

UNVEILING THE POTENTIAL: EXPLORING NOVEL PLANT-BASED PROTEIN SOURCES FOR INNOVATIVE PLANT-BASED FOOD PRODUCTS

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Abstract

Vegan eggs are gaining popularity in the food sector as plant-based alternatives to traditional eggs made from legumes, grains, and starches. These eggs products are designed to mimic the flavour, texture, and functioning of eggs although they may lack the same nutritional content and texture. This paper aims to utilize protein rich plant-based alternatives, vitamins and minerals, aquafaba, thickeners, and emulsifiers to develop a plant-based substitute for regular chicken eggs with a balanced nutritional profile. After creating a hard-boiled vegan egg, nutritional and textural study revealed a plant-based alternative with comparable levels of protein (11.86%), fat (1.4%), minerals (5.5%), and vitamins to those found in chicken eggs. The egg also contains fibre (3.2%), moisture content (29.05%) and water activity (0.986 aw), making it suitable for a plant-based diet and accommodating dietary restrictions. This vegan egg exhibits similar textural qualities and higher protein content which is noted in the result. SPSS is utilized for analysing sensory data and for comparing sensory analysis between vegan eggs and traditional eggs using the paired sample t-test tool. The vegan eggs will be packaged , ensuring sustainable, eco-friendly materials that preserve their quality and contribute a greener earth.

Keywords: Balanced nourishing profile; Plant-based alternative; SPSS; Vegan egg

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Introduction

Despite the consequences, animal products are nevertheless consumed more widely than ever before, which shows that consumers are not primarily motivated by concerns about the ethical and environmental implications of their dietary choices. Instead, cost and flavour are the most significant factors of what influence the food choices (Bryant, 2022). The vegetarian and vegan population have increased significantly over the past few years. Animal husbandry is a major contributor to public health issues, deforestation, eutrophication, and direct emissions of greenhouse gases into the atmosphere. Numerous food-borne pathogens have developed antibiotic resistance due to the frequent consumption of prophylactic antibiotics (Selinger *et al.*, 2022). Consequently, it is a source of both antibiotic resistance and zoonotic infections, thereby increasing the risk of pandemic (Theurl *et al.*, 2020).

The first thought that comes to mind when considering a high-quality protein source is traditional eggs which are also considered a complete food. The over consumption has been linked to cause chronic degenerative disorders that lead to cardiovascular disease and mortality because of the elevated cholesterol level. Irrespective of its drawbacks, the nutritional benefits and efficacy of eggs as a dietary product are exceptional (Sugano and Matsuoka, 2021). Another significant concern in the poultry industry is the use of antibiotics and other substances in poultry products to promote growth and health (Rahman *et al.*, 2022). By inducing allergy symptoms and facilitating the spread of antibiotic-resistant microbial infections, the eventual accumulation of drug residues in eggs

can pose serious significant health risks (Arsène *et al.*, 2022). Consumers are becoming increasingly concerned about foodborne infections associated with the rising consumption of eggs. Food safety concerns arise as contamination by the presence of fipronil and other acaricide residues was detected in chicken eggs and poultry products, as stated in the 2018 report by Reich and Triacchini (2018). In 2018-2019, a multi-country *Salmonella* Enteritidis outbreak associated to table eggs brought greater attention to the need for more stringent regulations on egg production and distribution throughout Europe (Carter *et al.*, 2020). Hence, the development of an egg using plant-based protein sources is ongoing area of research worldwide (Rondoni *et al.*, 2021).

The most widely accepted alternative proteins, based on a systematic analysis of consumer acceptance, are plant-based meat substitutes (Selinger *et al.*, 2022). It was discovered that soy products contained significantly higher levels of calories, riboflavin, fibre, carbohydrates, omega 3, zinc, vitamin B6, vitamin B1 and folic acid compared to the other four plant-based protein sources including nuts, legumes and grains (Fresán *et al.*, 2019). In a randomized cross-over trial, it was found that consumption of plant proteins facilitated weight loss and comparable to animal products regarding muscle synthesis (Crimarco *et al.*, 2020). Studies have shown that plant-based protein substitutes contain significantly lower amounts of saturated fat and calories per serving while providing much higher levels of fibre and salt (Alessandrini *et al.*, 2021).

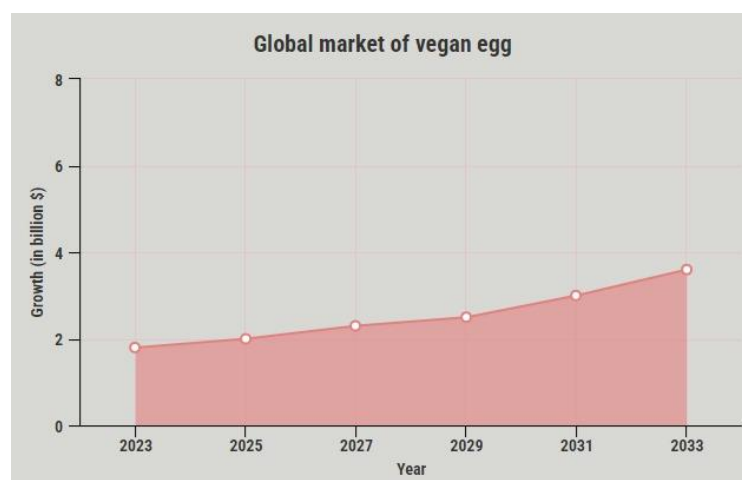


Figure 1. Estimated growth rate of the global vegan egg market

Vegan eggs are rich in nutrients and contain equal to higher protein than regular eggs. The market for vegan eggs is projected to grow at a robust Compound Annual Growth Rate (CAGR) of 8.3% by 2033 (Figure 1). Besides the versatility of conventional eggs, their nutritional value is a key component. In comparison to traditional egg production methods, plant-based eggs provide stable market stability, are immune to avian influenza, and are environmentally sustainable (Réhault-Godbert *et al.*, 2019). Vegan eggs contain little to no cholesterol and can be beneficial for those with heart conditions like atherosclerosis. It reduces incidence of diseases that can be transmitted from animals to humans, including the avian flu (Boukid and Gagaoua, 2022).

In the commercial market, plant-based eggs come in both liquid and powdered forms that are intended to resemble the appearance and functionality of conventional eggs. Liquid eggs are produced through protein isolation and are used in baking, omelette and scrambled eggs whereas powdered eggs are produced by protein fermentation. Vegan eggs made from tofu and algae are frequently utilised (Sudhakaran and Bukkan, 2021). Cashews, coconuts, almonds, along with added flavours and colours, are currently utilized in the production of the plant-based hard-boiled eggs. This is costly and not economically feasible.

This research aims to replicate the nutritional content of the regular eggs to the fullest extent and to develop a hard-boiled vegan egg. Because of their high protein content and ability to replicate the nutrient profile of conventional eggs, products derived from *Glycine max* (soy), *Cicer arietinum* (chickpea), *Vigna radiata* (green gram), and *Macrotyloma uniflorum* (horse gram) are chosen as the raw materials for the production of vegan

eggs. These materials can serve as an alternate to normal eggs because they are readily available and reasonably priced. The binding and emulsifying properties of eggs can be replicated by soy. Green gram is an excellent source of protein, vitamins and minerals, including folate, iron, magnesium, and potassium (Sudhakaran and Bukkan, 2021). Horse gram provides a substantial amount of plant protein (22%), as well as fibre and phenolic compounds (Prasad and Singh, 2015). Black salt imparts a unique eggy or sulfurous flavour (Flores and Piornos, 2021). Nutritional yeast, turmeric, spices and herbs are also utilized to enhance depth and flavour. Thickeners and stabilisers are utilized to achieve the gel-like texture while further improving the binding properties and consistency of the finished product. Commercial thickening and stabilizing agents that are commonly used include Xanthan gum, agar-agar, tapioca starch, Carrageenan, and chickpea flour (Saha and Bhattacharya, 2010) (Figure 2).

Aquafaba, soy protein isolate (SPI), agar-agar, and tofu are the essential components used in the formulation of a novel vegan egg white (Stasiak *et al.*, 2023). Aquafaba, a plant-based rheological agent, is a solution that is produced when pulse seeds, such as (chickpea) are cooked in water. To enhance its texture and nutritional properties, soy protein isolate (SPI), silken tofu and agar-agar are added to the resulting aquafaba. The mixture was blended to achieve homogeneity and then gently heated to develop structural rigidity. The final vegan egg white mixture was the moulded into egg-shaped forms and carefully frozen to strengthen its structural integrity (Xiao *et al.*, 2019). Horse gram, green gram, agar-agar and calcium lactate are the primary ingredients used in the formulation of vegan egg yolk. Using the principle of reverse

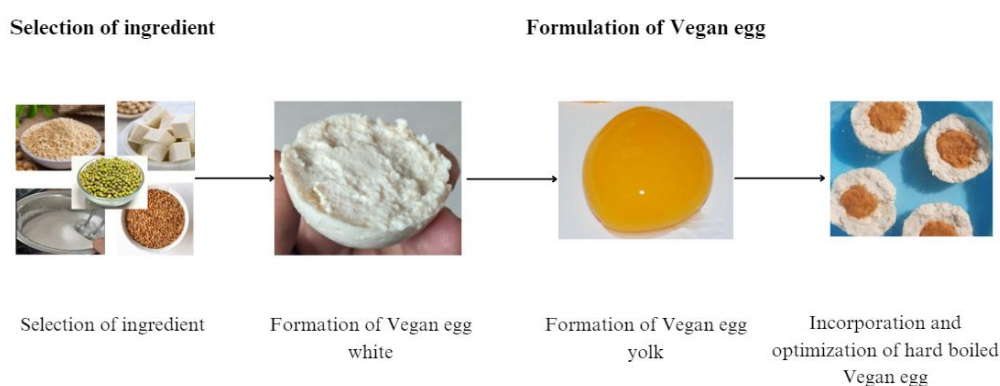


Figure 2. Formulation of Vegan egg using *Glycine max*-derived products (Soy), *Cicer arietinum* (chickpea), *Vigna radiata* (green gram), *Macrotyloma uniflorum* (horse gram)

spherification to preserve the spherical structure, the yolk was immersed in a sodium alginate solution after the ingredients were formulated. (Lee and Rogers, 2012).

Materials and Methods

The soybean, chickpea, agar-agar, horse gram, green gram and black salt were purchased from a local supermarket, while silken tofu and soy protein isolate SPI were produced in our laboratory. The chemicals and solvents used for analysis was of analytical grade and supplied by Sri Mahalakshmi Chemicals (Coimbatore, India). Soy protein isolate is extracted using an alkaline solution, followed by centrifugation for purification. The SPI is then blended with water in the appropriate ratio to create the base for the vegan egg white formulation. To create the other features, agar-agar, aquafaba, flavours, and seasonings are utilized. The composition of vegan yolk utilizes pulses and calcium lactate. To create a convincing vegan egg, the frozen egg yolk and egg white are required. To compare the vegan eggs and traditional eggs, the nutritional composition of traditional eggs was obtained from literature reviews.

Extraction of Soy Protein – Alkali Extraction

Soybean was milled using a hammer mill (250 μ m sieve mesh) equipped with a 250 μ m sieve

mesh and SPI was extracted following the alkali extraction method described by Wagner *et al.* (2000). For the preparation of silken tofu, soymilk was heated to 95°C, then cooled to 80°C. A solution of magnesium chloride (0.2%) and calcium sulfate (0.2%) was added, stirred, and allowed to coagulate. The milk was subsequently transferred to a cheesecloth mold, pressed with various weights, and stored in water under refrigerated conditions (Rekha and Vijayalakshmi, 2013).

Soybeans are initially soaked and grounded into a slurry for the alkali extraction of soy protein. To separate the protein from other components, alkali, such as sodium hydroxide (NaOH), is added to the slurry to rise the pH to approximately 9-10. The mixture is neutralised with an acid, such as hydrochloric acid (HCl), after a predetermined period, lowering the pH to approximately 4.5-5, which results in the precipitation of the soy protein. To separate the protein from the liquid and solid particles, the mixture is filtered. A centrifuge may also be employed for further purification. The resulting soy protein can then be dried to produce a usable product. This procedure produces soy protein isolate (SPI), a valuable source of plant-based protein that is suitable for use in a variety of food applications. The procedure can be modified for different protein concentrations and applications while still adhering to essential safety considerations (Shanthakumar *et al.*, 2022) (Figure 3).

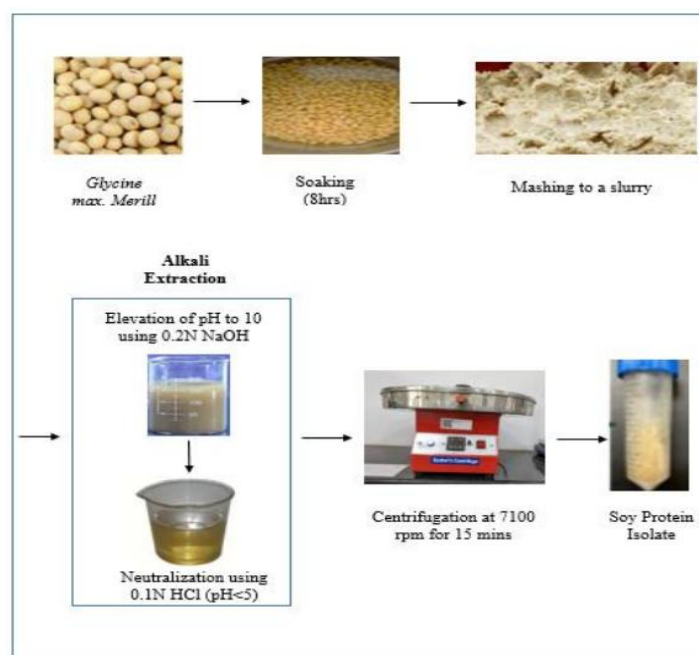


Figure 3. Extraction of SPI from *Glycine max. Merrill* using Alkali extraction method

Soy protein isolate is extracted using an alkali, followed by centrifugation for purification. The SPI is then blended with water in appropriate ratio to create the base for the vegan egg white formulation. To create the additional replication features, agar-agar, aquafaba, flavours, and seasoning are utilized. The composition of vegan yolk makes use of pulses and calcium lactate. To create a convincing vegan egg, the frozen egg yolk and egg white alternatives have been thawed and carefully blended. The yolk is gently poured into the egg white, aiming to replicate the texture and appearance of traditional eggs. Consistency is monitored throughout the process to ensure complete assimilation.

Formulation of Vegan egg White

The formulation of vegan egg white involves a step-by-step process that utilizes a combination of plant-based ingredients. The soy protein solution was prepared by mixing, soy protein isolate (SPI) with water, paying careful attention to the ratio to achieve the desired consistency. This solution establishes the foundation for a vegan egg white alternative. Blend silken tofu, selected for its

smooth texture, with black salt to mimic the sulphurous flavour of traditional eggs (Boukid and Gagaoua, 2022). To achieve a creamy texture, agar-agar is incorporated into the mixture. Additionally, aquafaba, acting as an emulsifier, is introduced to the blend. Flavours and seasonings such as garlic powder, nutritional yeast and mushroom seasonings can be added to suppress the, dominating taste of soy-derived products. These ingredients are blended until a thick and cohesive mixture forms, which serves as the base of vegan egg whites. The mixture is heated for 10 min, allowing the agar-agar to activate and the mixture to solidify. Before cooling and solidification, the mixture is poured into the desired mold (Figure 4).

Formulation of Vegan Egg Yolk

The formulation of a plant-based egg yolk substitute involves a straightforward process that utilizes green gram, horse gram, food colouring (E110) and calcium lactate. Initially, green gram is soaked and then cooked until it becomes tender (Wang *et al.*, 2022). Horse gram is sprouted and cooked to decrease its phytic acid content while

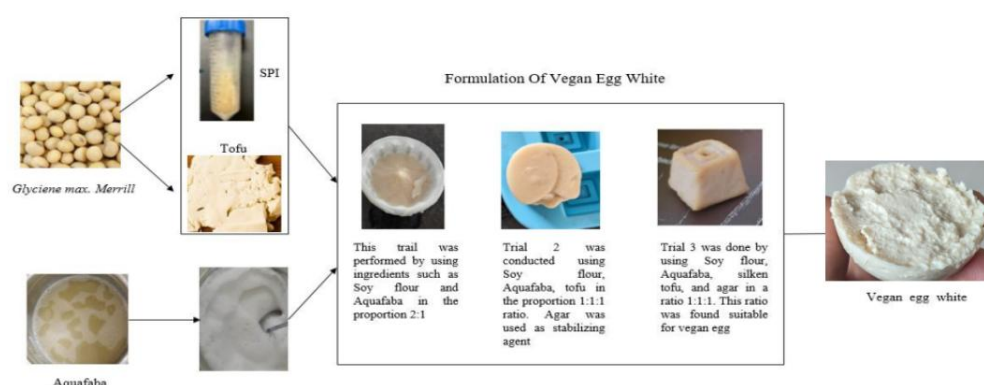


Figure 4. Formulation and optimization of vegan egg white using soy-derived products and aquafaba

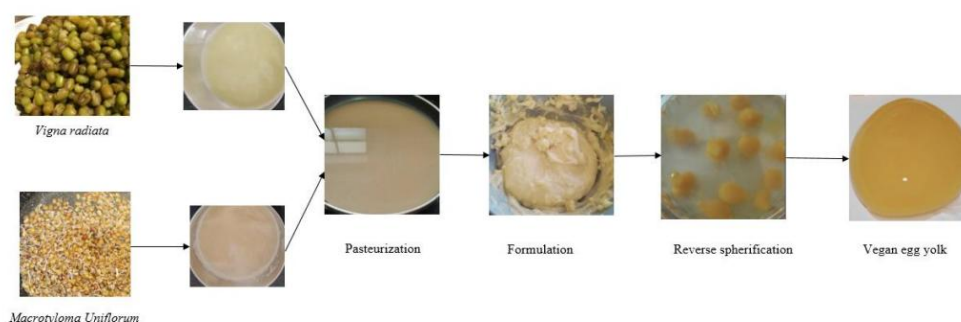


Figure 5. Formulation and optimization of vegan egg yolk using *Vigna radiata* and *Macrotyloma uniflorum*

enhancing its protein content (Sharma *et al.*, 2019). After cooking, the ingredients are blended into separate pastes, with the water amount adjusted to achieve for the desired consistency. They are pasteurized at 80°C for 5 min. These pastes are then combined to form the base for the egg yolk substitute. Calcium lactate powder is gradually added to the mixture, maintaining its texture and imparting a flavour reminiscent of traditional egg yolks. The mixture is cooled to ambient temperature. Following the principle of reverse spherification, a sodium alginate bath is prepared and the mixture is submerged in the bath (Lee and Rogers, 2012). This preserves and maintains the spherical structure of the yolk (Figure 5).

Incorporation of Egg Yolk with White

A crucial step in creating a comprehensive and convincing vegan egg product is the incorporation of egg yolk substitute to the egg white alternative. The frozen egg yolk and egg white equivalents should be completely defrosted, usually by cooling them at 4°C until they reach the appropriate temperature for blending. To place the egg yolk, carefully scoop out the substitute for the frozen egg white. Gradually pour the thawed egg yolk. The goal is to maintain the texture and appearance that closely resemble traditional eggs. Periodically the consistency to ensure that the two components are thoroughly combined.

Proximate Analysis

The determination of moisture content using the (Mettler Toledo HE53 Moisture analyser) is achieved which by evaporating and quantifying the water in the sample, typically with a hot air oven. To assess ash content, the sample is incinerated in a muffle furnace. The crude protein content is determined using KjelTRON KDIGB4M and KjelDIST EA equipment which estimates nitrogen levels as a proxy for protein. To quantify crude fat, a SoxTRON SOX-2 apparatus dissolves fats in a solvent. Fiber analyzers such as the FibroTRON FRB-2 are employed to analyze crude fiber by digesting it with acid and alkali allowing for the determination of indigestible fibers.

Furthermore, the colorimeter was utilized to determine the colour of the vegan egg white and vegan egg yolk. The Lab* values include, L = lightness, a = red(negative), green(positive), b = blue(negative), yellow(positive). Additionally, water activity is measured using specialized instruments that detect the equilibrium relative humidity (ERH) of a sample. The Pre AQUA LAB Water activity meter is commonly used to measure water activity.

Sensory Analysis

The sensory analysis was conducted with 20 participants using a 9-point hedonic scale. The survey data were analysed using SPSS to compare the preference for the vegan egg.

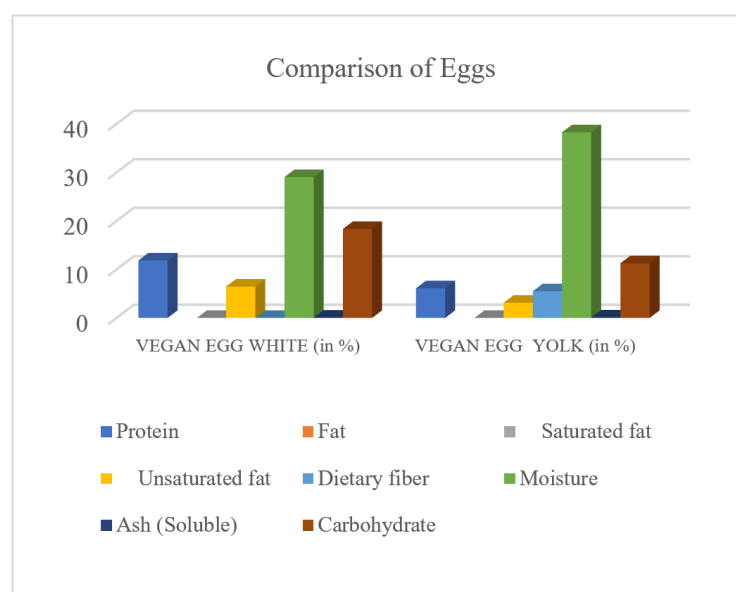


Figure 6. Nutritional comparison between vegan egg white and Vegan egg yolk

Table 1. Proximate analysis of vegan egg white and vegan egg yolk

I	Vegan egg white (in %)	Vegan egg yolk (in %)
Protein	11.86	6.12
Fat		
Saturated fat	0	0
Unsaturated fat	6.46	3.12
Dietary fiber	3.2	5.5
Moisture	29.05	38.28
Ash (Soluble)	0.06	0.09
Carbohydrate	18.35	11.28

The appearance and texture were satisfactory. Therefore, the overall acceptability of the product was deemed acceptable and aligned with the image provided. (Figure 6).

Shelflife Studies

The research examines the shelflife study of the vegan egg under various factors like protein, fat, fibre, ash, appearance, white colour, yellow colour, odour, flavour and texture. Sensory evaluation is conducted to assess the products visual appeal, taste and textural attributes providing a better understanding of the quality changes over a period of time.

SPSS Data for Normal Egg and Vegan Egg

In our current study, we are conducting a comprehensive comparison of the sensory attributes of traditional eggs and vegan eggs. This analysis includes a detailed examination of taste, texture, aroma, and appearance. To conduct this analysis, we are utilizing IBM SPSS Statistics 26 software, which will enable us to effectively process and interpret the data gathered from our sensory evaluations.

A Paired Samples T-Test is used to determine whether there is a statistically significant difference between the means of two related groups. In the context of sensory evaluation, the same 20 panellists rating both traditional and vegan eggs, in the paired data points for each panelist. Each sensory attribute is presented in two columns: one for traditional eggs and another for vegan eggs.

Results

Result

The plant-based hard-boiled egg has been successfully developed that closely mimics the nutritional composition of traditional chicken eggs while also providing additional benefits such as dietary fiber was successfully developed. The key findings indicate developed product contains

11.86% protein, 1.4% fat, 3.2% of dietary fiber and an increased mineral content of 5.5%. It did not match the vitamin content of traditional eggs. Therefore, fortifying it with micro-nutrients from plant-based sources such as Spirulina which provides Vitamin B, Green leafy vegetables which provide Vitamin A, D, E and K can be viable and convincing.

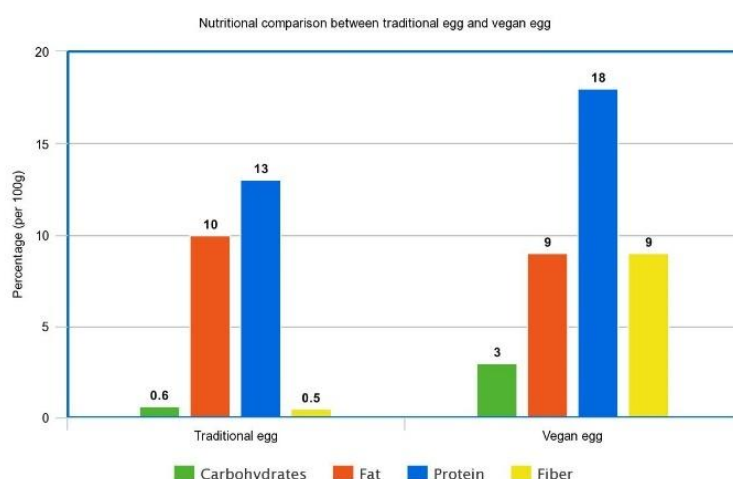
The moisture content of our vegan egg substitute as measured by Metter Toledo HE53 Moisture Analyser is 29.05%, This level ensures a desirable texture and consistency. The water activity measured by the pre AQUA LAB Water Activity Meter was found to be 0.986, indicating effective preservation and a low risk of microbial growth. The colour value of vegan egg white ($L^* = 72$, $a^* = 6$, $b^* = 3$) and vegan egg yolk ($L^* = 46$, $a^* = 13$, $b^* = 32$) were also determined along with their texture. (Table 1).

Through systematic mixing and controlled processing, a stable and palatable vegan egg substitute with remarkable equivalence has been developed. A medium-sized vegan egg contained 11.86% protein which was analysed using 1. KjelTRON KDIGB4M and KjelDIST EA, SoxTRON SOX-2 were used to analyse the fat level which was found to be 1.4 %, The dietary fibre content measured at 3.2%, was analysed using FibroTRON FRB-2 and while the mineral content was determined to be 5.5% . Our meticulous color analysis revealed that our vegan egg exhibits specific L^* , a^* , and b^* values, which reflect its distinctive beige hue. Although it lacks some of the micro-nutrients, it can be fortified later. The majority of the results from a standardised sensory analysis indicated that the mouthfeel and taste should be improved.

The development of the vegan egg substitute represents a pivotal significant meeting the increasing demand for plant-based and sustainable food options. The product's ability to closely replicate the nutritional content of traditional chicken eggs, combined with the addition of dietary fiber, represents a significant advancement in

Table 2. Nutritional comparison between traditional egg and vegan egg

Nutritional facts (per serving)	Traditional egg (in %)	Vegan egg (in %)
Protein	12-13	17.9-19
Fat		
Saturated fat	3.3	0
Unsaturated fat	7	9.4
Dietary fiber	<0.5	8.7
Ash (Soluble)	1	0.15
Carbohydrate	1.1	29.79-30

**Figure 7. Nutritional (macronutrients) comparison between traditional chicken eggs and vegan egg**

offering consumers with versatile and nutritious alternatives. Beyond its nutritional benefits, our project emphasizes a commitment to maintaining high product quality, aligning with a broader mission to meet diverse consumer needs and preferences. Moreover, it addresses the urgent environmental and ethical concerns within the food industry by providing a sustainable and cruelty-free alternative to conventional eggs. In essence, the significance of our project lies in its ability to transform the food landscape, offering consumers with a compelling and responsible choice that aligns with their dietary goals and values.

One limitation of vegan egg substitutes is their potential to lack the essential nutrients that are naturally found in traditional eggs, such as vitamin B12, iron, and various other micronutrients. To address this gap, fortifying with these nutrients may be necessary, which can complicate the formulation process. Additionally, while vegan eggs can closely mimic the taste and texture of traditional eggs, there may still be subtle differences that some consumers notice, which could impact their overall sensory experience. Availability and cost can also be limiting factors in certain regions, as traditional eggs

are often more accessible and cost-effective. Finally, it's important to acknowledge that individual taste preferences vary, and some consumers may have a strong inclination toward the distinct taste and texture of traditional eggs. This preference can hinder the widespread adoption of vegan egg products.

Comparison of Nutrition Content of whole Egg with Vegan Egg

However, it has a lower in fat content compared to the 5-6% fat content of chicken eggs, with a 5.5% mineral content. (Table 2) (Figure 7). It also contains dietary fiber, comprising 3.2% of its weight, which is absent in chicken eggs. The color of the vegan egg substitute may vary, from the familiar white or brown shades, depending on the materials used.

Sensory Analysis

The sensory analysis indicated that the vegan egg substitute exhibited an acceptable appearance and texture, lacking an eggy flavour or unpleasant aroma according to the statistics (Figure 8).

Table 3. Shelf-life analysis at controlled humidity and temperature

Parameters	Day-1	Day-7	Day-14	Day-21	Day-28
Protein %	17.9±0.2	17.5±0.1	17.49±0.1	17.49±0.0	16.42±0.1
Fat %	9.4±0.4	9.2±0.1	9.2±0.0	9.00±0.1	9.00±0.1
Fibre %	8.53±0.1	8.52±0.1	8.52±0.1	8.51±0.1	8.51±0.1
Ash %	0.15±0.01	0.15±0.02	0.14±0.01	0.14±0.02	0.138±0.0
Appearance	6.26±0.8	6.24±1.0	6.24±1.0	6.20±0.8	6.17±0.9
White colour	5.67±1.5 ^a	5.60±1.5 ^a	5.58±1.5 ^a	5.58±1.5 ^a	5.50±1.0 ^a
Yolk colour	26.7±0.8 ^b	26.5±1.0 ^b	26.2±1.0 ^b	26.18±1.0 ^b	26.10±1.0 ^b
Odour	6.62±1.2	6.58±1.0	6.54±1.0	6.48±1.2	6.31±1.0
Flavour	5.93±0.3	5.91±0.5	5.8±1.0	5.78±1.0	5.75±1.0
Texture	6.73±1.5	6.62±1.0	6.59±1.0	6.31±1.5	5.59±1.0

*Appearance, flavor, texture and odour were evaluated based on Hedonic scale from 1 to 9, where 1 means dislike extremely and 9 means like extremely. ** a, b are the variables in color space. ***humidity was set to 55.5% and temperature to 3°C.

Table 4. Shelf-life analysis at atmospheric conditions

Parameters	Day-1	Day-7	Day-14	Day-21	Day-28
Protein %	17.9±0.2	14.05±0.1	13.01±0.2	11.89±0.0	10.72±0.1
Fat %	9.4±0.4	9.12±0.1	9.02±0.0	8.72±0.1	8.70±0.1
Fibre %	8.53±0.1	8.06±0.1	7.52±0.1	7.40±0.1	7.24±0.1
Ash %	0.15±0.01	0.15±0.02	0.14±0.01	0.14±0.02	0.138±0.0
Appearance	6.26±0.8	5.23±1.0	4.04±1.0	4.01±0.8	3.39±0.9
White color	5.67±1.5 ^a	5.20±1.5 ^a	5.16±1.5 ^a	5.15±1.5 ^a	5.02±1.0 ^a
Yolk color	26.7±0.8 ^b	26.5±1.0 ^b	25.3±1.0 ^b	24.10±1.0 ^b	24.01±1.0 ^b
Odour	6.62±1.2	5.08±1.0	4.74±1.0	4.15±1.2	3.51±1.0
Flavour	5.93±0.3	4.21±0.5	4.12±1.0	3.78±1.0	3.55±1.0
Texture	6.73±1.5	5.45±1.0	4.27±1.0	3.6±1.5	3.48±1.0

*Appearance, flavor, texture and odour were evaluated based on Hedonic scale from 1 to 9, where 1 means dislike extremely and 9 means like extremely. ** a, b are the variables in color space.

Interpretation

The results of the paired sample test provide important insights into the sensory attributes of traditional and vegan eggs, highlighting both similarities and differences. There is no statistically significant difference in appearance, with a mean difference of -0.050 and a p-value of 0.804, indicating that consumers view the visual characteristics as nearly identical. Similarly, no significant difference was found in texture, evidenced by a mean difference of -0.050 and a p-value of 0.841, suggesting comparable mouthfeel and consistency.

In contrast, significant differences were observed in aroma and taste. The mean difference for aroma was -2.050, with a p-value of 0.000, indicating a substantial distinction between the scents of vegan and traditional eggs. Likewise, the mean difference in taste was -1.800, also with a p-value of 0.000, reflecting notable variations in flavor profiles.

Shelf-life Studies

Shelf-life studies were conducted using a humidity chamber under controlled humidity

(55.5%) and temperature, demonstrating that the product remained stable for 28 days at -3°C temperature. However, when stored under atmospheric conditions, the product exhibited significant changes in sensory attributes and became unstable from day two. Thus we conclude that the vegan egg remained stable for 28 days under refrigerated conditions (Tables 3-4).

Packaging

Eggs packed in (HDPE) high density polyethylene maintain their quality effectively, offering a protective barrier against moisture and external contaminants. Hard-boiled vegan eggs can be stored for approximately 5 to 7 days when packed in airtight HDPE containers and kept in a refrigerator at temperatures below 40°F (4°C). However, the actual shelf life can vary depending on factors such as initial quality of the eggs, the ingredients used, and the presence of preservatives. It is essential to check for signs of spoilage and follow storage or expiration date recommendations to ensure food safety.

Conclusions

This vegan egg effectively mimics the composition of traditional eggs. The development of vegan eggs is a viable and promising alternative in light of the ongoing dynamic shift in dietary preferences and the increasing awareness of the ecological consequences of food choice.

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