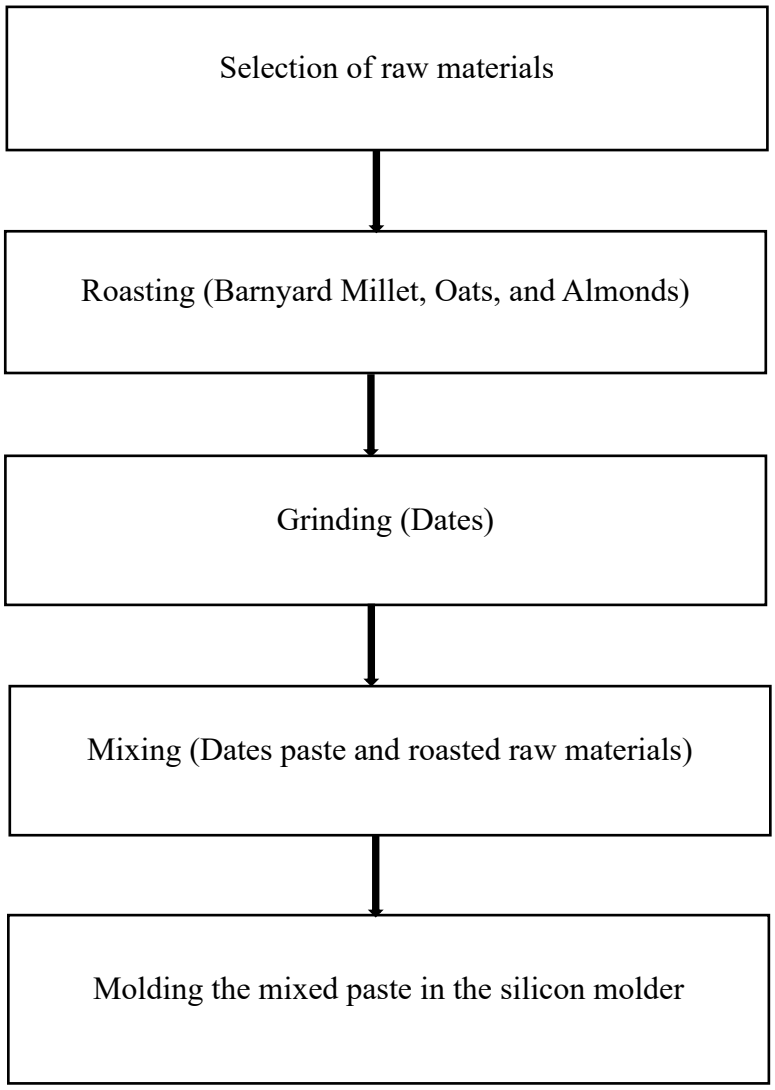


Fig.3. Flow diagram of the preparation of Barnyard Millet Layer for the Yogurt Energy Bar

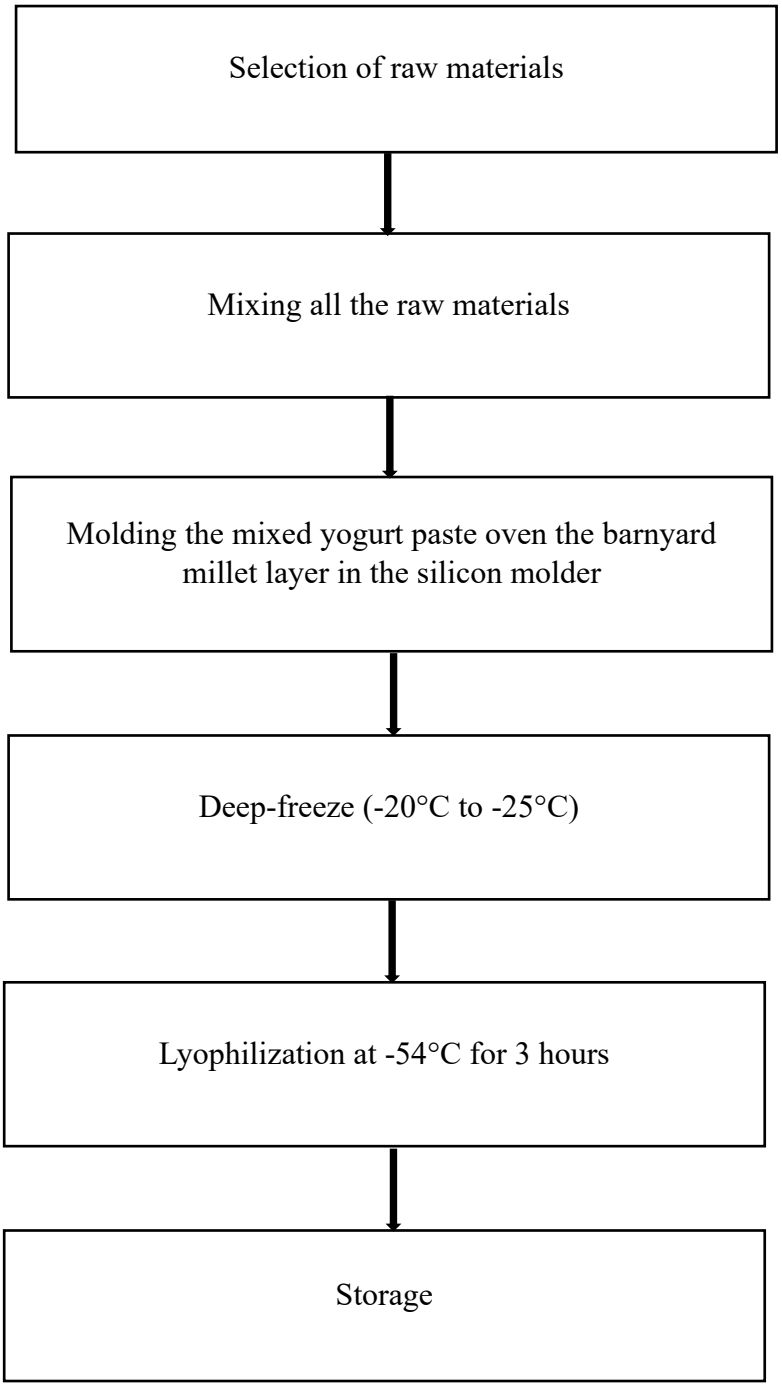


Fig.3. Flow diagram of the preparation of the Yogurt layer of Yogurt Energy Bar

Fig. 1 Selection of raw materials

Fig. 2 Roasting

Fig. 3 Grinding

Fig. 4 Mixing

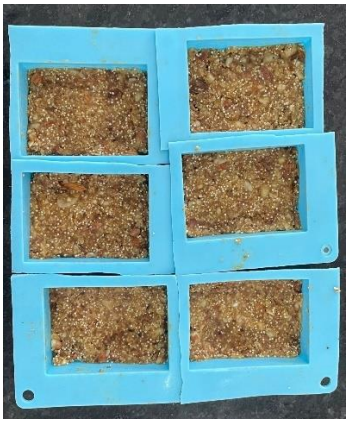


Fig. 5 Molding

Fig. 6 Selection of raw material

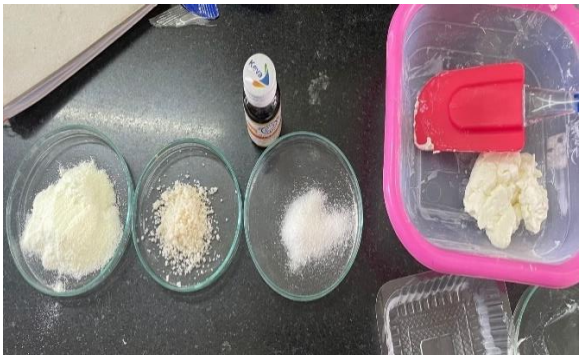


Fig. 7 Mixing

Fig. 8 Molding

Fig. 9 Deep-freezer

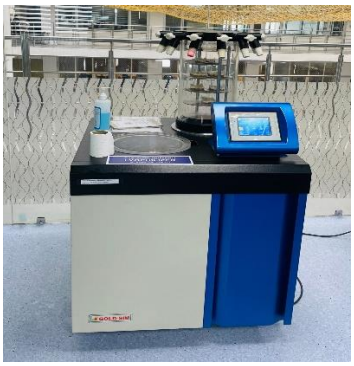
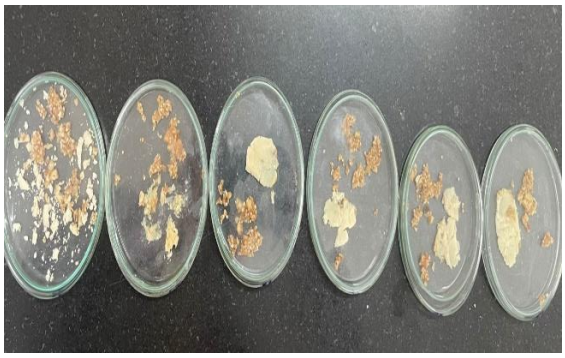


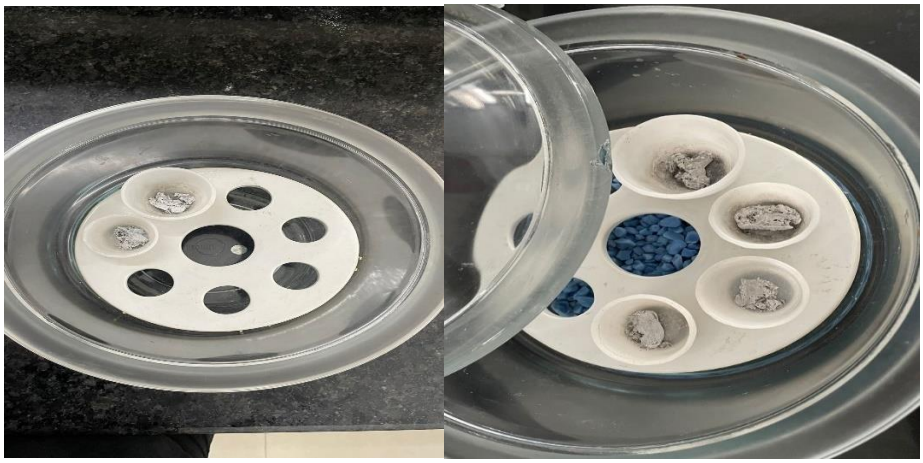
Fig. 10 Lyophilization



a) **b)**

Fig. 11 Moisture Content Analysis

a)



b)

Fig. 12 Determination of Ash Content

Fig. 13 pH determination

Fig. 14 Titratable Acidity

Fig. 15 Total Soluble Solids

Fig. 16 Fat Content Analysis

Fig. 17 Protein Content Analysis

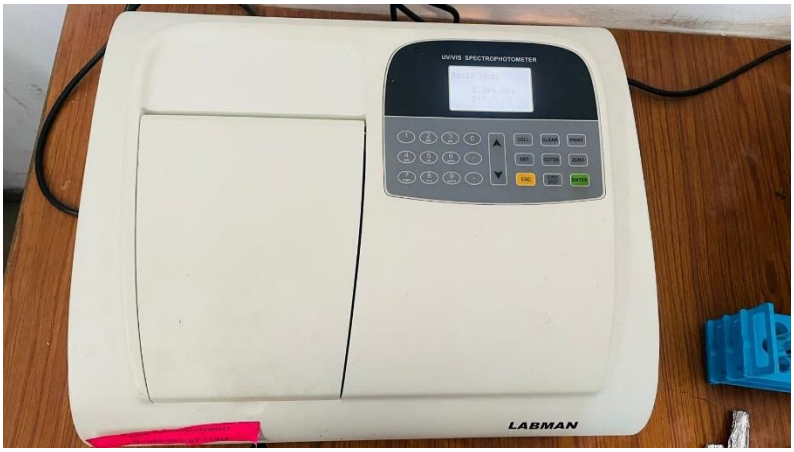
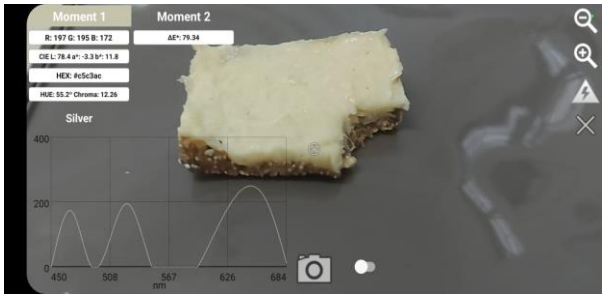
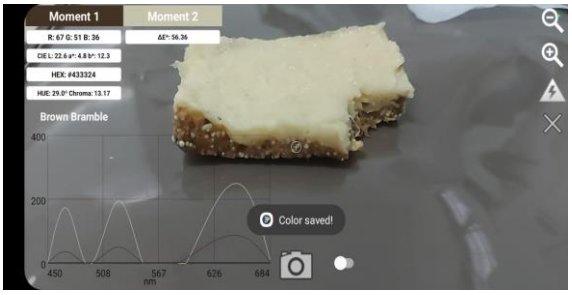


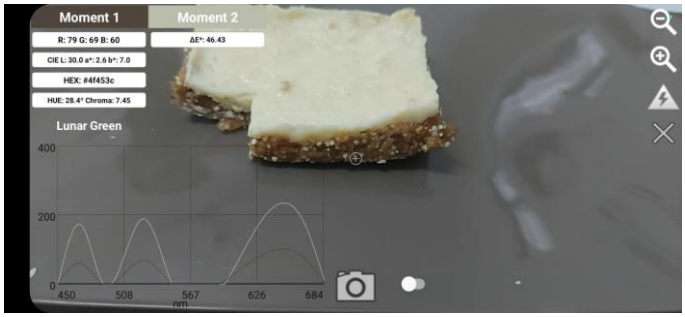
Fig. 18 a) DPPH Anti-oxidant b) Total Phenolic Content

a) C1





b) C2



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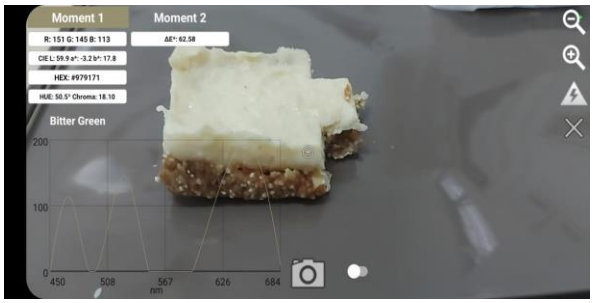
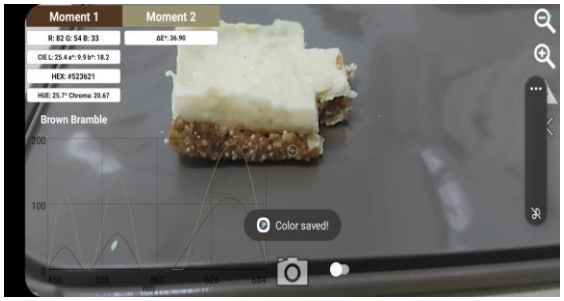
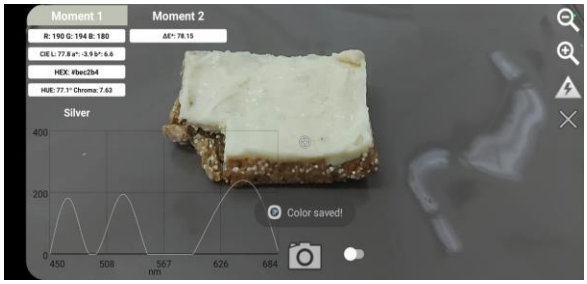
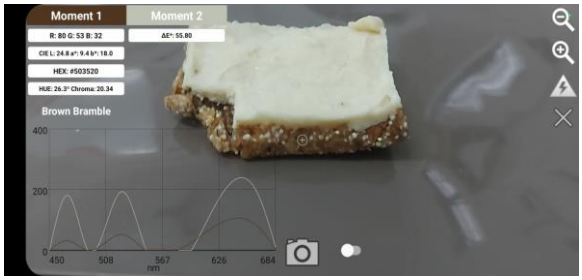




d) S4





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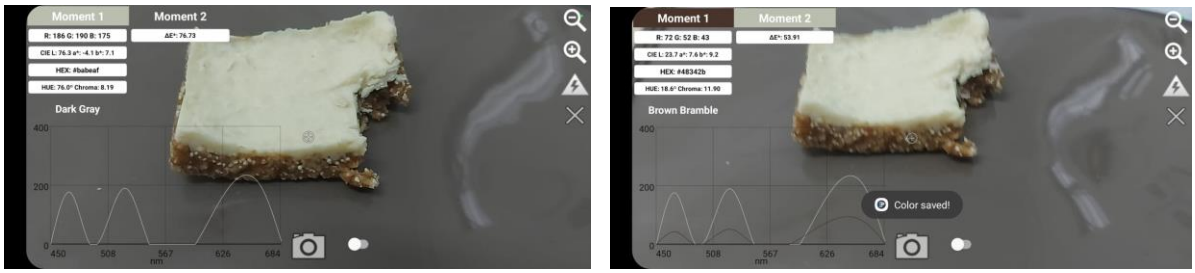


f) S6

Fig. 19. a) b) c) d) e) f) Colorimeter Analysis using CIE Lab system

Fig. 20 Sensory Analysis of Yogurt Energy Bar samples prepared

Fig. 21 Yogurt Energy Bar

3.4 Physico-chemical Analysis

3.4.1 Moisture Content

Moisture Content analysis is a process used to measure the amount of water present in the Yogurt Energy Bar. For the determination of Moisture content, each sample of Yogurt Energy Bar was taken and weighed 3gm equally and taken in triplicates. These samples were then crushed in homogenized form using a motor pestle. After crushing these samples, they were then kept in Petri dishes and placed inside Hot Air Oven at 105°C for 3 hours. Moisture Content Analysis is shown in **Fig. 11.** Determination of Moisture Content Analysis was done following the method of AOAC, (2000). Moisture Content Analysis was calculated using the equation given below:

$$Moisture\ content\ (\%) = \frac{W1-W2}{W1}\ X\ 100 \qquad \text{eq..1}$$

where,

W1= weight of the sample, and

W2= weight of the sample after drying.

3.4.2 Ash Content

Ash Content Determination is a method used to determine the amount of inorganic materials, and mainly minerals present in Yogurt Energy Bar is calculated. This determination takes at a very high temperature. For the determination of Ash Content. Each sample of Yogurt Energy Bar was taken and weighed 3gm equally. These samples were taken in triplicates. These samples were then homogenized using a motor pestle. After the samples were crushed, they were kept in clean and sanitized crucibles and placed inside a pre-heated muffle furnace at 550°C for 5 hours. Prior to placing the crucible in a muffle furnace, the crucible is kept on the stove to get burned for avoiding the production of fumes. The determination of Ash Content is shown in **Fig. 12.** Determination of Ash Content was done using the method and formula of AOAC, 2000. Ash Content was calculated using the equation given below:

$$Ash\ content\ (\%) = \frac{S1-S2}{S3} X\ 100 \qquad \text{eq..2}$$

Where,

S1= weight of the crucible before ashing,

S2= weight of the crucible after ashing, and

S3= weight of the sample.

3.4.3 pH

pH estimation is an approach to measure the alkaline or acidic nature of a Yogurt Energy Bar. pH scale ranges from 0 to 14, where pH 7 is considered neutral, values below 7 is acidic, and above 7 is alkalinity. For the determination of pH, AOAC 1995 method was followed. 3 grams of crushed Yogurt Energy Bar samples were added into 50ml of distilled water at 25°C. This mixture was mixed using an electronic agitator for 30 minutes and left for resting for the next 10 minutes. Later the electrode of pH meter was dipped in each beaker of the mixture & pH was measured. Before and after dipping the electrode in the beaker of the samples, the electrodes were washed and cleaned by distilled water. pH determination of the Yogurt Energy bar is shown in **Fig. 13.**

3.4.4 Titratable Acidity (TA)

Titratable Acidity (TA) is a measurement used to determine the total amount of acid present in the Yogurt Energy Bar. Titratable Acidity (TA) was determined using AOAC, 1965. Each sample was weighed 3gm equally and in triplicate. These samples were further diluted in distilled water and titrated from the initial point to the endpoint with 0.1N Na OH using 0.3ml phenolphthalein for each 100ml solution of the samples. The slight presence of pink color indicated the endpoint of the titration. Titratable acidity analyzed is shown in **Fig. 14**. The Titratable Acidity was calculated using the equation given below:

$$\textit{Titratable Acidity (\%) acid} = \frac{(ml\ of\ NaOH\ used)x\ (0.1\ N\ NaOH)x\ (miliequivalent\ factor)}{(grams\ of\ sample)}\ x\ 100 \quad \text{eq..3}$$

3.4.5 Total Soluble Solids (TSS)

Total Soluble Solids (TSS) refers to the concentration of all the soluble substances present in the Yogurt Energy Bar. Total Soluble Solids (TSS) is determined using FSSAI, 2016 standards. 3 grams of samples were weighed equally and homogenized in 50ml water. These samples

were filtered using 0.1µ filter paper. The sample obtained from the Yogurt Energy Bar was analyzed using a refractometer. The Total Soluble Solids (TSS) of the Yogurt Energy Bar was shown in **Fig. 15.**

3.4.6 Fat Content

The process of determination of Fat content is done by measuring the amount of fat present in the Yogurt Energy Bar samples. For the determination of fat content, 3gm samples each was weighed from the Yogurt Energy Bar and crushed using a motor pestle. Each crushed samples were placed in the thimble and covered with cotton. These samples were placed inside the Soxtec apparatus. The weight of solvent containers is measured and solvent is poured and placed inside the Soxtec apparatus and the extraction process is started. The solvent evaporates with the sample in a thimble at 90°C -100°C. The process was running till the extraction was completed. Fat content determination is shown in **Fig. 16.** Determination of fat content was done following AOAC, 2000. Fat content was calculated using the equation given below:

$$Fat\ content\ (\%) = \frac{V1-V2}{V1}\ x\ 100 \qquad \text{eq..4}$$

Where,

V1= weight of empty solvent containers; and

V2= weight of solvent containers after fat extraction

3.4.7 Protein Content

Protein content determination is a process of calculating the amount of protein present in the Yogurt Energy Bar samples. For determining the protein content in Yogurt Energy Bar AOAC, 2000 was followed. Kjeltec Apparatus was used as shown in **Fig. 17.** The estimation of protein in Kjeltec apparatus takes place in 3 steps: Digestion, Distillation and Titration. 2 gm samples was weighed and crushed and placed in the digestion chamber along with 10 parts of $KuSO_4$ (potassium sulfate) with 1 part of $CuSO_4$ (copper sulfate) and 20 ml of H_2SO_4 (sulfuric acid) of the kjeltec apparatus. The digestion chamber was continued for heating at 100°C until the sample turned crystal green and then kept for cooling. Later on cooling the sample, the color turns to crystal light blue. The digestion vessel is then placed inside the distillation unit of the

kjeltec and the automated distillation unit is connected to the NaOH solution filled in a plastic jar. 50ml of 2% Boric acid is added in a conical flask with 4-5 drops of phenolphthalein indicator in it. This conical flask is placed in the outlet of the distillation unit with making sure that the tube is properly immersed into the conical flask. The program setting is set for 4-5 minutes and adding 50ml of NaOH is run. The amount of NaOH will change the alkaline medium for ammonia liberation. After completion of 4-5 minutes of distillation, ammonia will be absorbed into the boric acid solution and the color will change from purple to green. The digestion vessel is removed and kept inside the digestion stand and the conical flask is removed. 4-5 drops of Methyl Blue Indicator is added in it and placed for further titration with 0.1% HCL. The end point is indicated as the color changes to pink. The titre value is noted and calculated as per the given equation:

$$Protein\ content\ (\%) = \frac{(A-B)\ X\ N\ X\ 14.007\ X\ 6.25}{W} \qquad \text{eq..5}$$

Where,

A= volume of HCL used for sample titration,

B= volume of HCL used for blank titration,

C= normality of HCL,

W= weight of sample,

14.007= atomic weight of nitrogen, and

6.25= conversion factor for food product.

3.5 Phytochemical Analysis

3.5.1 DPPH Anti-oxidant Activity

Anti-oxidant activity is used to analyze the ability of Yogurt Energy Bar to reduce the stable radical DPPH to a non-radical form. The analysis of DDPH anti-oxidant activity was done following AOAC, 2012. About 1.5ml of sample solution was mixed with 1.5ml of Methanolic solution of DPPH (0.2 mM). this mixture of solution was incubated for 30 minutes in the dark at room temperature. The absorbance of the resulting solution was measured with the help of a spectrophotometer at 517nm, as shown in **Fig. 18.a .** For the control, methanol was used

instead of the sample in the solution. Analysis was done in triplicate for each sample **(Al-Sayyed, H. F., 2022).** The DPPH scavenging capacity of the tested sample was calculated as a decrease in the absorbance and was calculated by the given equation:

$$Anti - oxidant\ activity = \frac{Absorbance\ (Control) - Absorbance\ (Sample)}{Absorbance\ (Control)} x\ 100\ eq..5$$

3.5.2 Total Phenolic Content

Total Phenolic Content (TPC) is a method used to measure the total the amount of phenolic compound present in Yogurt Energy Bar. total phenolic content was measured following AOAC, 2018, using Folin-ciocalteu reagent. 1.5mL sample was added to 1.5ml of diluted Folin-ciocalteu reagent (1:10, v/v) and was incubated at room temperature for 15 minutes **(Aiyegoro, 2010).** Later, 4ml of 7.5% Na_2CO_3 was added to the mixture of solution. The solutions were shaken uniformly and was later incubated in the dark for 2 hours. Later, the absorbance of the combination was determined by utilising a spectrophotometer at 760 nm after incubation, as shown in Figure.**. 18.b.** The same analytical process as samples was used to create the standard gallic acid range of 0-125 mg/ml. the result was represented in mg of GAE per gram of materials **(Rodiah, 2018).** The equation used for calculating the Total Phenolic Content is :

$$C = c\ X\ (v/m) \qquad eq..6$$

Where,

C = Total Phenolic Content (mg/ml gallic acid equivalent)

c = X/1000 = Concentration of gallic acid in mg/ml

v = Volume of extract

m =Mass of the extract (gm)

3.6 Color Analysis (L* a* b*)

Color Analysis CIE Lab* color space is a widely used method for describing colors and quantifying them. It is a 3-dimensional color model that represents colors based on 3 components: L* - Lightness 0 (black) to 100 (white), a* - a trend of Green (-) to Red (+) and b* - Blue (-) to Yellow (+) **(Ganesan, 2010).** The color analysis of the Yogurt Energy Bar was analyzed using CIE Lab system with the help of digital colorimeter. The color analysis is shown in **Fig. 19.**

3.7 Sensory Analysis

A Set of three panelists evaluated the sensory parameters of the Yogurt Energy Bar samples using a 9-scale hedonic sensory evaluation method **(Lim, 2011).** The sensory panel is categorized into these categories: trained, semi-trained, and consumer panel. 9-scale Hedonic sensory evaluation was done by the panelist which followed the sequence of : 9- Like extremely, 8- Like very much, 7- like moderately, 6- like slightly, 5- nor like nor dislike, 4- dislike slightly, 3- dislike moderately, 2- dislike very much, 1- dislike extremely **(Foods, 1971).** Sensory analysis is shown in **Fig. 20.**

3.8 Shelf-life Analysis

Shelf-life analysis of the Yogurt Energy Bar was done on the basis of the sensory analysis. The Yogurt Energy Bar was analyzed on the interval of every 15 days till 90 days (3 months). The sensory analysis was don using 9-scale hedonic sensory evaluation. This was done to understand the changes in the bar during this storage period under a refrigerator temperature of (3°C-4°C).

3.9 Cost Analysis

Cost analysis is the process of evaluation of the cost the and product developed by comparing it with a market product. The cost analysis was done by calculating the cost of the entire raw materials added in the Yogurt Energy Bar and comparing it with the product already available in the market. The individual cost of the raw materials was calculated as per the composition of a 70 gm Yogurt Energy Bar produced.

3.10 Fourier Transform Infrared (FT-IR) Spectroscopic Analysis

Fourier Transform Infrared Spectrophotometer (FT-IR) is the most powerful analytical tool for measuring the infrared spectrum of a sample. FTIR works on the principle of Fourier Transform Spectroscopy, which involves the measurement of the interaction between infrared radiations of the sample. It also aids in identifying in the types of chemical bonds/ functional groups present in phytochemicals. Distinguishing characteristics of the chemical bonds in the Yogurt Energy Bar sample is shown in the spectrum with the wavelength of light absorbed. The chemical bond in the substance is identified by reading the infrared absorption spectra. FT-IR analysis was conducted using dried Yogurt Energy Bar powder. To create translucent disc, 10mg dried Yogurt Energy Bar sample was encapsulated in 100mg of KBr pellet. The powdered sample was placed in FT-IR spectrophotometer with a scan range of 400-4000 cm^{1} with a resolution of $4cm^{-1}$.

CHAPTER 4

RESULT & DISCUSSION

Yogurt was used as the main ingredient in the development of the Yogurt Energy Bar, whereas, Barnyard Millet was used as the base ingredient for the preparation of the base layer of the Yogurt Energy Bar. Some other ingredients like Oats, Dates, Almonds, Honey, Agar, Vanilla extract, Gelatin, and Skim Milk Powder were used. These raw materials were cost-effective and easily available in the local grocery stores in India as it is a country rich in yogurt as a traditional use and millets and other sources of vitamins and minerals. Yogurt is a probiotic used in many dishes in India due to its alluring and versatile nature as a food habitat. The incorporation of yogurt in Indian cuisine is a culture. India is also a green country that is rich in seed-crop cultivation, which makes India rich in millet cultivation. Millets are known for their nutritional value, and resilience to diverse climatic conditions and have been as integral part of the tradition in India.

Total 6 samples of the Yogurt Energy Bar using the same raw materials with different compositions of Skim Milk Powder and Agar (China Grass) were prepared. All these samples of the Yogurt Energy Bars were analyzed in two phases. The first phase of analysis included various responses of physico-chemical analysis, phytochemical analysis, color analysis, sensory analysis, shelf-life analysis, and cost analysis. The second phase of analysis included the characterization of FT-IR analysis.

Optimization of the sample was done to generate the optimum point of the independent variables for the best possible combinations of independent variables. Furthermore, the actual experiments were performed at optimum points and were compared with the optimized result to verify the product.

4.1 Preliminary Trials

In the preliminary phase of the experimental plan, the aim was to observe and select the most suitable palatable parameter for the decision of selection of independent variable levels for development the best Yogurt Energy Bar. These include:

Yogurt layer composition: Sugar, Skim milk powder, Agar gelatin, and Honey

Barnyard Millet layer composition: Peanuts, Peanut Butter, Butter, Honey

Lyophilization time: 4hours, 3hours

Considering the responses, the preliminary trials were conducted for the development of the Yogurt Energy Bar. The observed response provided the following results:

1) Sensory parameter showed the maximum palatability with the addition of skim milk powder, agar, gelatin and honey in the Yogurt Energy Bar.
2) Sensory parameter showed the maximum palatability with the addition of honey in the barnyard millet layer of the Yogurt Energy Bar.
3) Sensory parameter showed maximum palatability with 3 hours of lyophilization time as well as the best stability of the bar.

4.2 Physico-chemical Analysis

4.2.1 Moisture Content

Moisture content influences major parts of the physical parameter of any product including weight, density, viscosity, conductivity, and water activity. Moisture content analysis is generally determined by the difference in the weight of the product which occurs due to drying. The moisture content of 6 samples prepared in the laboratory was analyzed and shown in **Table 4.1.** The moisture content of the Yogurt Energy Bar samples ranged from to 2.33±0.05 to 4.01±0.05. The highest moisture content of 4.01±0.05 was observed in Sample 6 whereas Sample 4 represented the lowest value of 2.33±0.05. The range of Moisture content is shown in **Fig 4.1.** according to the research of **Kulaitiene et al, 2021**; similar results were observed.

Table 4.1 Moisture Content Analysis of Yogurt Energy Bar Samples:

Sample	Moisture Content (%)
Control 1: Skim Milk Powder 13.84% and Agar 0%	2.68±0.05
Control 2: Skim Milk Powder 0% and Agar 13.84%	3.55±0.06
Sample 3: Skim Milk Powder 7% and Agar 6.15%	3.02±0.05
Sample 4: Skim Milk Powder 9.23% and Agar 4.61%	2.33±0.05
Sample 5: Skim Milk Powder 10.76% and Agar 3.07%	3.14±0.02
Sample 6: Skim Milk Powder 12.30% and Agar 1.5%	4.01±0.05

Values are written as mean ± standard deviation

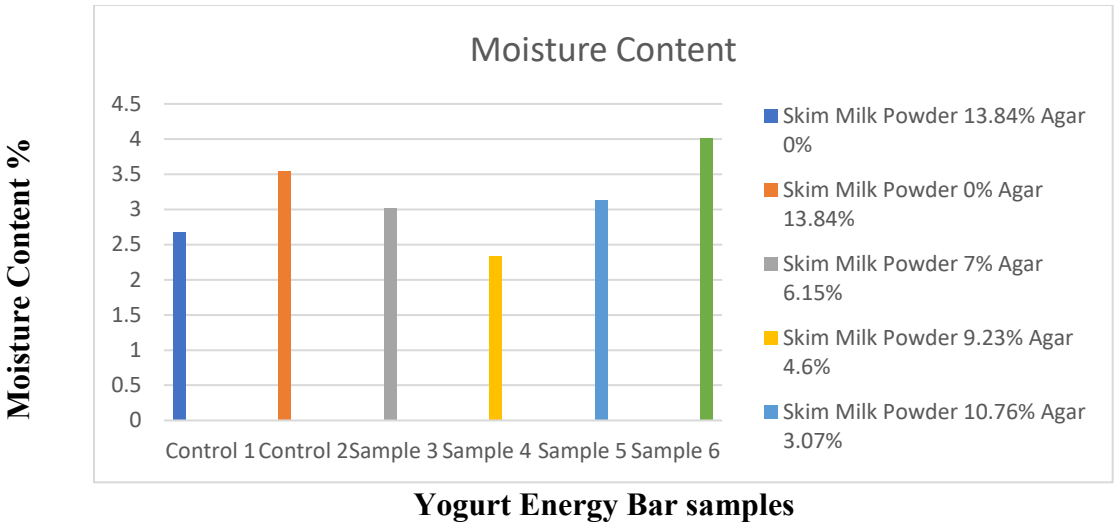


Fig. 4.1 Moisture Content in Yogurt Energy Bar samples

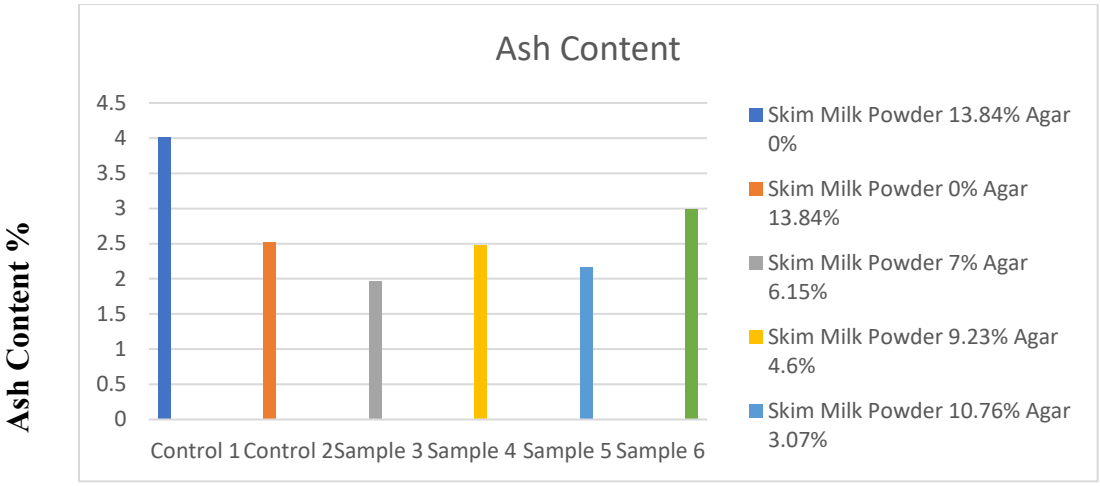
4.2.2 Ash Content

Ash content is the method which is used in determining inorganic materials. Ash is the inorganic residue left after the removal of moisture and other organic substance present by providing excessive heat. It is the measurement of the total amount of minerals present in the Yogurt Energy Bar samples. Ash content includes both minerals and toxic minerals. In general, organic food contains less than 5% ash and many processed foods have more than 10% Ash content. 6 samples of the Yogurt Energy Bar were analyzed for the determination of Ash Content which is shown in **Table 4.2.** The determined ash content ranged from 4.02±0.01 to 1.97±0.04. The highest Ash content of 4.02±0.01 was measured in Control 1 and the lowest Ash content of 1.97±0.04 was measured in Sample 3. The range of Ash content in the Yogurt Energy Bar samples can be shown in **Fig 4.2**.

Table 4.2 Ash content analysis of Yogurt Energy Bar samples

Sample	Ash Content (%)
Control 1: Skim Milk Powder 13.84% and Agar 0%	4.02±0.01
Control 2: Skim Milk Powder 0% and Agar 13.84%	2.52±0.11
Sample 3: Skim Milk Powder 7% and Agar 6.15%	1.97±0.04
Sample 4: Skim Milk Powder 9.23% and Agar 4.61%	2.48±0.01
Sample 5: Skim Milk Powder 10.76% and Agar 3.07%	2.16±0.07
Sample 6: Skim Milk Powder 12.30% and Agar 1.5%	3.00±0.02

Values are written as mean ± standard deviation



Yogurt Energy Bar samples

Fig. 4.2 Ash Content in Yogurt Energy Bar samples

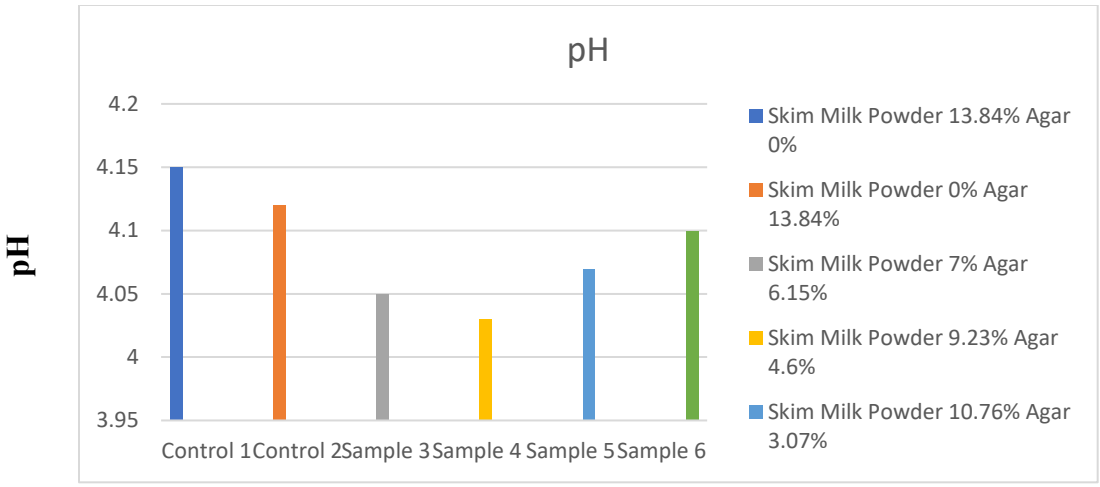
4.2.3 pH

Determination of pH represents the alkaline or acidic status that ranges from 0 to 14, in which 7 is regarded as neutral. Here, 0 to 6 represents acidity and 8 to 14 represents alkalinity. pH measures the hydrogen ion activity. pH of 6 samples were analyzed in laboratory and is shown in the **table 4.3.** pH of the Yogurt Energy Bar samples ranged from c, which denotes that the Yogurt Energy Bar samples have an acidic nature. Amongst the samples, a slight difference is denoted by the variation of the samples. The highest pH value determined was 4.15±0.12 in Control 1, whereas, the lowest determined value of pH is 4.03±0.02 in Sample 4; as shown in **Fig 4.3**.

Table 4.3 pH determination of Yogurt Energy Bar samples

Sample	pH
Control 1: Skim Milk Powder 13.84% and Agar 0%	4.15±0.12
Control 2: Skim Milk Powder 0% and Agar 13.84%	4.12±0.07
Sample 3: Skim Milk Powder 7% and Agar 6.15%	4.05±0.03
Sample 4: Skim Milk Powder 9.23% and Agar 4.61%	4.03±0.02
Sample 5: Skim Milk Powder 10.76% and Agar 3.07%	4.07±0.03
Sample 6: Skim Milk Powder 12.30% and Agar 1.5%	4.1±0.02

Values are written as mean ± standard deviation



Yogurt Energy Bar Samples

Fig 4.3 pH determination of Yogurt Energy Bar samples

4.2.4 Titratable Acidity (TA)

Titratable acidity (TA) was measured to determine the total amount of acids present in the Yogurt Energy Bar samples. A total of 6 samples of the Yogurt Energy Bar were analyzed for Titratable Acidity in the laboratory, as shown in **Table 4.4.** The results ranged from 0.10±0.03 to 0.20±0.07, as shown in **Fig 4.4**. The highest titratable acidity of 0.20±0.07 was analyzed in Sample 6, whereas, the lowest titratable acidity of 0.10±0.03 was analyzed in Sample 4.

Table 4.4 Titratable Acidity of Yogurt Energy Bar samples

Sample	Titratable Acidity
Control 1: Skim Milk Powder 13.84% and Agar 0%	0.19±0.07
Control 2: Skim Milk Powder 0% and Agar 13.84%	0.11±0.02
Sample 3: Skim Milk Powder 7% and Agar 6.15%	0.17±0.01
Sample 4: Skim Milk Powder 9.23% and Agar 4.61%	0.10±0.03
Sample 5: Skim Milk Powder 10.76% and Agar 3.07%	0.20±0.04
Sample 6: Skim Milk Powder 12.30% and Agar 1.5%	0.20±0.07

Values are written as mean ± standard deviation

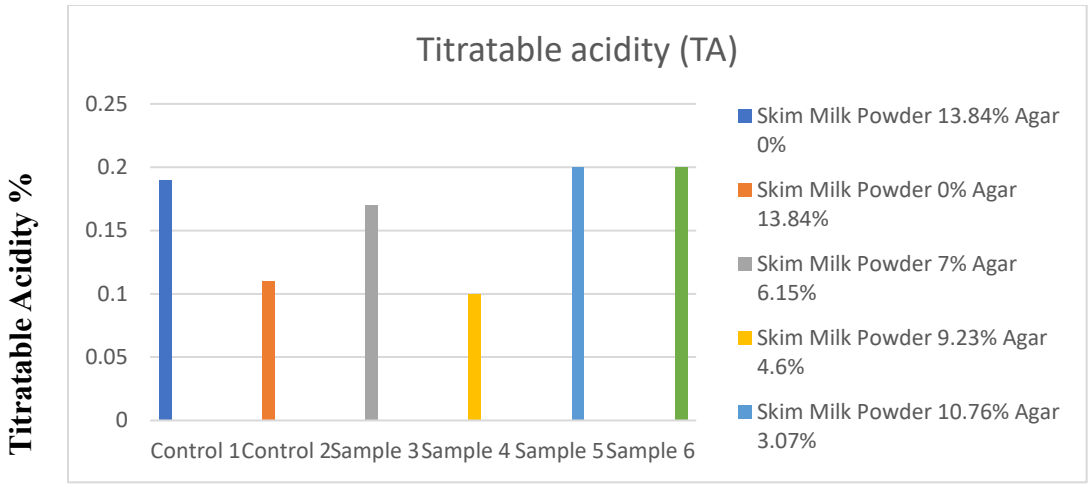


Fig 4.4 Titratable acidity (TA) in Yogurt Energy Bar samples

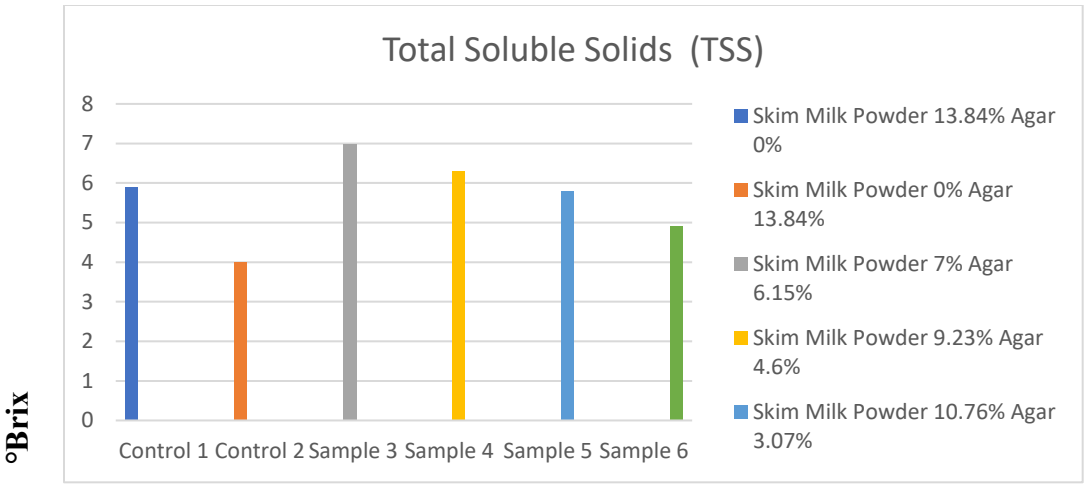
4.2.5 Total Soluble Solids (TSS)

Total Soluble Solids (TSS) is the concentration of all the soluble substances present in the Yogurt Energy Bar samples. TSS of 6 samples of the Yogurt Energy Bar was examined in the laboratory as shown in **Table 4.5.** TSS of the Yogurt Energy Bar samples ranged from 4.0±0.14 to 7.0±0.17 as shown in **Fig. 4.5**. Sample 3 had the highest TSS value of 7.0±0.17, whereas, Control 2 had the lowest TSS value of 4.0±0.14.

Table 4.5 Total Soluble Solids of Yogurt Energy Bar samples

Sample	Total Soluble Solids
Control 1: Skim Milk Powder 13.84% and Agar 0%	5.9±0.13
Control 2: Skim Milk Powder 0% and Agar 13.84%	4.0±0.14
Sample 3: Skim Milk Powder 7% and Agar 6.15%	7.0±0.17
Sample 4: Skim Milk Powder 9.23% and Agar 4.61%	6.3±0.50
Sample 5: Skim Milk Powder 10.76% and Agar 3.07%	5.8±0.52
Sample 6: Skim Milk Powder 12.30% and Agar 1.5%	4.9±0.57

Values are written as mean ± standard deviation



Yogurt Energy Bar samples

Fig 4.5 TSS of Yogurt Energy Bar samples

4.2.6 Fat Content

In a food product, Fat is the main constituent of the macronutrients along with protein, vitamins, minerals, and carbohydrates. The fat content of 6 samples of the Yogurt Energy Bar was determined and the result is shown in **Table 4.6.** The fat content in the samples of Yogurt Energy Bar ranged from 2.03±0.09 to 4.30±0.13 as shown in **Fig. 4.6**. The highest fat content was measured in Control 1 of 4.30±0.13, whereas, the lowest fat content was measured in Sample 4 of 2.03±0.09. Similar results were analyzed in the research of **Kulaitiene et al, 2021.**

Table 4.6 Fat Content in the Yogurt Energy Bar samples.

Sample	Fat Content (%)
Control 1: Skim Milk Powder 13.84% and Agar 0%	4.30±0.13
Control 2: Skim Milk Powder 0% and Agar 13.84%	3.11±0.22
Sample 3: Skim Milk Powder 7% and Agar 6.15%	2.75±0.19
Sample 4: Skim Milk Powder 9.23% and Agar 4.61%	2.03±0.09
Sample 5: Skim Milk Powder 10.76% and Agar 3.07%	2.28±0.22
Sample 6: Skim Milk Powder 12.30% and Agar 1.5%	2.57±0.30

Values are written as mean ± standard deviation

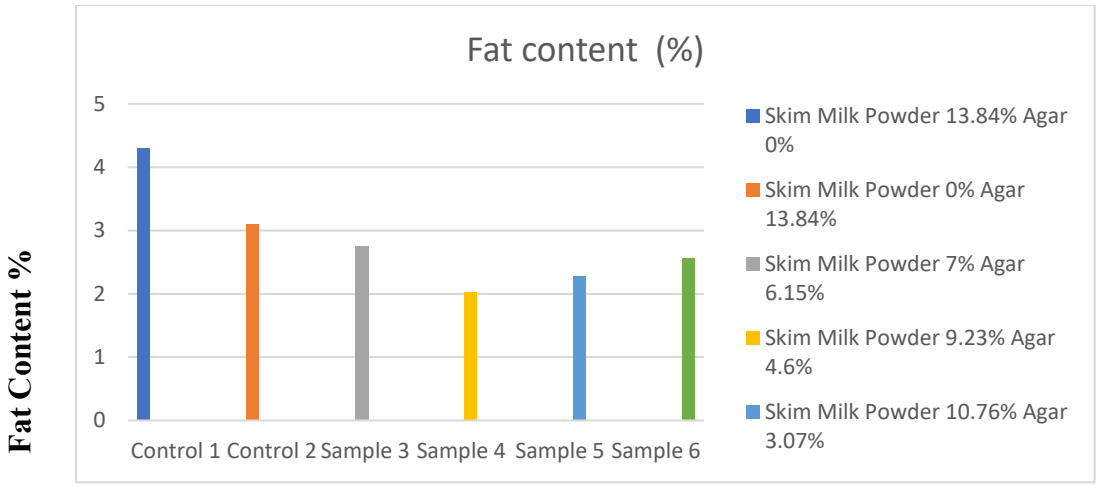


Fig. 4.6. Fat content of Yogurt Energy Bar samples

4.2.7 Protein Content

Protein is one of the most needed macronutrients during the consumption of any kind of food. It is a major nutrient for the growth of the human body. The protein content of 6 samples of Yogurt Energy Bars was analyzed as shown in **Table 4.7.** The results of the protein content present in the Yogurt Energy Bar ranged from 7.48±0.52 to 12.3±0.36. The highest protein content was measured in Sample 4 of 12.3±0.36, whereas, the lowest protein content was measured in Control 2 of 7.48±0.52. The protein content range of the Yogurt Energy Bar samples was shown in **Fig. 4.7.**

Table 4.7 Protein content of Yogurt Energy Bar samples

Sample	Protein Content (%)
Control 1: Skim Milk Powder 13.84% and Agar 0%	10.56±0.48
Control 2: Skim Milk Powder 0% and Agar 13.84%	7.48±0.10
Sample 3: Skim Milk Powder 7% and Agar 6.15%	8.21±0.52
Sample 4: Skim Milk Powder 9.23% and Agar 4.61%	12.3±0.36
Sample 5: Skim Milk Powder 10.76% and Agar 3.07%	9.04±0.14
Sample 6: Skim Milk Powder 12.30% and Agar 1.5%	9.96±0.11

Values are written as mean ± standard deviation

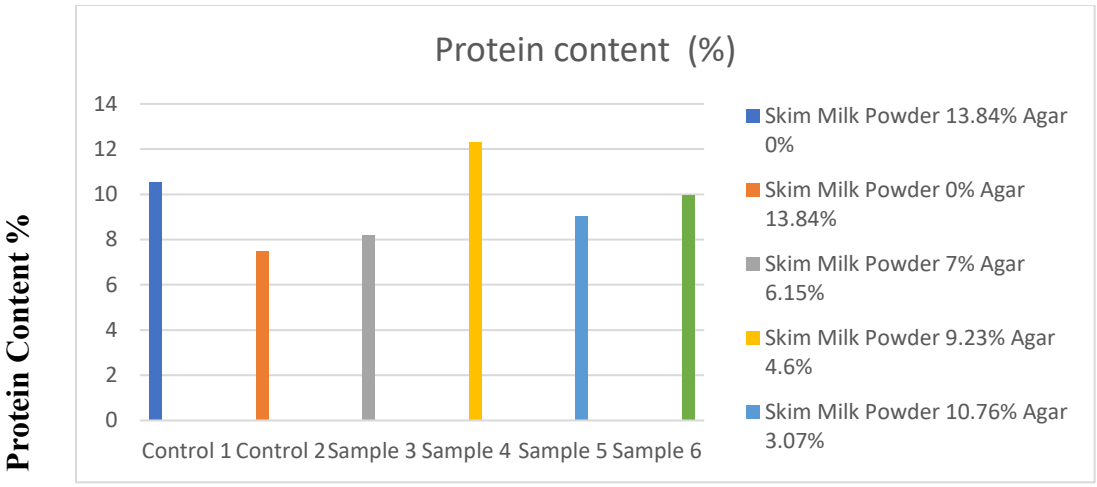


Fig. 4.7 Protein content of Yogurt Energy Bar samples

4.3 Phytochemical Analysis

4.3.1 Anti-oxidant Activity

Yogurt Energy Bar containing bioactive compounds was evaluated for anti-oxidant activity using the DPPH assay. 6 samples of Yogurt Energy Bar were analyzed for anti-oxidant activity. **Table 4.8** shows the value for the DPPH Anti-oxidant Activity. The samples were analyzed in triplicate. The Anti-oxidant activity ranged from 84.18±2.20 to 87.76±2.49. The highest Anti-oxidant activity was seen in Sample 4 of 87.76±2.49. The measured result was compared with the standard result of the absorbance of Ascorbic acid at 50% concentration as shown in **Fig.4.8.**

Table 4.8 DPPH Anti-oxidant of Yogurt Energy Bar samples

Sample	Anti-oxidant (%)
Control 1: Skim Milk Powder 13.84% and Agar 0%	86.00±0.72
Control 2: Skim Milk Powder 0% and Agar 13.84%	85.88±2.08
Sample 3: Skim Milk Powder 7% and Agar 6.15%	84.18±2.20
Sample 4: Skim Milk Powder 9.23% and Agar 4.61%	87.76±2.49
Sample 5: Skim Milk Powder 10.76% and Agar 3.07%	85.84±0.83
Sample 6: Skim Milk Powder 12.30% and Agar 1.5%	85.14±0.46

Values are written as mean ± standard deviation

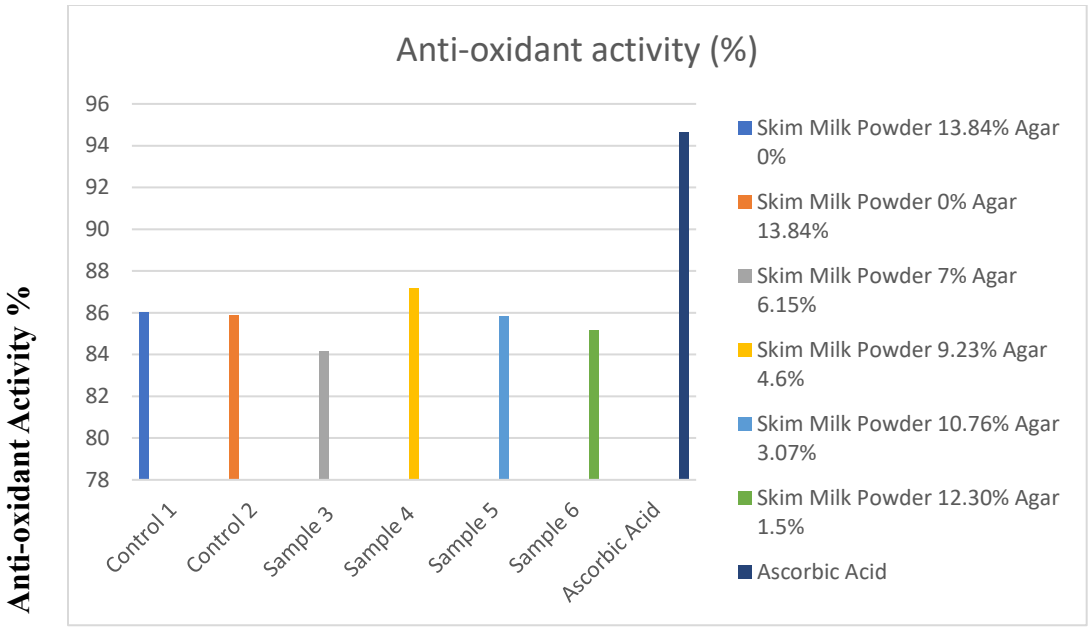


Fig.4.8. Anti-oxidant Activity of Yogurt Energy Bar samples

4.3.2 Total Phenolic Content (TPC)

Total Phenolic Content (TPC) was used to measure the total amount of Phenolic compound present in the Yogurt Energy Bar samples. The analysis was done using the Folin-ciocalteu reagent. 6 samples of Yogurt Energy Bars were analyzed as shown in **Table 4.9** and the value ranged from 47.00±7.5 to 64.57±9.33. The highest measured value of TPC was found in Sample 4 at 64.57±9.33, whereas, the lowest measured value of TPC was found in Control 2 at 47.00±7.5. The standard graph of Gallic Acid is shown in **Fig.4.9.** The range of the measured values of Total Phenolic Content in the Yogurt Energy Bar samples is shown in **Fig. 4.10.**

Table 4.9 Total Phenolic Content (TPC) of Yogurt Energy Bar samples

Sample	Total Phenolic Content
Control 1: Skim Milk Powder 13.84% and Agar 0%	54.06±5.12
Control 2: Skim Milk Powder 0% and Agar 13.84%	61.61±4.35
Sample 3: Skim Milk Powder 7% and Agar 6.15%	52.63±5.10
Sample 4: Skim Milk Powder 9.23% and Agar 4.61%	64.57±9.33
Sample 5: Skim Milk Powder 10.76% and Agar 3.07%	47.00±7.5
Sample 6: Skim Milk Powder 12.30% and Agar 1.5%	48.33±6.06

Values are written as mean ± standard deviation

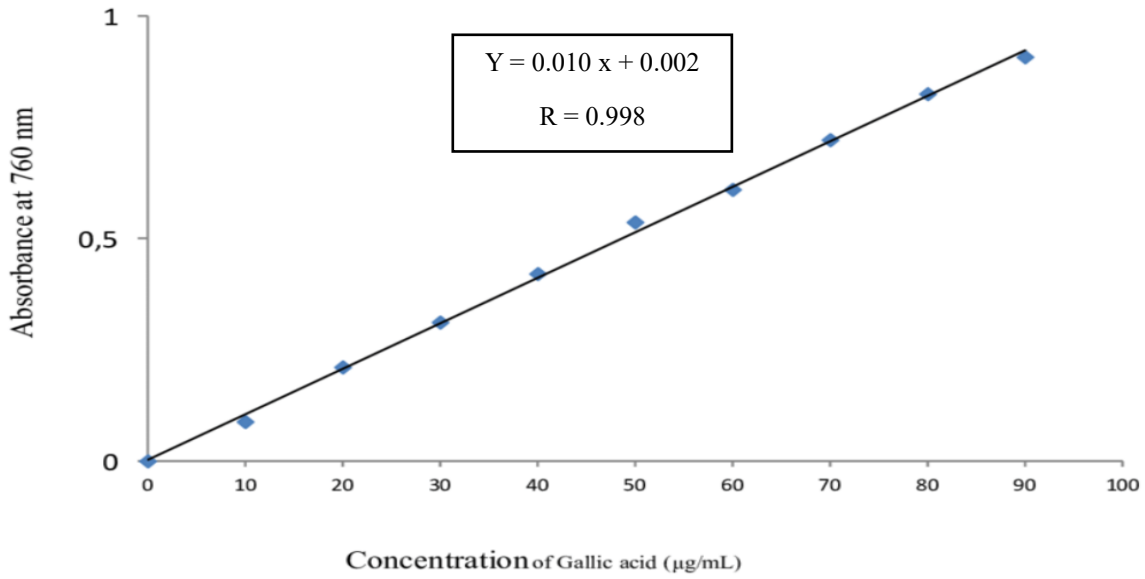


Fig. 4.9 Gallic Acid Standard Graph

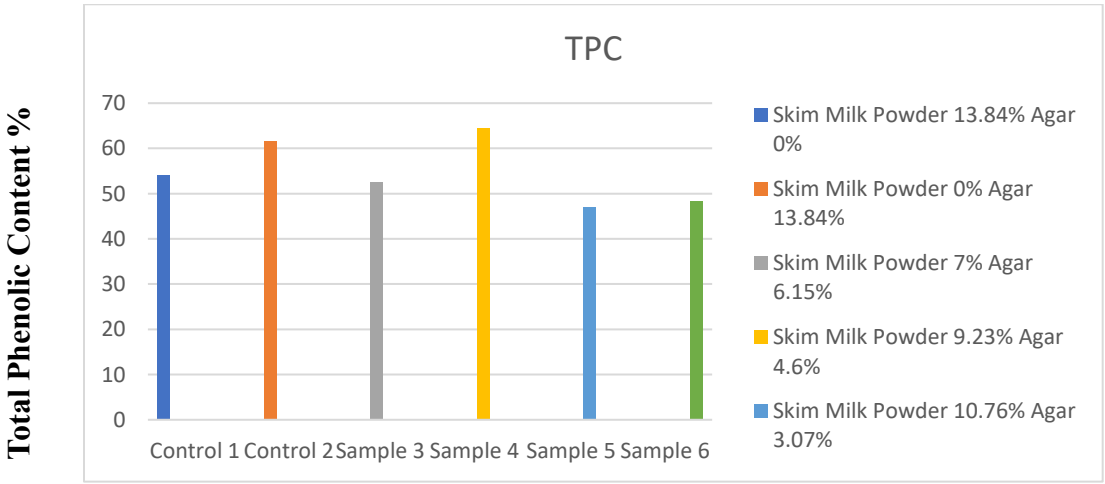


Fig. 4.10 Total Phenolic Content of Yogurt Energy Bar samples

4.4 Color Analysis

Color analysis is a technique for the determination of colored substances in a solution. A colorimeter is an apparatus that monitors light absorption at different wavelengths to estimate concentration. Color analysis of 6 samples were performed in the laboratory as shown in **Table 4.10** and **4.11.** L* value of Yogurt Layer of the Yogurt Energy Bar samples ranged from 58.32±1.46 to 77.40±1.16, as shown in **Fig.4.11_** with Sample 4 showing the lightest color

value amongst all the other samples. Sample 4 shows the value of 58.32±1.46. a* value of Yogurt Layer of the Yogurt Energy Bar samples, as shown in **Fig.4.12,** ranged from 3.25±0.17 to 4.86±0.22, with Sample 3 which was more towards red. b* value (yellowness) of Yogurt Layer of the Yogurt Energy Bar samples, as shown in **Fig.4.13,** ranged from 6.50±0.33 to 18.52±0.48. It was maximum in Control 1.

L* value of Barnyard millet layer of the Yogurt Energy Bar samples ranged from 21.26±1.18 to 34.49±0.86, in which Control 2 was showing the lightest color as shown in **Fig.4.14.** a* value of Barnyard Millet layer of the Yogurt Energy Bar samples ranged from 2.63±0.33 to 9.24±0.58, as shown in **Fig.4.15.** Sample 4 was more towards red. b* value (yellowness) of Barnyard Millet layer of the Yogurt Energy Bar samples ranged from 7.23±0.58 to 17.93±0.30, as shown in **Fig.4.16.** This value was maximum in Sample 4.

Table 4.10 Color Analysis of Yogurt Layer of Yogurt Energy Bar

Sample	L*	a*	b*
Control 1: Skim Milk Powder 13.84% and Agar 0%	61.8±1.53	3.98±0.53	18.52±0.48
Control 2: Skim Milk Powder 0% and Agar 13.84%	76.34±1.81	4.29±0.89	11.62±0.57
Sample 3: Skim Milk Powder 7% and Agar 6.15%	76.15±2.33	4.86±0.22	8.33±0.15
Sample 4: Skim Milk Powder 9.23% and Agar 4.61%	58.32±1.46	3.25±0.17	17.22±0.49
Sample 5: Skim Milk Powder 10.76% and Agar 3.07%	77.40±1.16	4.01±0.11	6.50±0.33
Sample 6: Skim Milk Powder 12.30% and Agar 1.5%	75.56±2.96	4.67±0.49	6.6±0.62

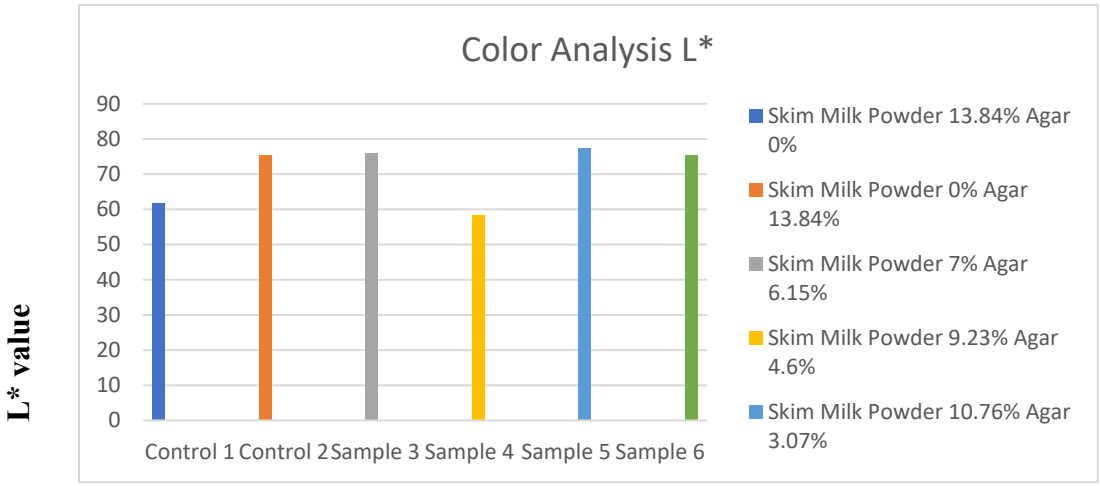
Values are written as mean ± standard deviation

Table 4.11 Color Analysis of Barnyard Millet Layer of Yogurt Energy Bar

Sample	L*	a*	b*
Control 1: Skim Milk Powder 13.84% and Agar 0%	34.49±0.86	4.07±0.20	7.76±0.22
Control 2: Skim Milk Powder 0% and Agar 13.84%	21.26±1.18	4.07±0.20	12.12±0.16
Sample 3: Skim Milk Powder 7% and Agar 6.15%	30.15±2.24	2.63±0.33	7.23±0.58
Sample 4: Skim Milk Powder 9.23% and Agar 4.61%	24.67±0.55	9.24±0.58	17.93±0.30

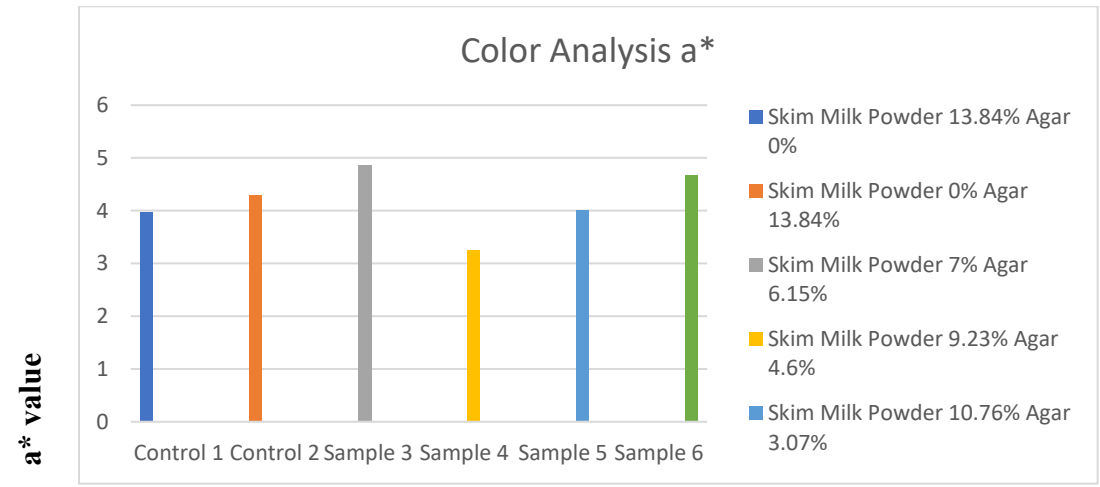
Sample 5: Skim Milk Powder 10.76% and Agar 3.07%	24.56±0.57	9.1±0.97	17.8±0.52
Sample 6: Skim Milk Powder 12.30% and Agar 1.5%	24.12±0.66	7.47±0.48	9.09±0.11

Values are written as mean ± standard deviation



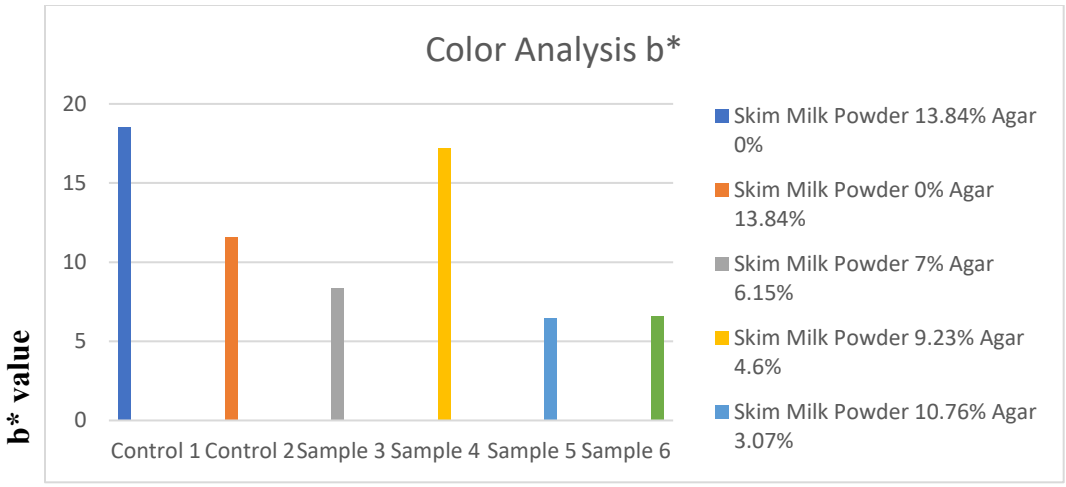
Yogurt Energy Bar samples

Fig. 4.11 L* value of Yogurt layer of Yogurt Energy Bar samples



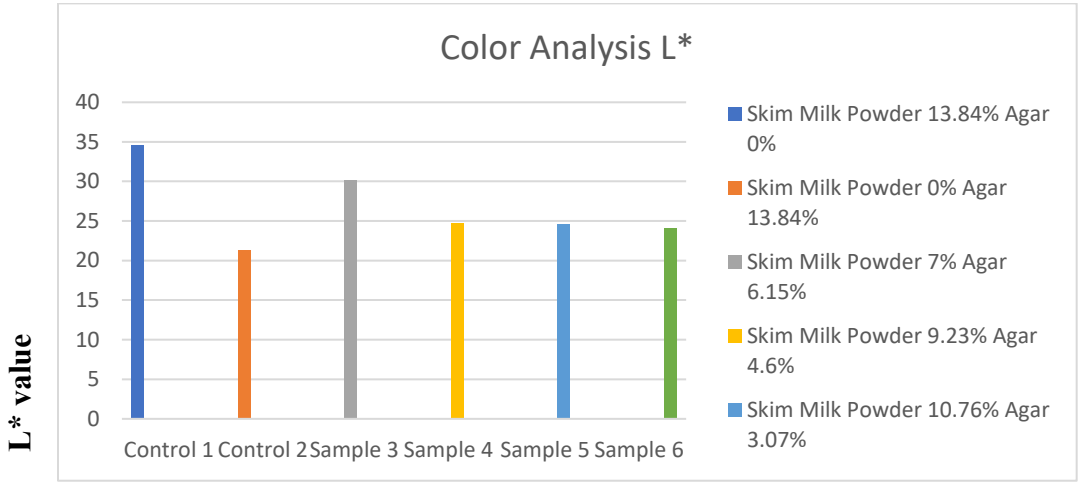
Yogurt Energy Bar samples

Fig. 4.12 a* value of Yogurt Layer of Yogurt Energy Bar samples



Yogurt Energy Bar samples

Fig. 4.13 b* values of Yogurt layer of Yogurt Energy Bar samples



Yogurt Energy Bar samples

Fig. 4.14 L* values of Barnyard Millet layer of Yogurt Energy Bar samples

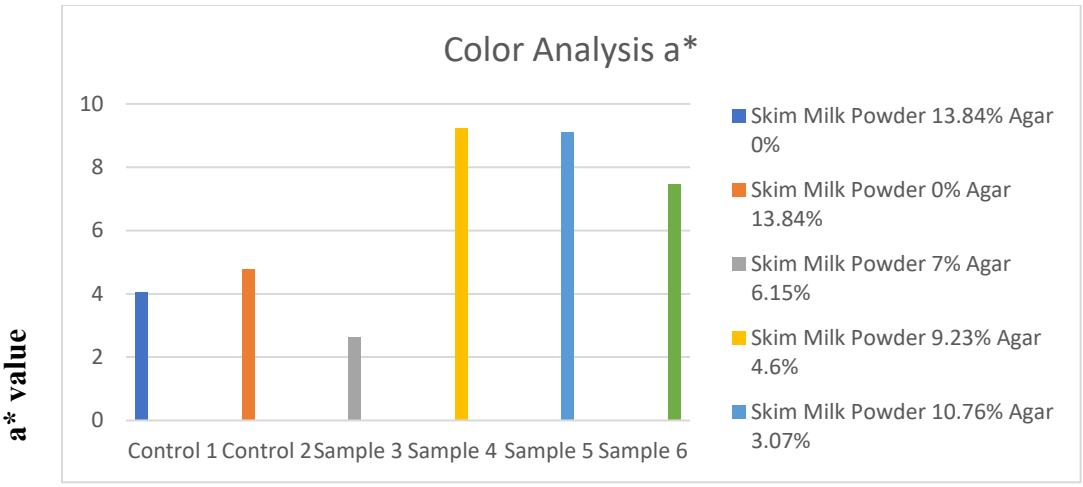


Fig. 4.15 a* values of Barnyard Millet layer of Yogurt Energy Bar samples

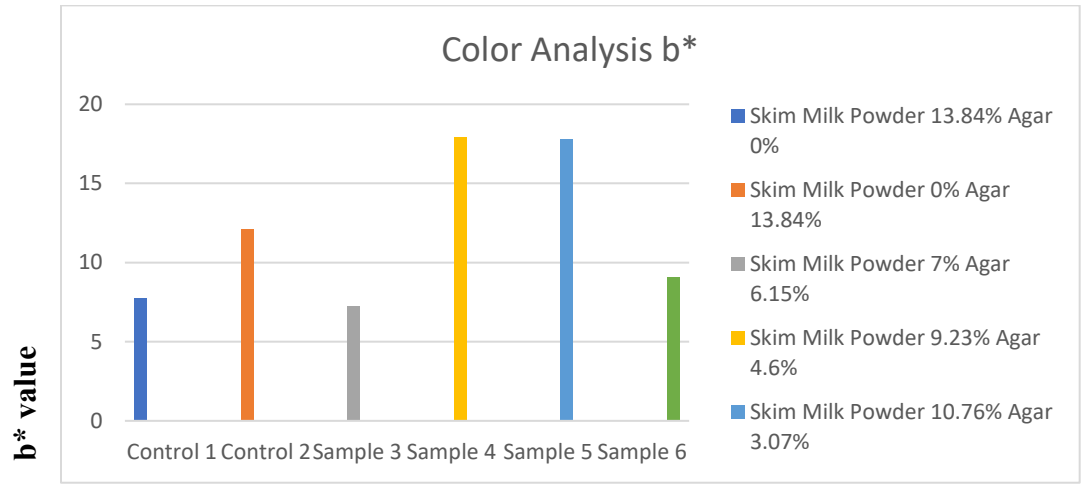


Fig. 4.16 b* values of Barnyard Millet layer of Yogurt Energy Bar samples

4.5 Sensory Analysis

Sensory Analysis is the most important parameter to be examined in a food product development process. 6 samples were examined for sensory analysis to analyze the best Yogurt Energy Bar sample. The sensory analysis was done using 9-scale Hedonic sensory evaluation in which 5 factors were considered: Color, Taste, Texture, Aroma, and Overall Acceptability. The samples were ranked according to the 9-0 (Like extremely to dislike extremely) Hedonic scale as shown in **Table 4.12.** Color Ranges from 6.1±0.35 to 8.49±0.33, as shown in **Fig.4.17.**

Texture ranges from 6.59±0.51 to 8.34±0.22, as shown in **Fig.4.18.** Taste ranges from 6.9±0.90 to 8.53±0.40, as shown in **Fig.4.19.** Aroma ranges from 7.43±0.40 to 8.51±0.46, as shown in **Fig.4.20.** And the overall acceptability of the Yogurt Energy Bar ranges from 6.92±0.70 to 8.46±0.08, as shown in **Fig.4.21.** According to the results analyzed by the sensory analysis through 9-scale hedonic sensory evaluation, Sample 4 seems to be the most palatable sample of the Yogurt Energy Bar.

Table 4.12 Sensory Analysis of Yogurt Energy Bar Samples on 9-Scale Hedonic sensory evaluation

Sample	Color	Texture	Taste	Aroma	Overall Acceptability
Control 1	7.00±0.1	6.6±0.49	6.9±0.90	7.96±0.15	7.11±0.20
Control 2	6.1±0.35	6.59±0.51	7.59±0.51	7.43±0.40	6.92±0.70
Sample 3	7.47±0.50	7.91±0.31	7.67±0.48	7.52±0.40	7.64±0.19
Sample 4	8.49±0.33	8.34±0.22	8.53±0.40	8.51±0.46	8.46±0.08
Sample 5	8.1±0.11	8.14±0.16	7.82±0.23	7.98±0.12	8.01±0.14
Sample 6	7.97±0.21	7.6±0.47	7.53±0.54	8.03±0.05	7.78±0.25

Values are written as mean ± standard deviation

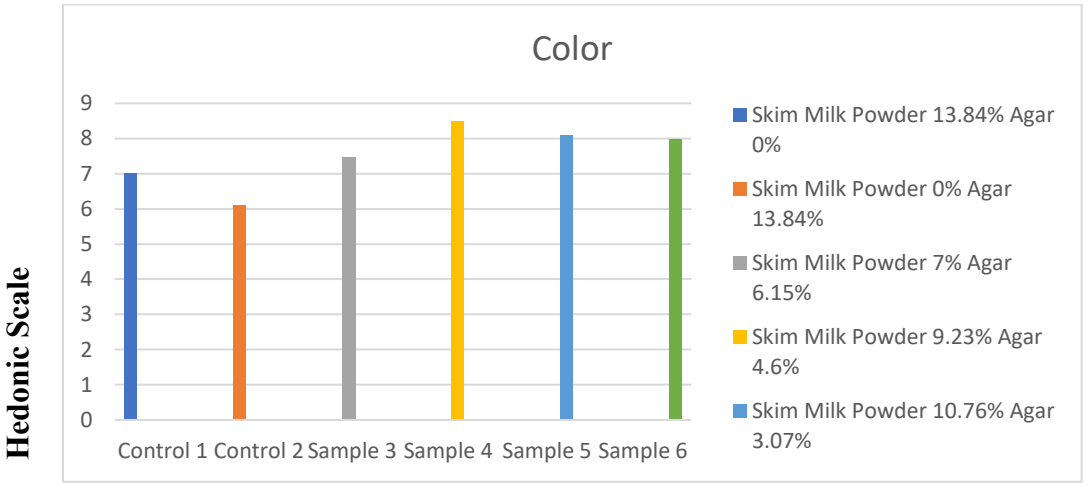
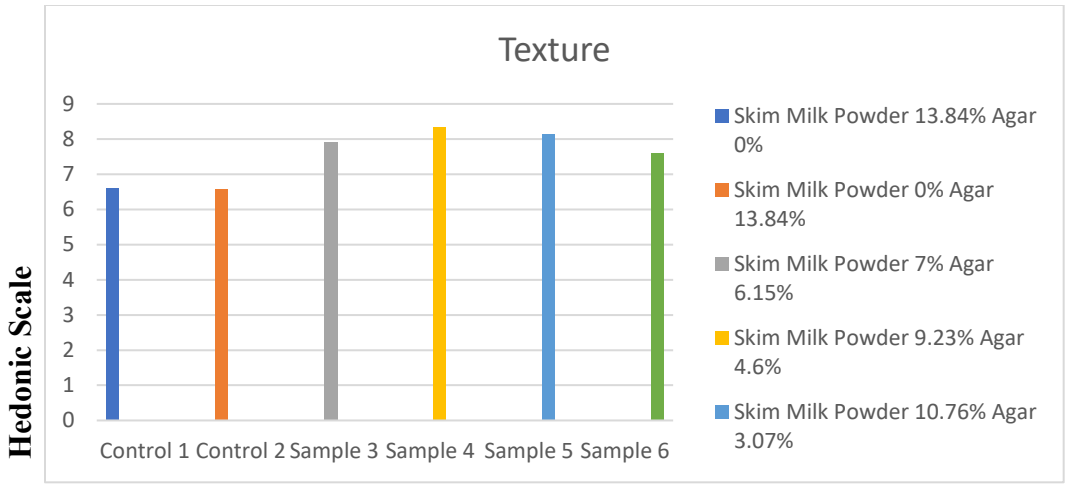
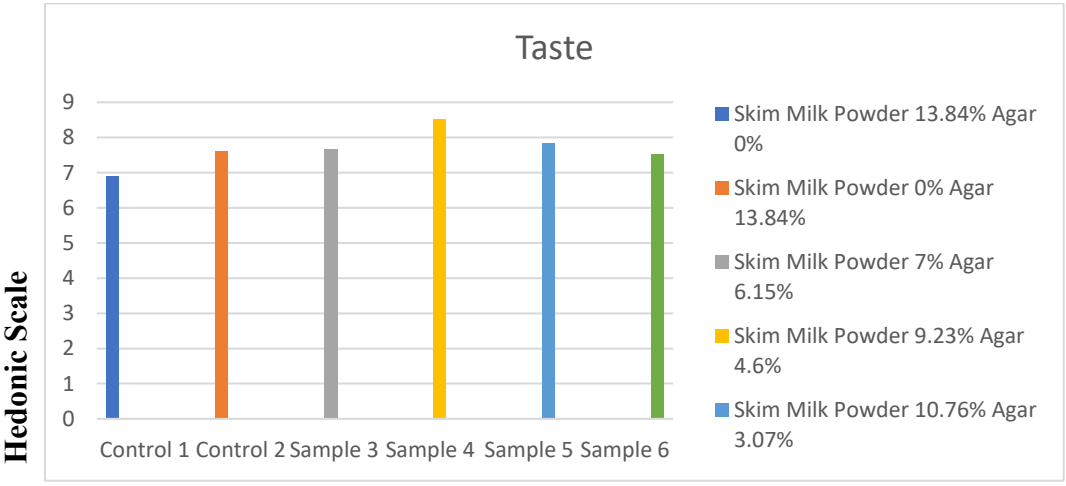


Fig.4.17 Color from sensory evaluation



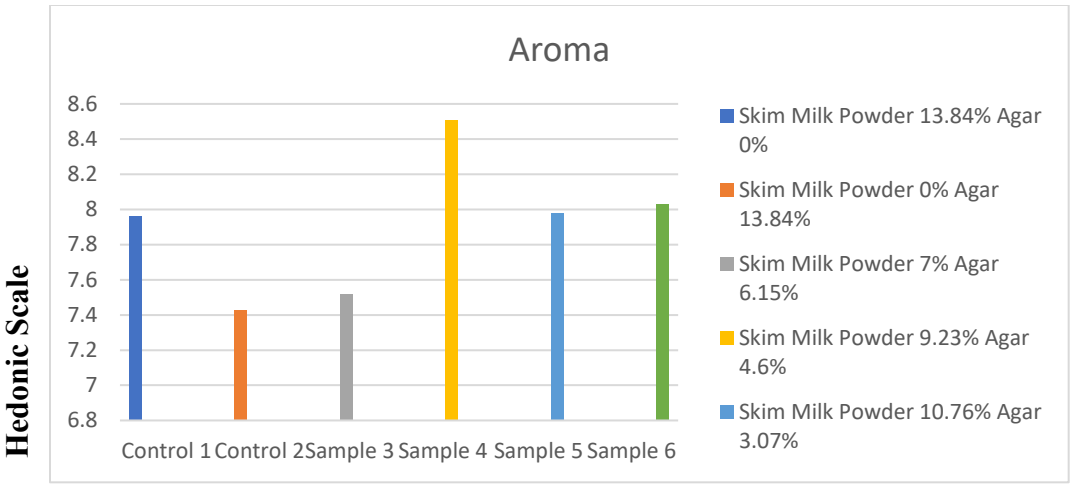
Yogurt Energy Bar samples

Fig.4.18 Texture from sensory evaluation



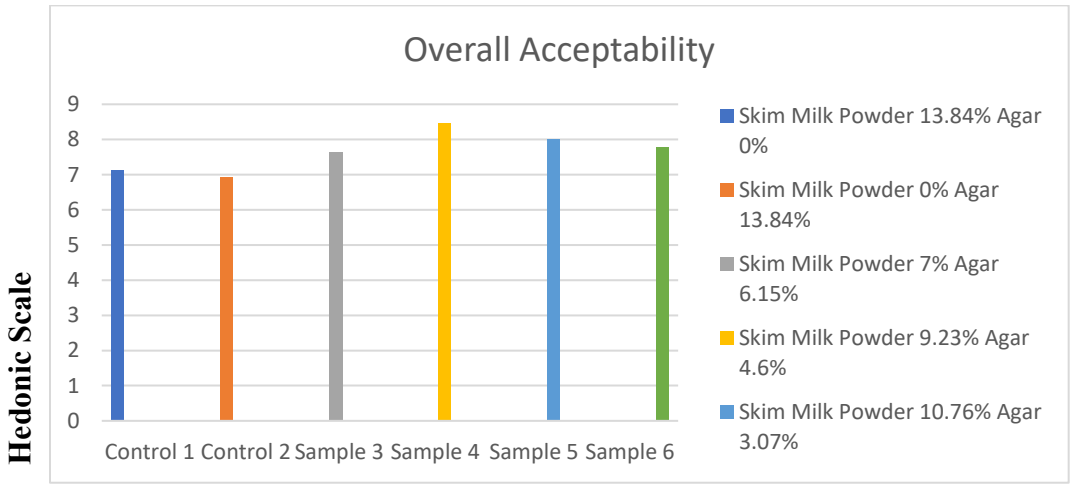
Yogurt Energy Bar samples

Fig.4.19 Taste from sensory evaluation



Yogurt Energy Bar samples

Fig.4.20 Aroma from sensory evaluation



Yogurt Energy Bar samples

Fig.4.21 Overall Acceptability from sensory evaluation

4.6 Storage Study of Yogurt Energy Bar

Storage study of the Yogurt Energy Bar samples was done using the sensory parameters for the analysis which took place from 0 to 90 days (3 Months). The sensory evaluation took place on the interval of every 15th day. Some minor changes were observed and noted in each Yogurt Energy Bar sample. These changes were dependent on the physical/chemical variations in the

composition of the Yogurt Energy Bar samples. Some changes were also noted due to the environmental condition.

4.6.1 0^{th} Day Analysis

Day 0 included freshly lyophilized Yogurt Energy Bar samples. 9-scale Hedonic Sensory evaluation was done for all the samples throughout the storage period, as shown in **Table. 4.13.** Color of the freshly prepared Yogurt Energy Bar samples ranged from 6.1±0.35 to 8.49±0.33, as shown in **Fig.4.22.** Sample 4 constituted the highest color score of 8.49±0.33. Texture ranged from 6.59±0.51 to 8.34±0.22, as shown in **Fig.4.23.** Sample 4 had the highest score of 8.34±0.22. Taste ranges from 6.9±0.90 to 8.53±0.40, as shown in **Fig.4.24.** Aroma ranges from 7.43±0.40 to 8.51±0.46, as shown in **Fig.4.25.** And the overall acceptability of the Yogurt Energy Bar ranges from 6.92±0.70 to 8.46±0.08, as shown in **Fig.4.26.**

Table 4.13. Sensory analysis of Yogurt Energy Bar on day 0

Sample	Color	Texture	Taste	Aroma	Overall Acceptability
Control 1	7.00±0.1	6.6±0.49	6.9±0.90	7.96±0.15	7.11±0.20
Control 2	6.1±0.35	6.59±0.51	7.59±0.51	7.43±0.40	6.92±0.70
Sample 3	7.47±0.50	7.91±0.31	7.67±0.48	7.52±0.40	7.64±0.19
Sample 4	8.49±0.33	8.34±0.22	8.53±0.40	8.51±0.46	8.46±0.08
Sample 5	8.1±0.11	8.14±0.16	7.82±0.23	7.98±0.12	8.01±0.14
Sample 6	7.97±0.21	7.6±0.47	7.53±0.54	8.03±0.05	7.78±0.25

Values are written as mean ± standard deviation

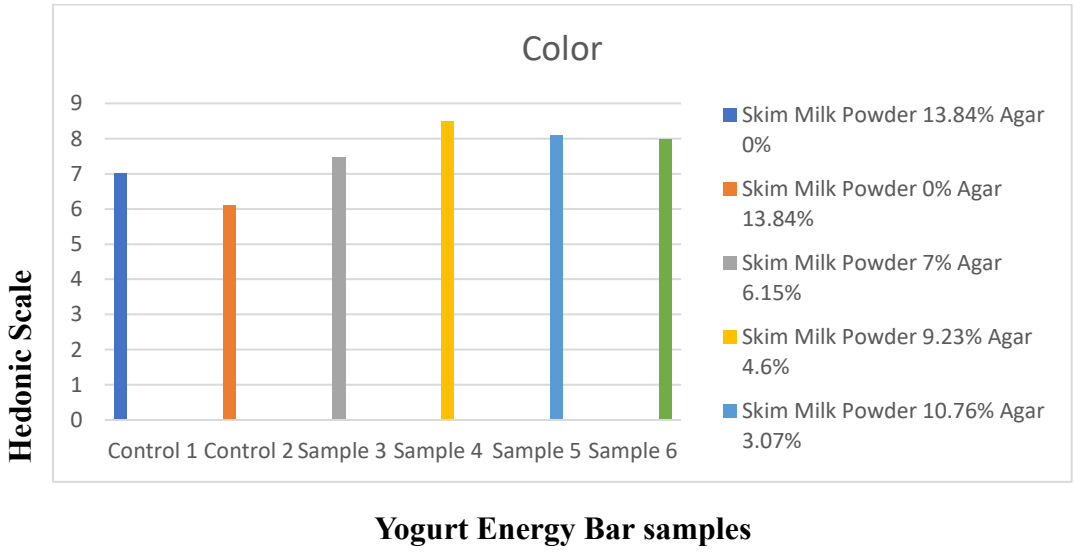
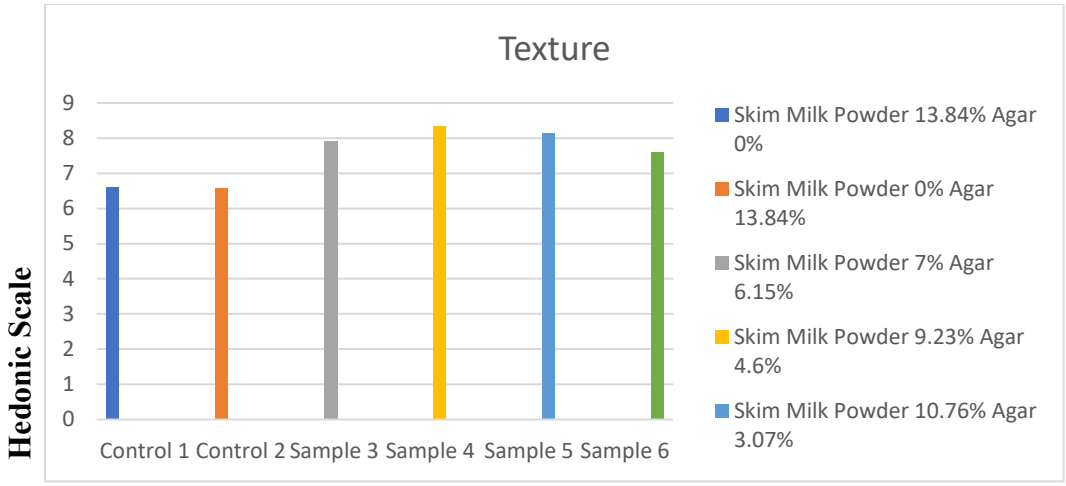
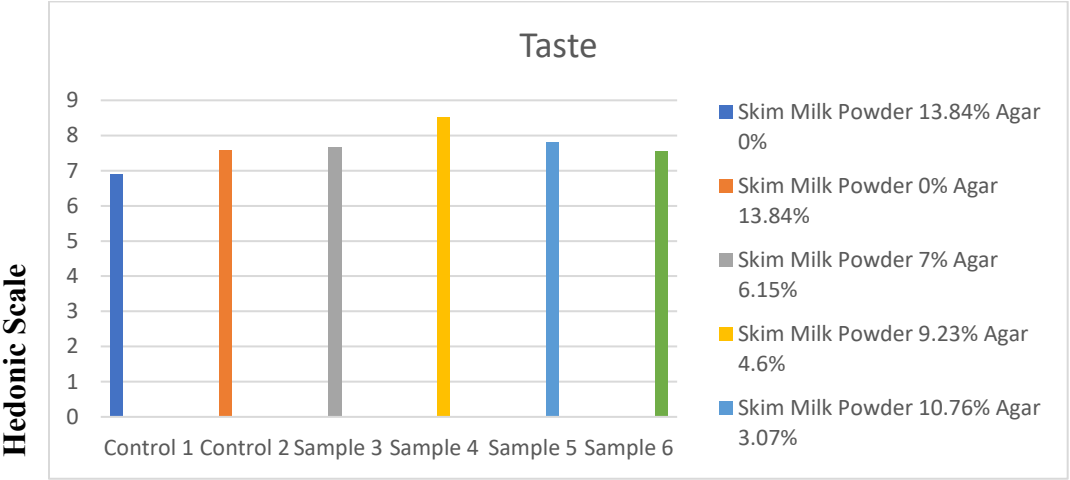


Fig. 4.22 Color on day 0



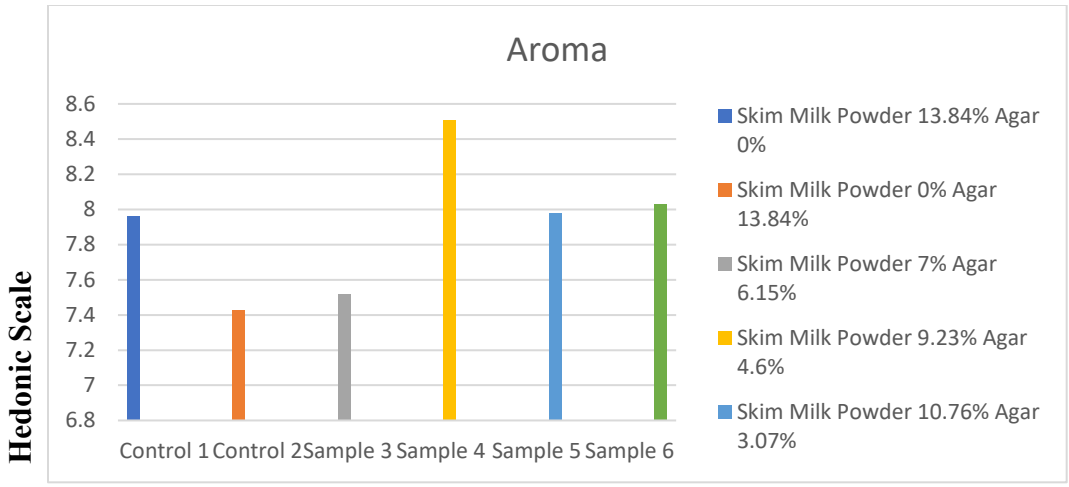
Yogurt Energy Bar samples

Fig.4.23 Texture on day 0



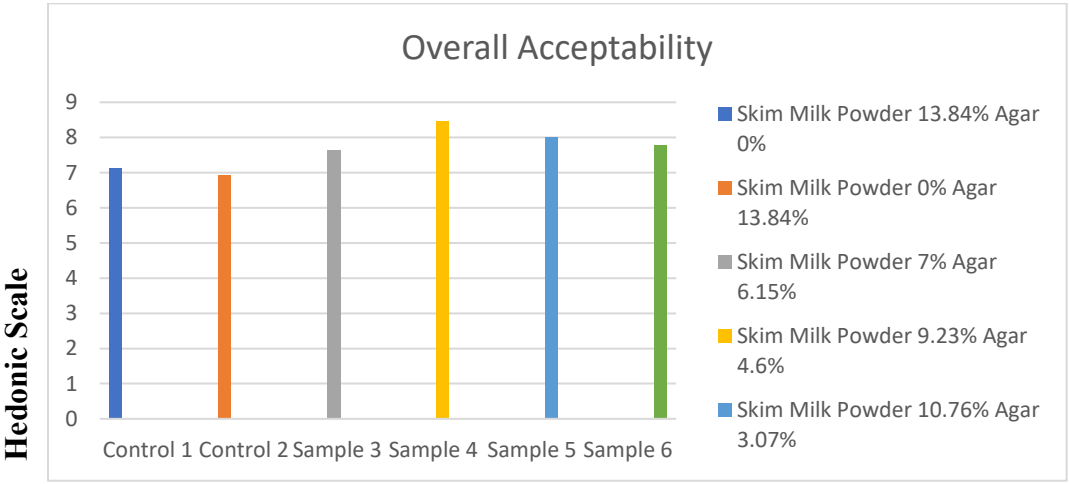
Yogurt Energy Bar samples

Fig.4.24 Taste on day 0



Yogurt Energy Bar samples

Fig.4.25 Aroma on day 0



Yogurt Energy Bar samples

Fig.4.26 Overall acceptability on day 0

4.6.2 15th Day analysis

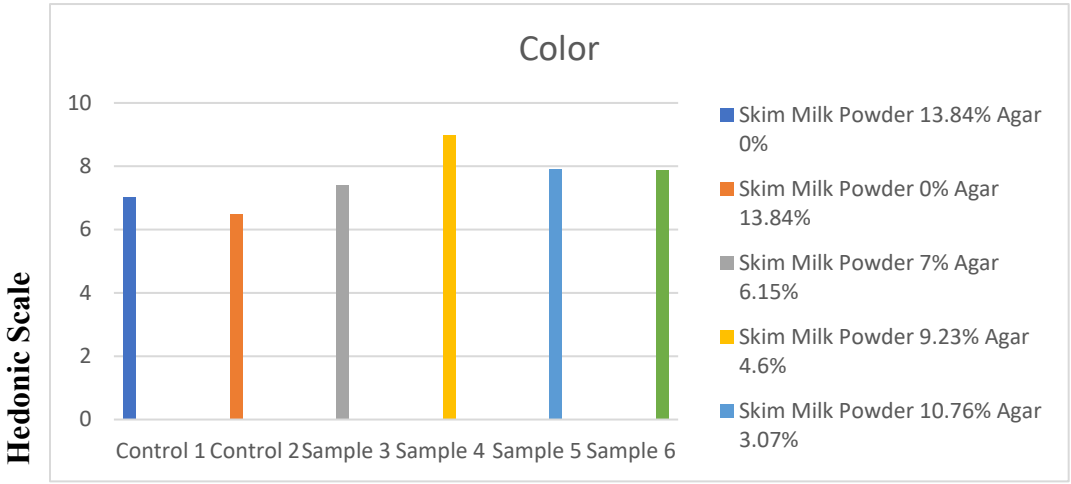
On day 15th the sensory analysis of Yogurt Energy Bar samples was analyzed as shown in **Table 4.14.** The color of the analyzed Yogurt Energy Bar samples ranged from 6.51±0.05 to 8.99±0.68, as shown in **Fig.4.27**. Texture of the Yogurt Energy Bar ranged from 6.03±0.11 to 8.54±0.54., as shown in **Fig.4.28.** Taste of the Yogurt Energy Bar ranged from 6.51±0.91 to 8.04±0.63, as shown in **Fig.4.29.** Aroma of the Yogurt Energy Bar ranged from 7.39±0.35 to

8.80±0.45, as shown in **Fig.4.30.** Overall acceptability of the Yogurt Energy Bar ranged from 6.50±0.69 to 8.92±0.05, as shown in **Fig.4.31.**

Table 4.14. Sensory analysis of Yogurt Energy Bar on day 15

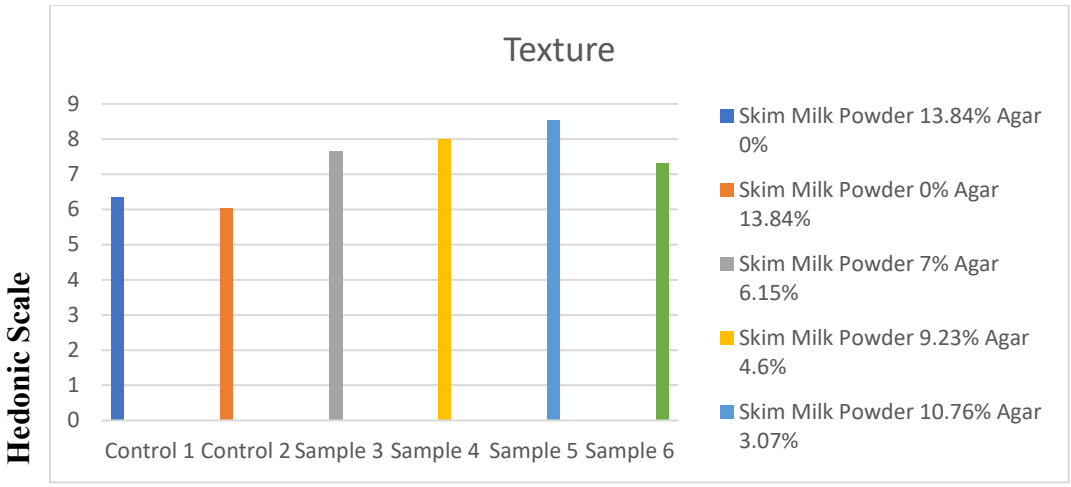
Sample	Color	Texture	Taste	Aroma	Overall Acceptability
Control 1	7.03±0.22	6.36±0.67	6.51±0.91	7.90±0.11	7.10±0.21
Control 2	6.51±0.05	6.03±0.11	7.89±0.72	7.39±0.35	6.50±0.69
Sample 3	7.40±0.51	7.65±0.04	7.64±0.65	7.40±0.42	7.64±0.57
Sample 4	8.99±0.68	8.00±0.31	8.04±0.63	8.80±0.45	8.92±0.05
Sample 5	7.92±0.09	8.54±0.54	7.81±0.20	7.92±0.15	8.23±0.18
Sample 6	7.89±0.28	7.32±0.60	7.06±0.71	8.23±0.01	7.83±0.35

Values are written as mean ± standard deviation



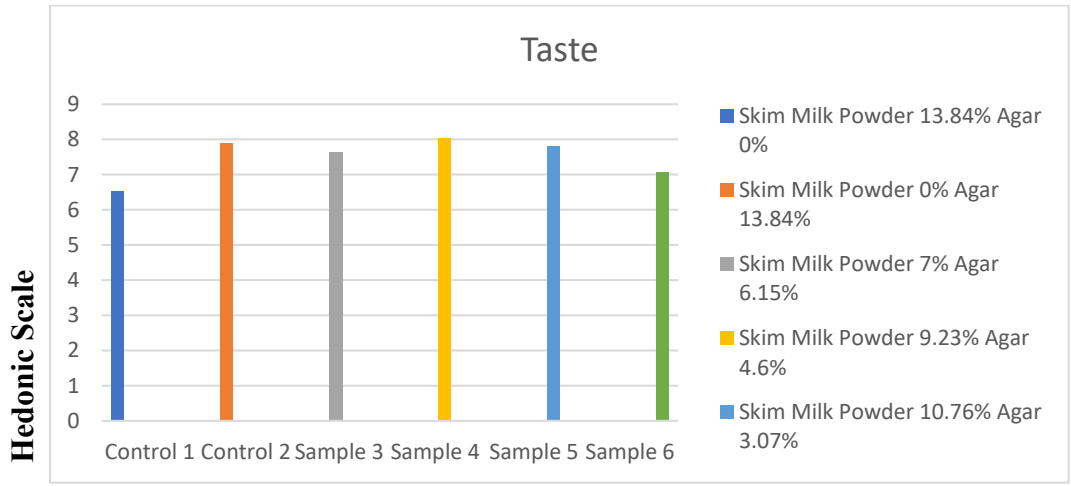
Yogurt Energy Bar samples

Fig.4.27 Color on day 15



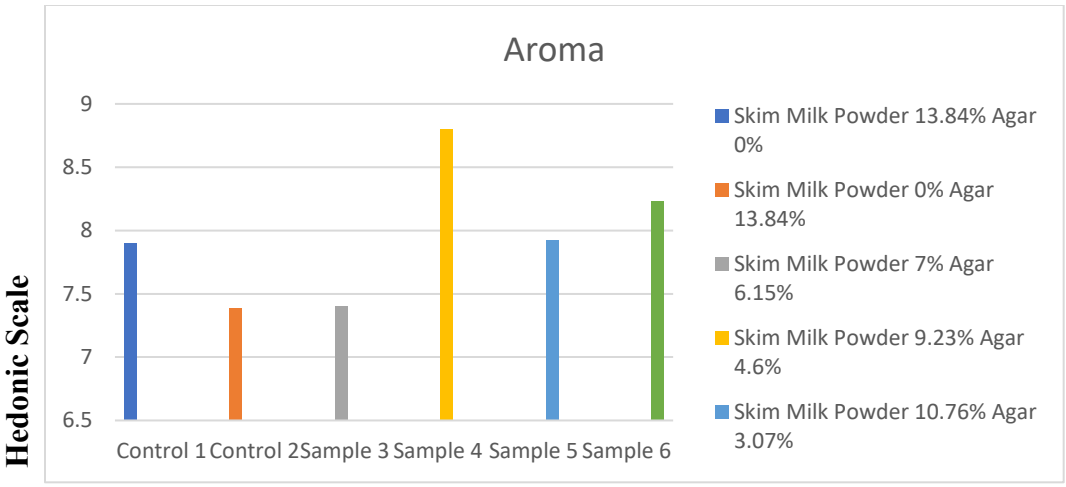
Yogurt Energy Bar samples

Fig.4.28 Texture on day 15



Yogurt Energy Bar samples

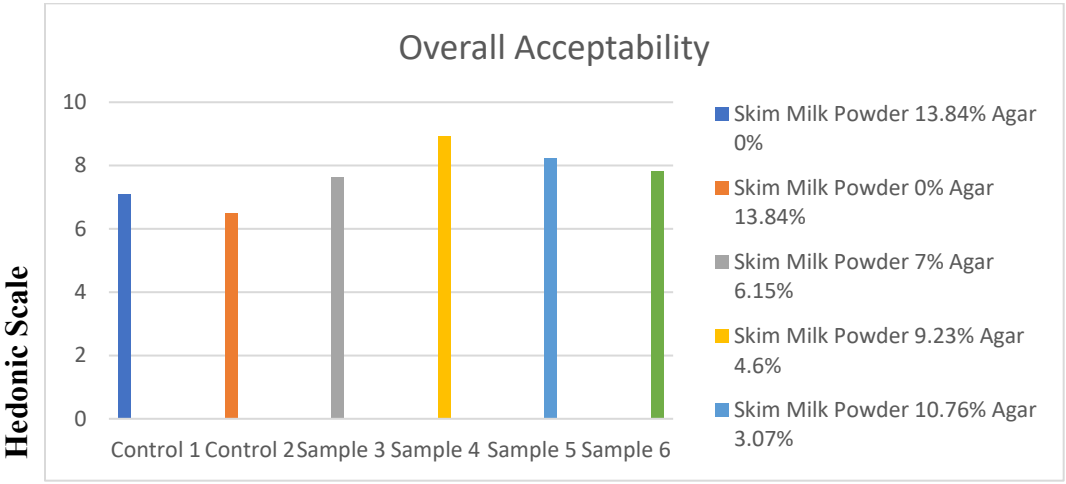
Fig.4.29 Taste on day 15



Hedonic Scale

Yogurt Energy Bar samples

Fig.4.30 Aroma on day 15



Hedonic Scale

Yogurt Energy Bar samples

Fig.4.31 Overall acceptability on day 15

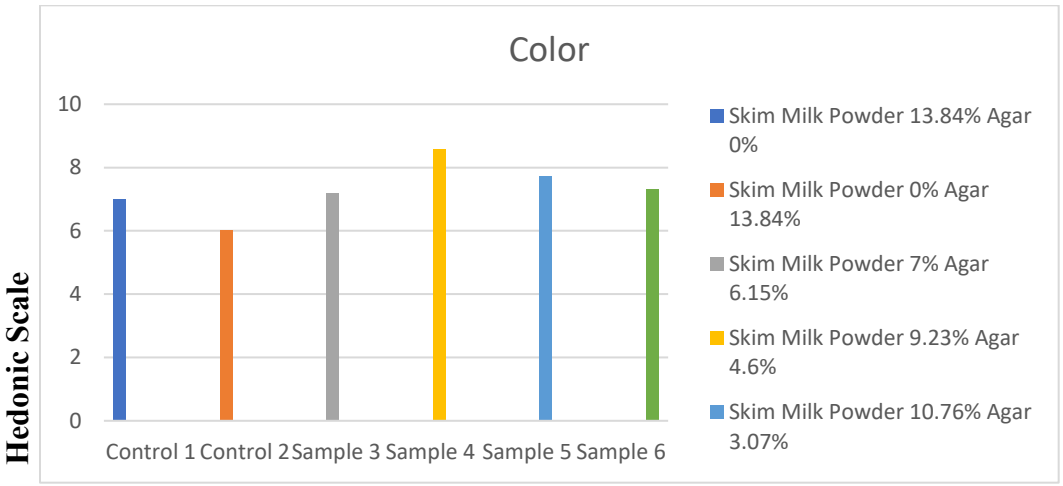
4.6.3 30th Day analysis

On day 30th the sensory analysis result is shown in **Table 4.15.** Color analysis ranged from 6.01±0.18 to 8.58±0.82, as shown in **Fig. 4.32.** Texture ranged from 6.00±0.11 to 8.34±0.56, as shown in **Fig.4.33.** Taste ranged from 6.49±0.89 to 8.00±0.59, as shown in **Fig.4.34.** Aroma ranged from 7.16±0.34 to 8.01±0.30, as shown in **Fig.4.35.** Overall acceptability ranged from 6.58±0.32 to 8.21±0.01, as shown in **Fig.4.36.**

Table 4.15. Sensory analysis of Yogurt Energy Bar on day 30

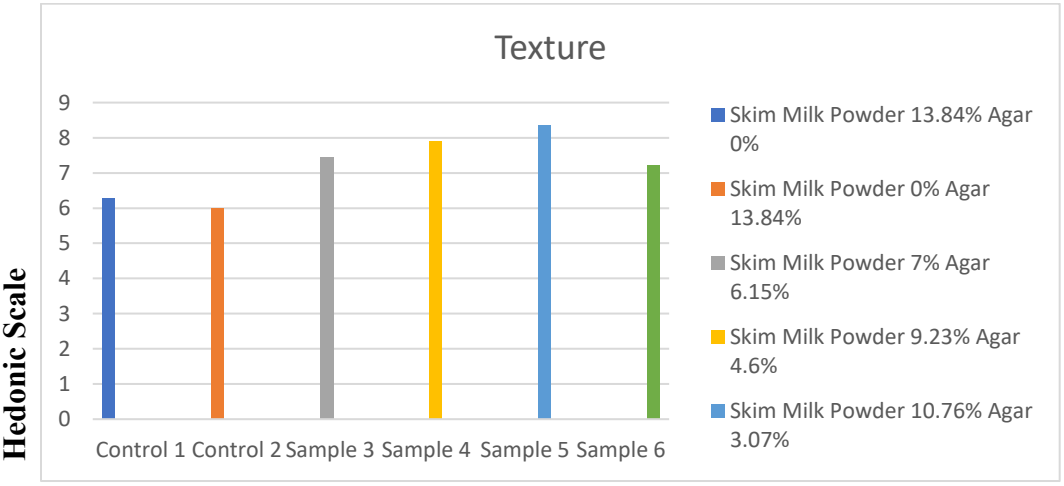
Sample	Color	Texture	Taste	Aroma	Overall Acceptability
Control 1	7.00±0.12	6.29±0.50	6.49±0.89	7.59±0.05	7.00±0.01
Control 2	6.01±0.18	6.00±0.11	7.00±0.58	7.23±0.28	6.58±0.32
Sample 3	7.20±0.52	7.45±0.01	7.53±0.34	7.16±0.34	7.30±0.30
Sample 4	8.58±0.82	7.90±0.20	8.00±0.59	8.01±0.30	8.21±0.01
Sample 5	7.73±0.56	8.34±0.56	7.30±0.12	7.50±0.10	8.00±0.11
Sample 6	7.30±0.56	7.21±0.58	6.98±0.39	7.98±0.02	7.43±0.20

Values are written as mean ± standard deviation



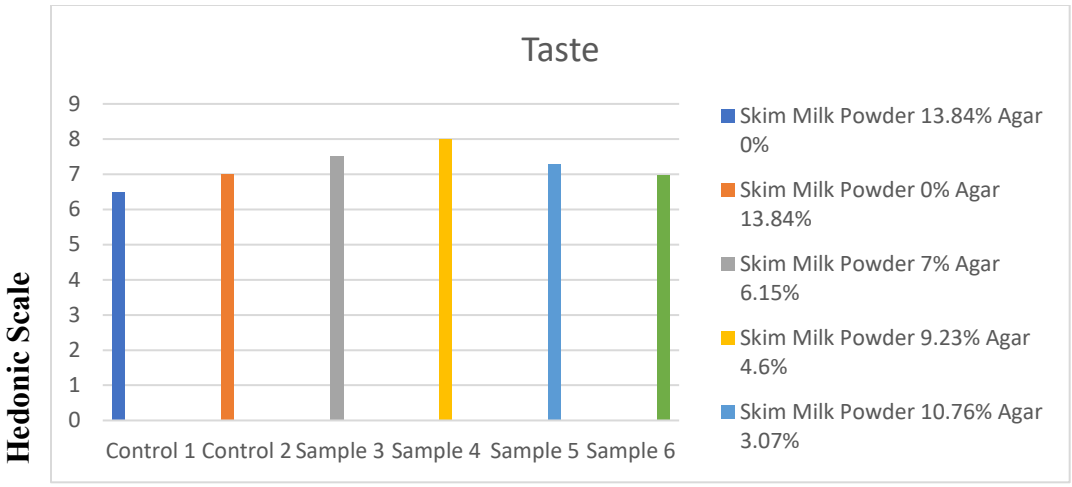
Yogurt Energy Bar samples

Fig.4.32 Color on day 30



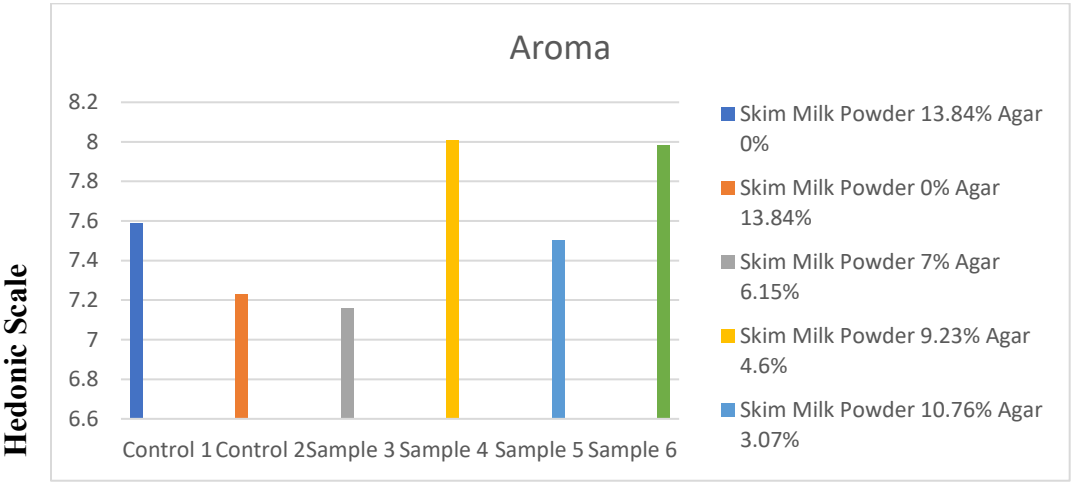
Yogurt Energy Bar samples

Fig.4.33 Texture on day 30



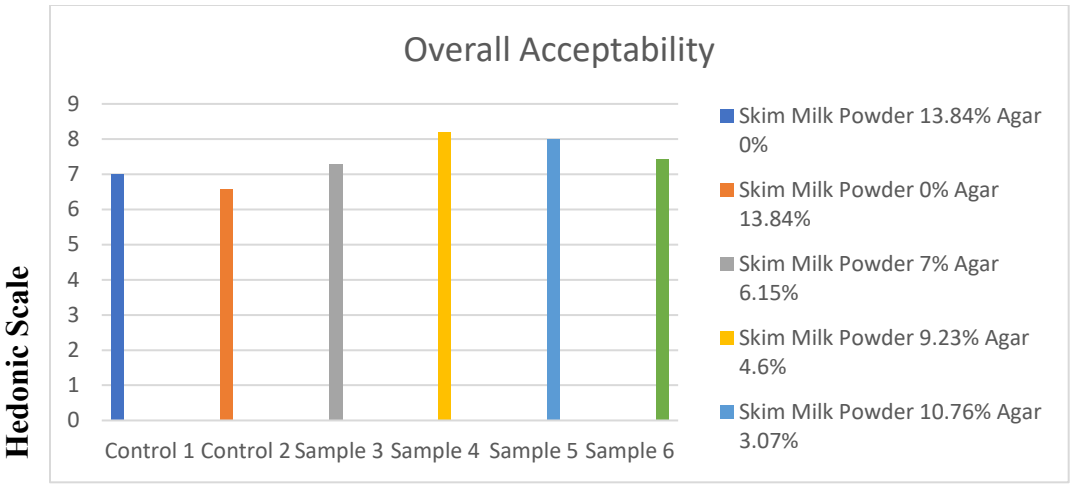
Yogurt Energy Bar samples

Fig.4.34 Taste on day 30



Yogurt Energy Bar samples

Fig.4.35 Aroma on day 30



Yogurt Energy Bar samples

Fig.4.36 Overall acceptability on day 30

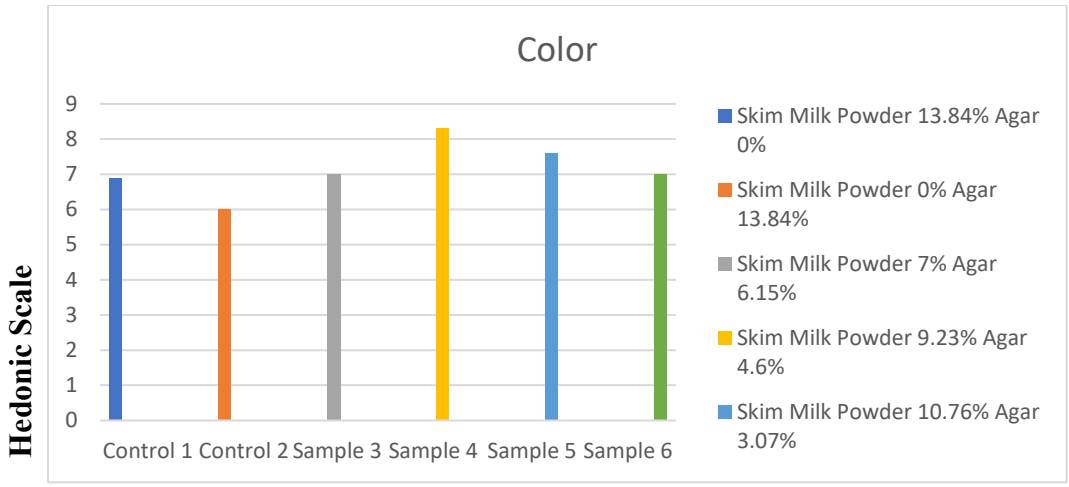
4.6.4 45th Day analysis

On day 45th the sensory analysis result is shown in **Table 4.16.** Color analysis ranged from 6.00±0.72 to 8.31±0.12, as shown in **Fig. 4.37.** Texture ranged from 6.00±0.30 to 8.23±0.50, as shown in **Fig.4.38.** Taste ranged from 6.32±0.6 0to 7.93±0.43, as shown in **Fig.4.39.** Aroma ranged from 7.00±0.60 to 8.00±0.29, as shown in **Fig.4.40.** Overall acceptability ranged from 6.30±0.29 to 8.01±0.05, as shown in **Fig.4.41.**

Table 4.16. Sensory analysis of Yogurt Energy Bar on day 45

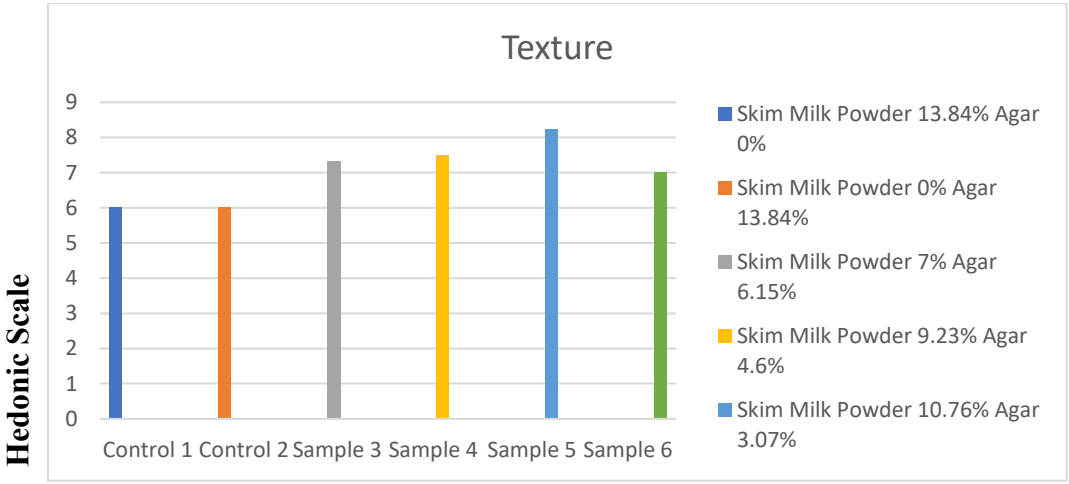
Sample	Color	Texture	Taste	Aroma	Overall Acceptability
Control 1	6.89±0.59	6.01±0.49	6.32±0.60	7.40±0.01	6.87±0.01
Control 2	6.00±0.72	6.00±0.30	7.00±0.40	7.10±0.49	6.30±0.29
Sample 3	7.01±0.13	7.31±0.05	7.27±0.24	7.00±0.60	7.20±0.07
Sample 4	8.31±0.12	7.50±0.19	7.93±0.43	8.00±0.29	8.01±0.05
Sample 5	7.59±0.40	8.23±0.50	7.21±0.10	7.30±0.10	8.00±0.10
Sample 6	7.00±0.31	7.01±0.18	6.70±0.20	7.40±0.02	7.40±0.11

Values are written as mean ± standard deviation



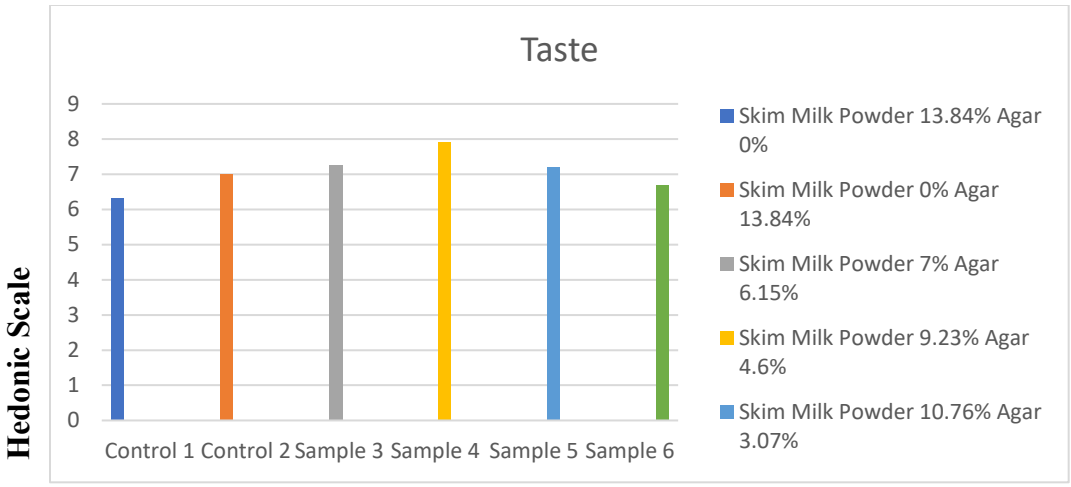
Yogurt Energy Bar samples

Fig.4.37 Color on day 45



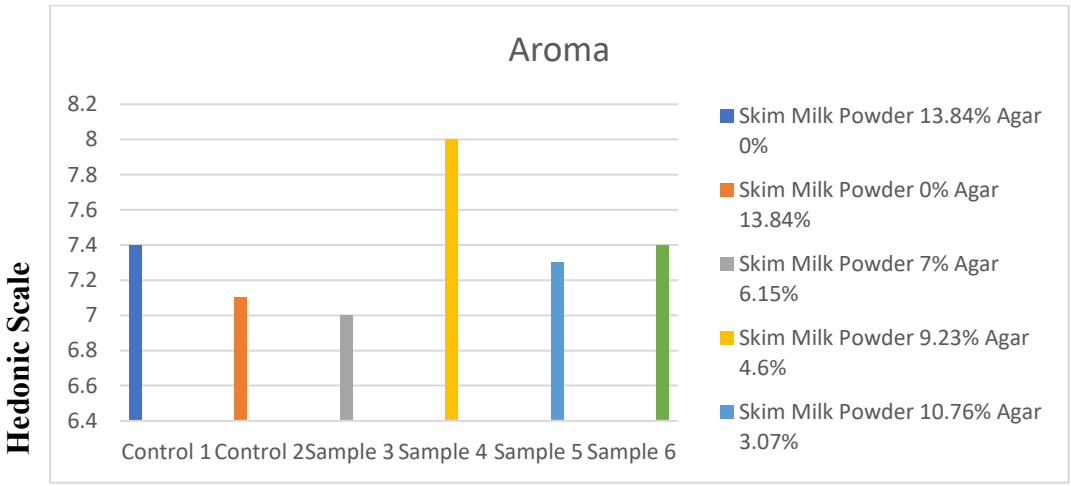
Yogurt Energy Bar samples

Fig.4.38 Texture on day 45



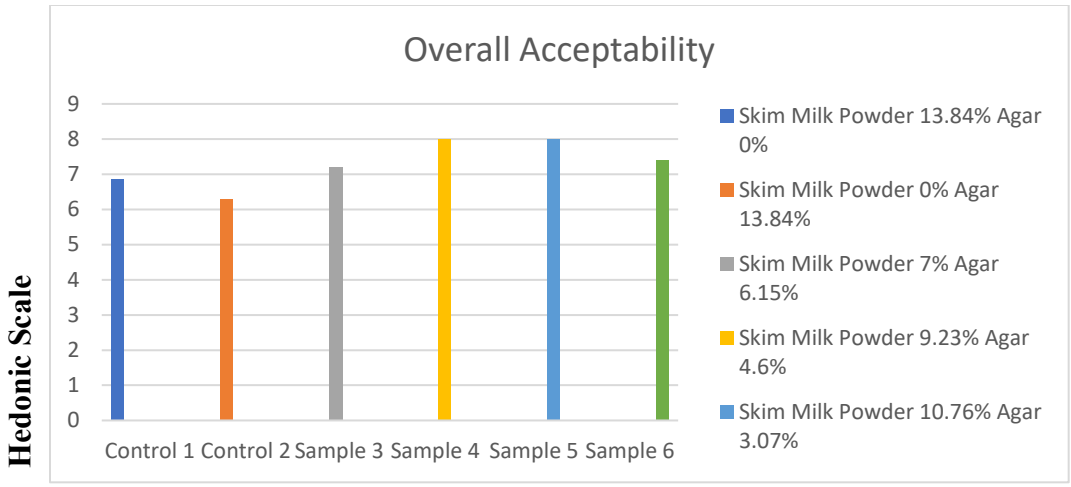
Yogurt Energy Bar samples

Fig.4.39 Taste on day 45



Yogurt Energy Bar samples

Fig.4.40 Aroma on day 45



Yogurt Energy Bar samples

Fig.4.41 Overall acceptability on day 45

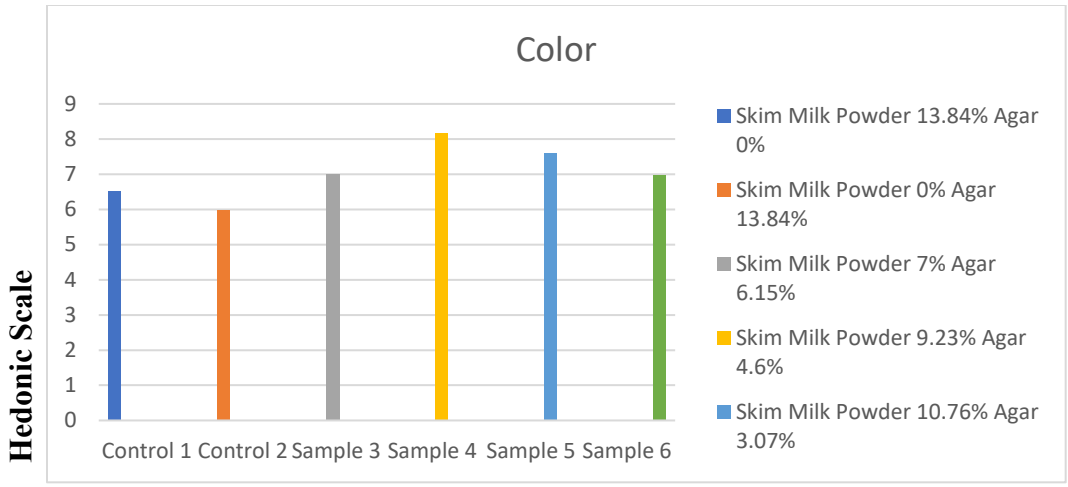
4.6.5 60th Day analysis

On day 60th the sensory analysis result is shown in **Table 4.17.** Color analysis ranged from 5.98±0.67 to 8.17±0.76, as shown in **Fig. 4.42.** Texture ranged from 6.00±0.13 to 8.12±0.08, as shown in **Fig.4.43.** Taste ranged from 6.21±0.54 to 7.67±0.34, as shown in **Fig.4.44.** Aroma ranged from 6.67±0.01to 7.98±0.73, as shown in **Fig.4.45**. Overall acceptability ranged from 6.12±0.13 to 7.80±0.06, as shown in **Fig.4.46.**

Table 4.17 Sensory analysis of Yogurt Energy Bar on day 60

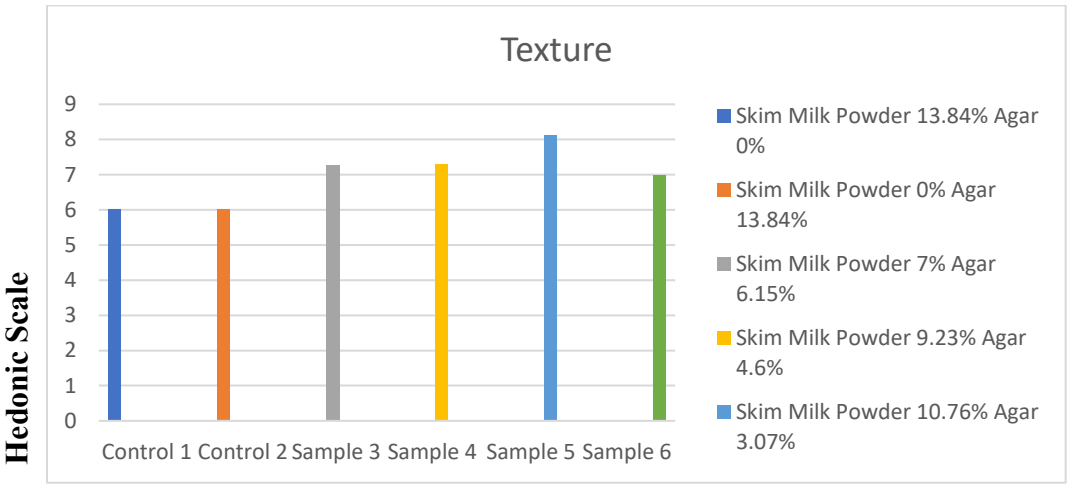
Sample	Color	Texture	Taste	Aroma	Overall Acceptability
Control 1	6.53±0.87	6.00±0.32	6.21±0.54	7.11±0.01	6.60±0.06
Control 2	5.98±0.67	6.00±0.13	6.94±0.59	7.05±0.74	6.12±0.13
Sample 3	7.00±0.23	7.26±0.54	7.12±0.48	6.67±0.01	7.11±0.01
Sample 4	8.17±0.76	7.28±0.91	7.67±0.34	7.98±0.73	7.68±0.02
Sample 5	7.60±0.98	8.12±0.08	7.12±0.18	7.20±0.30	7.80±0.06
Sample 6	6.98±0.02	6.98±0.11	6.30±0.20	7.21±0.05	7.46±0.10

Values are written as mean ± standard deviation



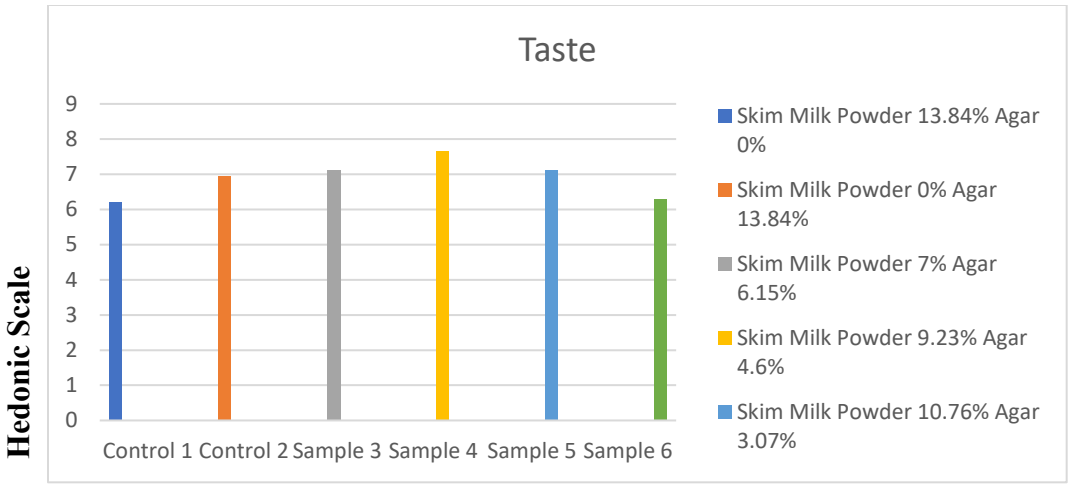
Yogurt Energy Bar samples

Fig.4.42 Color on day 60



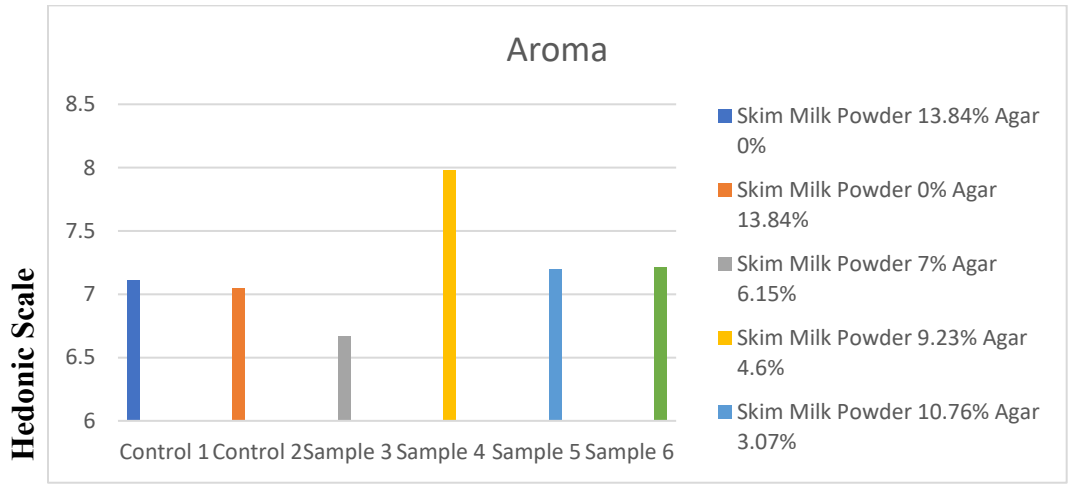
Yogurt Energy Bar samples

Fig.4.43 Texture on day 60



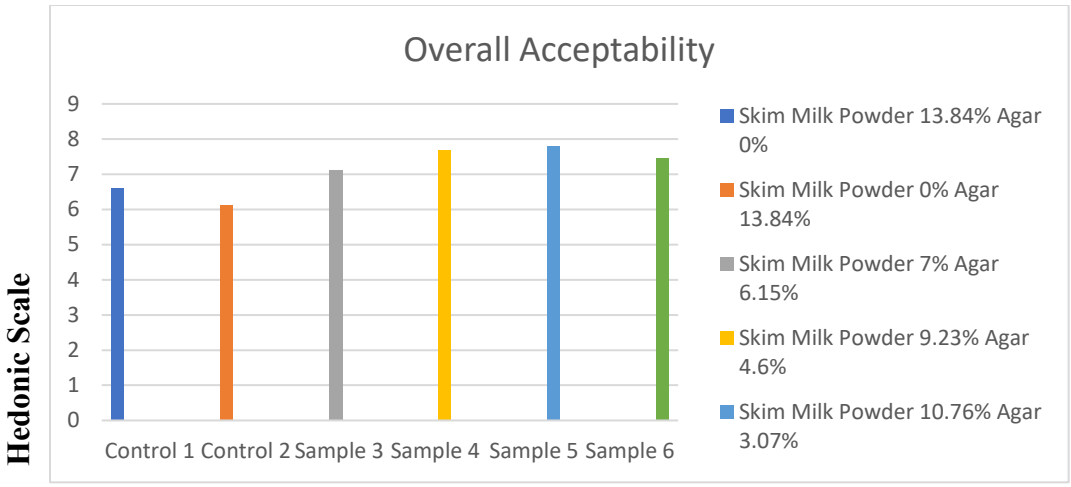
Yogurt Energy Bar samples

Fig.4.44 Taste on day 60



Yogurt Energy Bar samples

Fig.4.45 Aroma on day 60



Yogurt Energy Bar samples

Fig.4.46 Overall acceptability on day 60

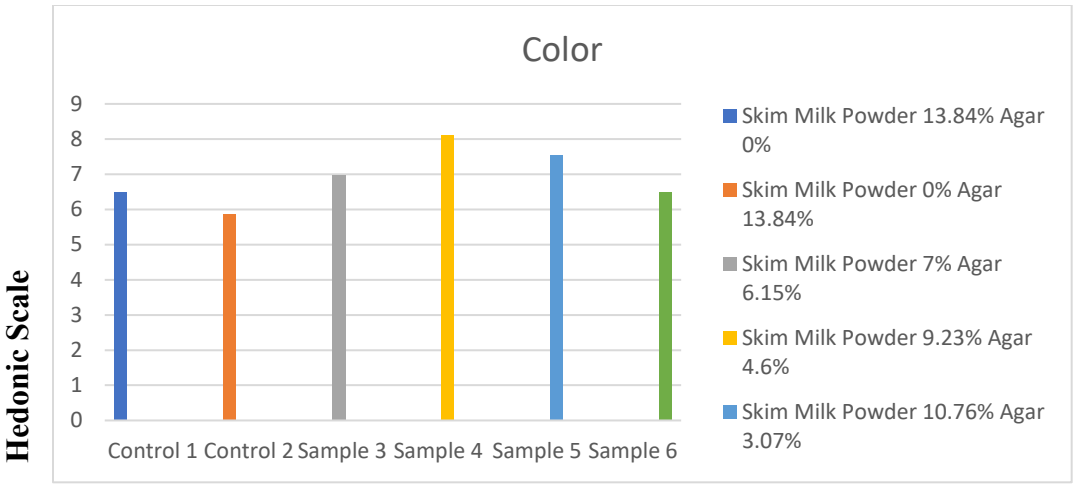
4.6.6. 75th Day analysis

On day 75th the sensory analysis result is shown in **Table 4.18.** Color analysis ranged from 5.87±0.82 to 8.11±0.12, as shown in **Fig. 4.47.** Texture ranged from 5.87±0.10 to 8.01±0.03, as shown in **Fig.4.48.** Taste ranged from 6.20±0.30 to 7.50±0.30, as shown in **Fig.4.49.** Aroma ranged from 6.50±0.82 to 7.70±0.50, as shown in **Fig.4.50.** Overall acceptability ranged from 6.10±0.13 to 7.49±0.06, as shown in **Fig.4.51.**

Table 4.18 Sensory analysis of Yogurt Energy Bar on day 75

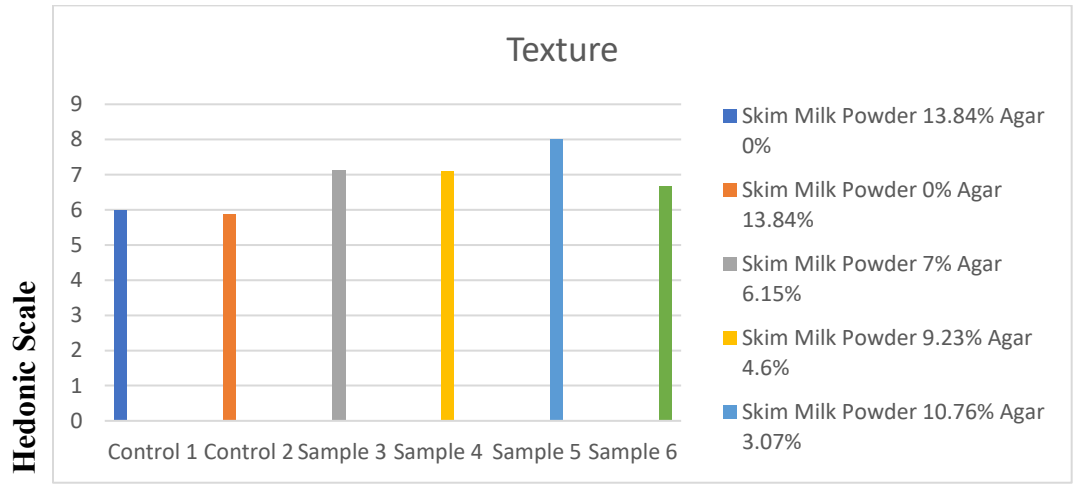
Sample	Color	Texture	Taste	Aroma	Overall Acceptability
Control 1	6.49±0.50	5.99±0.30	6.20±0.30	7.03±0.01	6.40±0.61
Control 2	5.87±0.82	5.87±0.10	6.50±0.40	7.01±0.40	6.10±0.13
Sample 3	6.99±0.39	7.11±0.40	7.11±0.29	6.50±0.82	7.10±0.30
Sample 4	8.11±0.12	7.10±0.50	7.50±0.30	7.70±0.50	7.30±0.22
Sample 5	7.54±0.23	8.01±0.03	7.10±0.15	7.11±0.29	7.49±0.06
Sample 6	6.50±0.29	6.67±0.10	6.29±0.18	7.10±0.05	7.39±0.10

Values are written as mean ± standard deviation



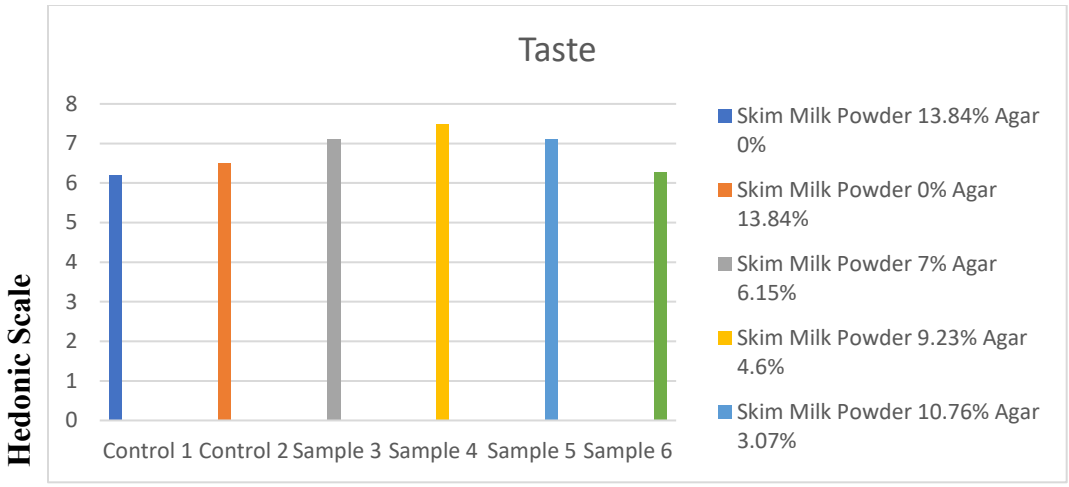
Yogurt Energy Bar samples

Fig.4.47 Color on day 75



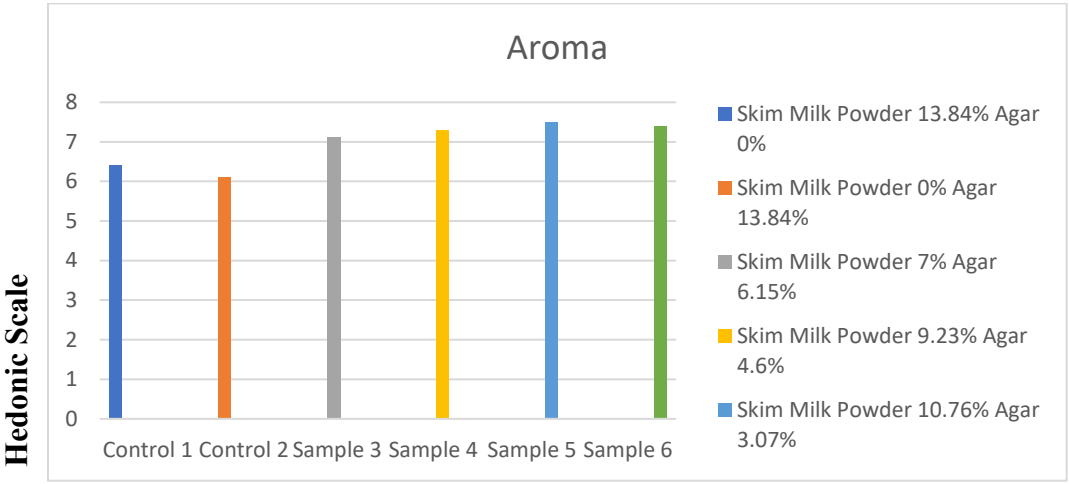
Yogurt Energy Bar samples

Fig.4.48 Texture on day 75



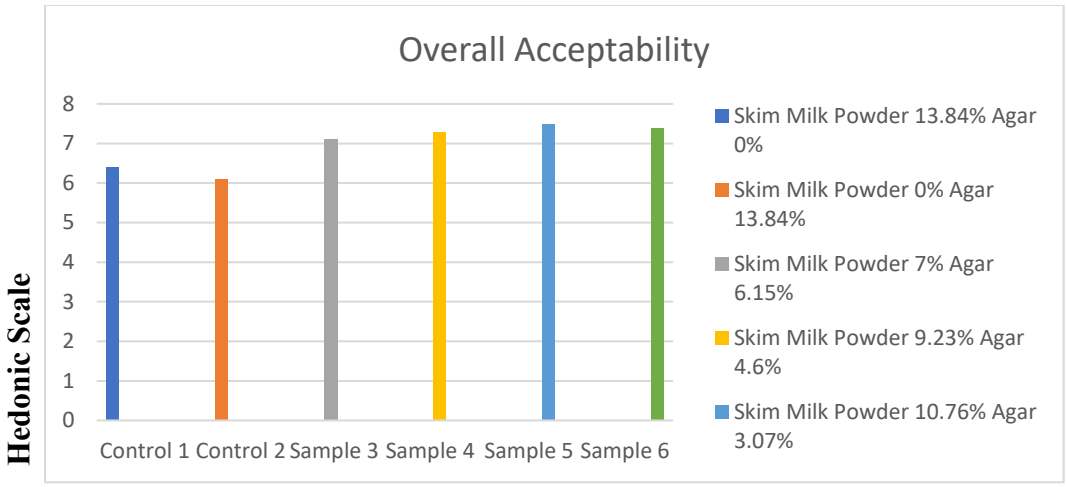
Yogurt Energy Bar samples

Fig.4.49 Taste on day 75



Yogurt Energy Bar samples

Fig.4.50 Aroma on day 75



Yogurt Energy Bar samples

Fig.4.51 Overall Acceptability on day 75

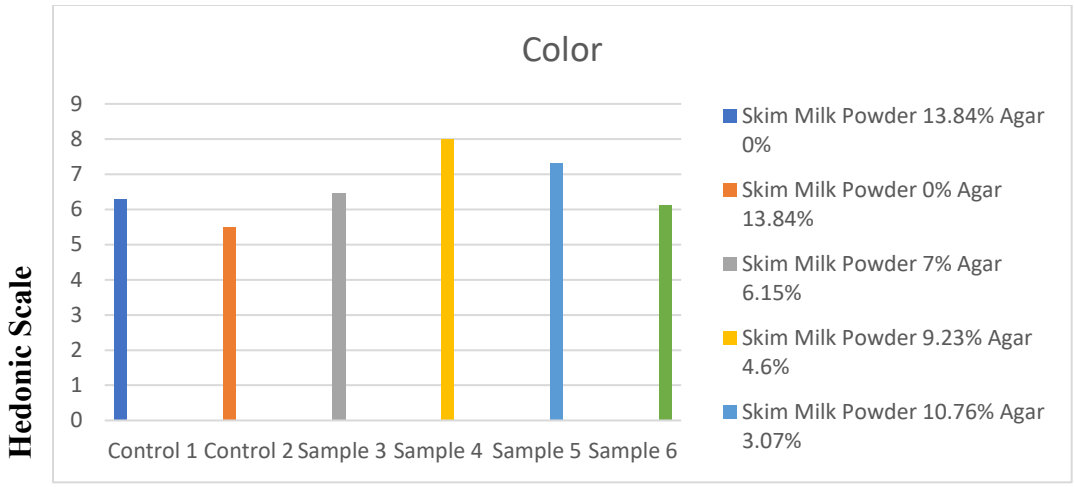
4.6.7 90th Day analysis

On day 90th the sensory analysis result is shown in **Table 4.19.** Color analysis ranged from 5.50±0.01 to 8.00±0.11, as shown in **Fig. 4.52.** Texture ranged from 5.32±0.13 to 7.80±0.01, as shown in **Fig.4.53.** Taste ranged from 6.01±0.20 to 7.32±0.03, as shown in **Fig.4.54.** Aroma ranged from 6.40±0.81 to 7.23±0.05, as shown in **Fig.4.55**. Overall acceptability ranged from 6.00±0.01 to 7.31±0.01, as shown in **Fig.4.56.**

Table 4.19 Sensory analysis of Yogurt Energy Bar on day 90

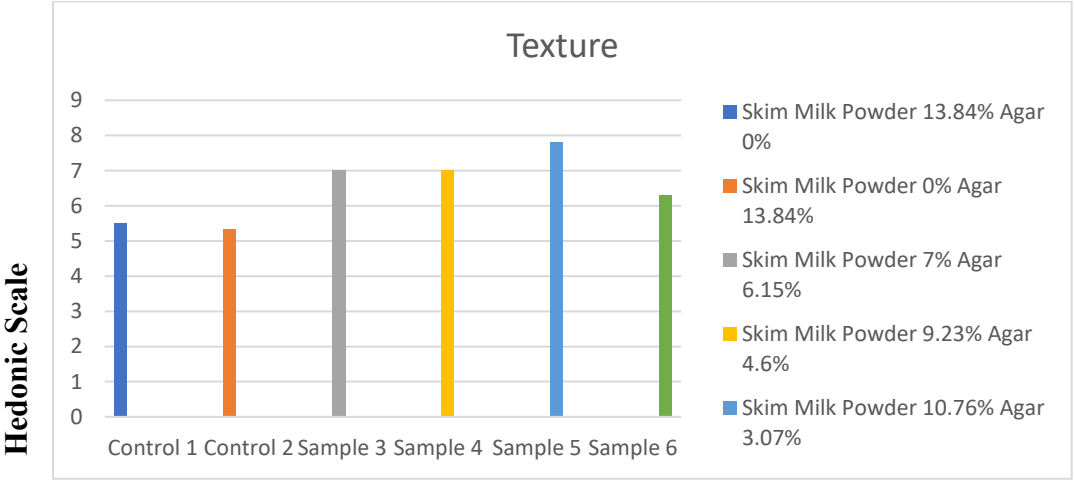
Sample	Color	Texture	Taste	Aroma	Overall Acceptability
Control 1	6.30±0.05	5.50±0.11	6.01±0.20	7.00±0.20	6.10±0.06
Control 2	5.50±0.01	5.32±0.13	6.20±0.32	6.87±0.45	6.00±0.01
Sample 3	6.45±0.21	7.01±0.32	7.00±0.29	6.40±0.81	7.01±0.31
Sample 4	8.00±0.11	7.02±0.05	7.32±0.03	7.23±0.05	7.19±0.02
Sample 5	7.32±0.85	7.80±0.01	7.01±0.05	7.00±0.02	7.27±0.06
Sample 6	6.12±0.74	6.30±0.17	6.13±0.08	7.00±0.05	7.31±0.01

Values are written as mean ± standard deviation



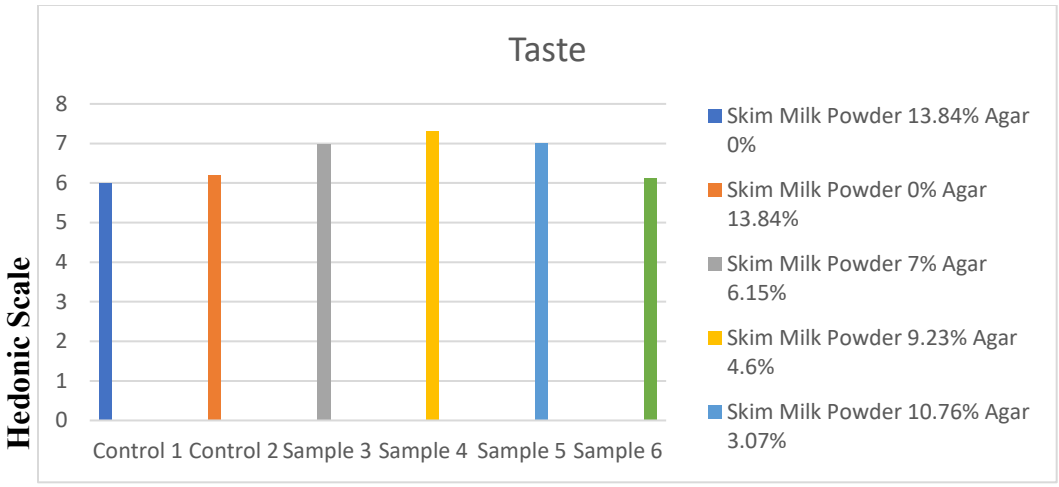
Yogurt Energy Bar samples

Fig.4.52 Color on day 90



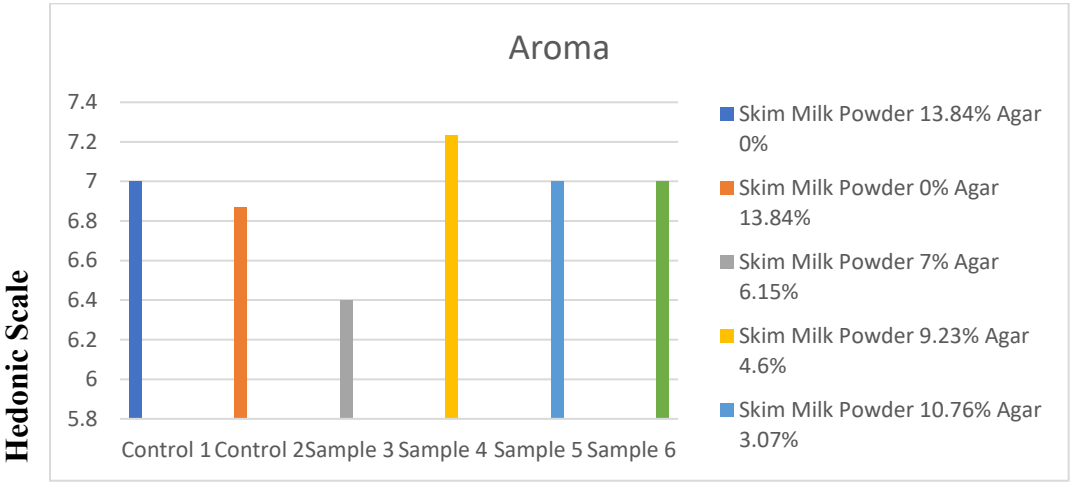
Yogurt Energy Bar samples

Fig.4.53 Texture on day 90



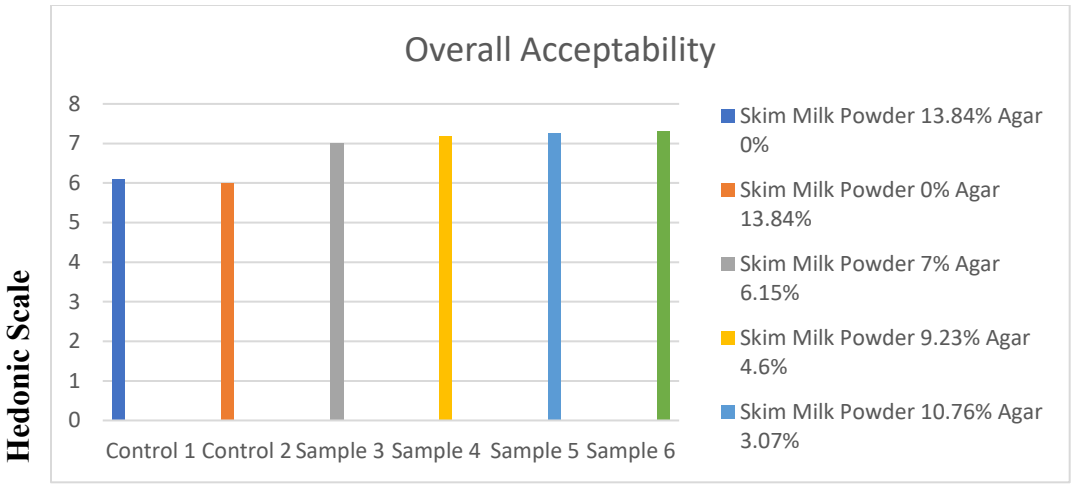
Yogurt Energy Bar samples

Fig.4.54 Taste on day 90



Yogurt Energy Bar samples

Fig.4.55 Aroma on day 90



Yogurt Energy Bar samples

Fig.4.56 Overall acceptability on day 90

4.7 Cost Analysis

Individual costs of all the raw materials were calculated on the basis of their compositional addition in the different samples of the Yogurt Energy Bar as shown in **Table.4.20.** The total cost of the Yogurt Energy Bar samples was then compared with the Energy bars produced by the large-scale industries that are easily available in the market as shown in **Table. 4.21.** The samples of the Yogurt Energy Bar developed in this study were much more economical than the commercially available samples.

Table 4.20 Cost Analysis

Raw Materials	Cost/70gm	Control 1	Control 2	Sample 3	Sample 4	Sample 5	Sample 6
Yogurt	24.5	7	7	7	7	7	7
Skim Milk Powder	39.55	5	0	4.2	4.4	4.6	4.8
Agar (China Grass)	49	0	6	2.8	2.1	1.4	0.7
Veg. gelatin	201	3	3	3	3	3	3
Vanilla Extract	147	8.5	8.5	8.5	8.5	8.5	8.5
Barnyard Millet	15.12	0.8	0.8	0.8	0.8	0.8	0.8
Oats	10.43	0.6	0.6	0.6	0.6	0.6	0.6
Almonds	63	3.6	3.6	3.6	3.6	3.6	3.6
Dates	12.74	3.0	3.0	3.0	3.0	3.0	3.0

Honey	23.1	2.5	2.5	2.5	2.5	2.5	2.5
Total cost		34	35	36	35.5	35	34.5

Table 4.21 Cost comparison

	Energy Bars	**Cost/70gm ₹**
Commercially available energy bars	RiteBite Max Protein Yogurt Energy Bar	80
	Yoga Bar	63
	Shanti Nutrition Bar Yogurt Delight	70
	Nestle koko krunch	84
Yogurt Energy Bars prepared	Sample 3	36
	Sample 4	35.5
	Sample 5	35
	Sample 6	34.5

4.8 Fourier Transform Infrared (FT-IR) Spectroscopic Analysis

Fourier Transform Infrared (FT-IR) spectroscopic analysis provide the data that helped to understand the unknown functional group in the freeze-dried Yogurt Energy Bar samples. The determination of the structure of functional groups was made easier to understand by the help of FT-IR. As shown in **Fig.4.57** A broader peak at wavenumber at 2854.49 cm^{-1} represent the O-H bonding along with a cumulative C-H stretch. Similarly, a peak at 1644.18 cm^{-1} represented the presence of functional compounds of the protein amide group which was attributed to C=O bond elongation. A sharp peak at wavenumber 1077.14 cm^{-1} shows the presence of the C-O group. Whereas, in research studied by **Widjanarko et al, 2011** shows that the peak 3400.27 cm-1 for CPI (C) are attributed to –OH stretching vibrations. A peak at 1647.1 cm-1 and 1634.56 cm-1 regions, respectively were showing the presence of functional compounds of protein amide groups –CONH– which were attributed to carbonyl (C=O) stretch vibration. The peaks of FTIR spectrum of the Yogurt Energy Bar sample is presenting desirable chemical characteristics that can be safely consumed by the consumer. The result predicted that the FTIR spectrum of the Yogurt Energy Bar sample has better results than other predicted results.

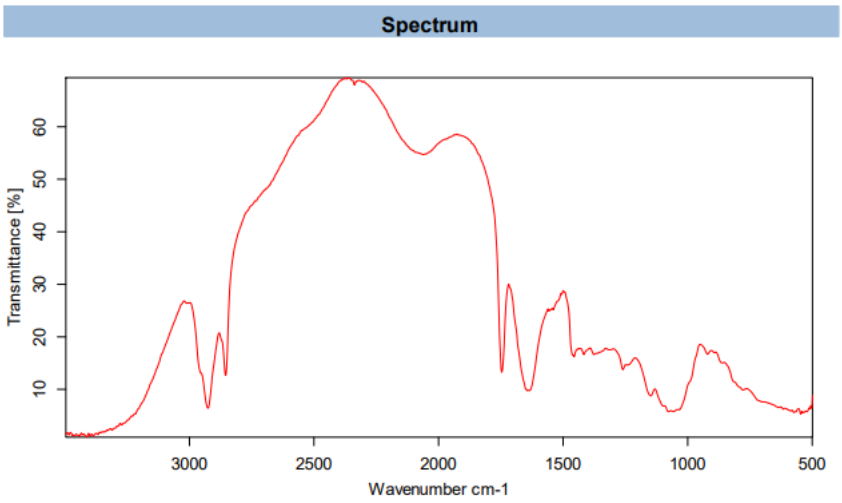


Fig. 4.57 FT-IR Spectrum of Yogurt Energy Bar Sample

Chapter 5

Summary and Conclusion

The summary of this research study includes a conclusion that a new product named as Yogurt Energy Bar enriched with Barnyard millet was successfully developed in the laboratory of Integral University, Lucknow. The main challenge of the usage of Yogurt in an energy bar was accomplished. Yogurt is a highly perishable product, and by the usage of the lyophilization technique, the freeze-dried Yogurt was incorporated for the development of the Yogurt Energy Bar samples. The developed Yogurt Energy Bar is a bar that is full of nutrition and compact form of energy. This Yogurt Energy Bar typically consists of raw materials: Yogurt, Skim milk powder, Agar (China grass), Veg. gelatin, Vanilla extract, Honey, Barnyard millet, Oats, Dates, and Almonds. 6 Samples of Yogurt Energy Bar samples were developed which constituted:

Control 1: Skim Milk Powder 13.84% and Agar 0%

Control 2: Skim Milk Powder 0% and Agar 13.84%

Sample 3: Skim Milk Powder 7% and Agar 6.15%

Sample 4: Skim Milk Powder 9.23% and Agar 4.61%

Sample 5: Skim Milk Powder 10.76% and Agar 3.07%

Sample 6: Skim Milk Powder 12.30% and Agar 1.5%

All of these samples of Yogurt Energy Bar were developed and analyzed for studying various responses,i.e., Physico-chemical analysis (Moisture content, Ash Content, pH, TSS, Titratable acidity, Protein estimation, Fat estimation, Color analysis, Anti-oxidant activity, TPC, Cost analysis, Sensory analysis, Shelf-life analysis and a characterization study of Fourier Transform oInfrared Spectroscopy (FT-IR) analysis. These energy bars were developed in an economic condition, which made the bars cost efficient. The cost analysis was done by comparing the yogurt energy bar raw materials with the cost of commercially available energy bars.

From this research study, it is concluded that Sample 4: Skim Milk Powder 9.23% and Agar 4.61% is considered to be the optimized sample by all means of analysis conducted. This bar

can be produced on large-scale in future. Sample 4 : Skim Milk Powder 9.23% and Agar 4.61% consisted a moisture content of 2.33±0.05, ash content of 2.48±0.01, pH of 4.03±0.02, titratable acidity of 0.10±0.03, TSS of 6.3±0.50, fat content of 2.03±0.09, protein content of 12.3±0.36; phytochemical analysis included Anti-oxidant activity of 87.76±2.49,and TPC of 144.57±9.33, Sensory analysis color (8.49±0.33) Texture (8.34±0.22) Taste (8.53±0.40) Aroma (8.51±0.46) Overall Acceptability (8.46±0.08). Shelf-life study included the analysis through sensory parameters of the 9-scale hedonic sensory evaluation from 0 day to 90 days. On day 90 the color decreased from 8.49±0.33 to 8.00±0.11, texture decreased from 8.34±0.22 to 7.02±0.05, taste decreased from 8.53±0.40 to 7.32±0.03, aroma decreased from 8.51±0.46 to 7.23±0.05, and overall acceptability decreased from 8.46±0.08 to 7.19±0.02

5.1 Future recommendation

1. Further research on the shelf-life can be conducted by doing the physico-chemical analysis for the storage period for a longer period.
2. An arising challenge is to produce this similar product for astronaut's consumption.
3. Variety products could be developed by incorporation of other underutilized and nutritious raw materials
4. Target market should be more aware of this product.
5. Incorporation of Honey-jelly could enhance the palatability as well as the nutritious demand of the product.

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