DOI: https://doi.org/10.36036/MR.34.1.2025.167215
Mushroom Research 34 (1) : 137-145, 2025

Development and evaluation of oyster mushroom (*Pleurotus ostreatus*) incorporated mayonnaise

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ABSTRACT

Despite of numerous health benefits, Oyster Mushroom (*Pleurotus ostreatus*) demand is low, due to shorter shelf life and limited storage technology. This study aimed at development of oyster mushroom incorporated mayonnaise as a value-added product to meet the enhance demand of food industries for convenient as well as a healthier mayonnaise choice. Different gums were used as substitute of egg for the preparation of vegan mayonnaise. Xanthan gum (1% w/v) based variants with 10% oyster mushroom powder was preferred to prepare vegan oyster mushroom mayonnaise and kept under both room temperature and refrigerated temperatures for further studies. Viscosity of mayonnaise samples increased significantly with addition of oyster mushroom powder. During storage, moisture content, pH, emulsion stability, anti-oxidant activity got decreased and titratable acidity, acid value, peroxide value, viscosity of mayonnaise got increased. Addition of preservatives and storage at refrigerated temperature supported the safety and quality of vegan mushroom incorporated mayonnaise.

Key words: Oyster mushroom, vegan mayonnaise, xanthan gum

Food and pharma industries are focusing on the development of convenient, healthier and nature-based products. Mushrooms have been traditionally used as food and ethnomedicines since ancient times in India as well as several countries in the world. Various edible species of mushrooms are good source of proteins, polysaccharides and dietary fibre. Furthermore, contain low overall fat and non-essential saturated and mono-unsaturated fatty acids. Edible species of mushrooms are cultivated depending on the environmental condition, consumers demand and utility. Oyster Mushroom (*Pleurotus ostreatus*), also known as "Dhingri" in India, is easy to cultivate and has significant nutritional value. Oyster mushrooms are rich in protein, vitamin B complex, vitamin C, and essential minerals such as calcium, potassium, sodium, phosphorus, and iron (Effiong *et al.,* 2024). Compared to other edible mushrooms, oyster mushrooms exhibit higher concentrations of essential amino acids, such as methionine, cysteine, and aspartic acid (Kim *et al*., 2009). Studies have also explored the hypoglycemic, hypolipidemic, antioxidant, antiviral, and antimicrobial activities of oyster mushrooms, emphasizing their potential medicinal and nutritional value. It has a biological efficiency of approximately 100% and can be preserved for 24 hours in room temperature conditions. Despite numerous benefits, consumer demand for oyster mushrooms remained limited. This can be attributed to factors such as low consumer awareness, short shelf life, and inadequate storage technology (Piska *et al.,* 2017).

Recieved on 22-07-2025; Accepted on 24-09-2025
https://epubs.icar.org.in/index.php/MR/article/view/167215

Value-added products from oyster mushrooms have been developed to address their short shelf life. These include mushroom soup powder, ketchup, cakes, and composite flours, showcasing the versatility of oyster mushrooms in various food products. Mushroom powders have emerged as safe and multifunctional dietary fibre-rich ingredients with high nutritional, functional, and microbial properties. Mayonnaise, a popular sauce, traditionally contains eggs for emulsion, flavour, and colour. However, the health concerns associated with cholesterol have led to an increased demand for vegan-based mayonnaise products. There are studies related the formulation of eggless mayonnaise, emphasizing the use of hydrocolloids and gums to achieve the desired consistency and texture. Plant based proteins and various hydrocolloids, such as xanthan gum, guar gum, karaya, and Arabic gums, are employed in eggless mayonnaise formulations to achieve the appropriate consistency and texture. Gums play a crucial role as stabilizing and thickening agents, contributing to the overall quality of vegan mayonnaise. Mushroom powder, such as *Pleurotus ostreatus* flour, have also been found to enhance emulsion stability and viscosity There are scanty studies reported on the development of oyster mushroom mayonnaise and its storage quality. Therefore, an attempt was made to investigate the potential of gums and oyster mushroom powder for the development of value-added vegan mayonnaise and its quality parameters.

MATERIALS AND METHODS

Materials

Oyster mushrooms procured from mushroom technology lab, CCSHAU, Haryana. Oil and other ingredients like Arabic gum, guar gum, karaya gum, xanthan gum, mustard, sugar, and salt were procured from the local market of Hisar. All chemicals used were of analytical reagent grade.

Mayonnaise Preparation

Vegan mayonnaise was prepared using arabic gum, guar gum, xanthan gum, and karaya gum. Firstly, the gums were dispersed in water (1%) at 25°C and hydrated by stirring at 1000 rpm in a magnetic stirrer until the gums gets dissolved completely in water and hydrated well enough. The obtained dispersion was used for the preparation of vegan mayonnaise. The required ingredients for the preparation of mayonnaise were mentioned in Table 1. The process steps for the preparation of mayonnaise were mentioned below.

Gums suspended in water (1%) → hydrated using magnetic stirrer (1000 rpm) → mixing gum alone for 30 second → addition of dry ingredients (salt, citric acid, sugar, mustard powder, preservatives and stabilizers → addition of vinegar and mixed for 20 seconds → addition of oil drop by drop with continuous stirring until stable emulsion formed.

Oyster mushroom mayonnaise preparation

Dried oyster mushrooms were pulverized into a fine powder in a mixer blender and passed through a 200-mesh sieve. This prepared oyster mushroom powder was used in the preparation of mushroom mayonnaise. Oyster mushroom mayonnaise variants were prepared similarly as mentioned above with the addition of mushroom powder (@ 10% replacement to the hydrated gum percentage used) at the dry ingredients mixing step in the process of vegan mayonnaise preparation. The best acceptable blend through sensory evaluation was selected for further studies. The required ingredients for the preparation of mayonnaise were mentioned in Table 1. Mayonnaise variants without preservatives are prepared with the same percentage of ingredients excluding adding preservatives.

Proximate Analysis

Moisture content, ash content, protein content, fat content, crude fiber content, and carbohydrate content were measured according to AOAC (2005) method.

Table 1. Formulation of vegan and oyster mushroom powder incorporated mayonnaise

Ingredients	Weight (%)	Weight (%)
Sunflower oil	50	40.5
Hydrated gum dispersion (1%)	35	31.5
Mushroom powder	-	3.5
Salt	1	1
Citric acid	0.2	0.2
Sugar	1.5	1.5
Vinegar	9	9
Sodium benzoate and Potassium sorbate	0.1	0.1
EDTA	0.075	0.075
Mustard powder	0.5	0.5
Water	2.625	12.125

Color parameters

Color parameters including L, a, b was measured using colorimeter lab (Konica Minolta CR-400). Suitable quantity of sample was uniformly spread in a petri dish suitable to fit in a circular section of the colorimeter and placed the colorimeter on it to analyze the mayonnaise colour in CIE space: lightness, (l*); redness, (a*); yellowness, (b*).

Syneresis

Conventional centrifugation method was applied to determine water syneresis of mayonnaise variants with minor modifications (Sanguansri *et al.*, 2008). About 25g of mayonnaise was taken for centrifugation, contained in a 35-mL polycarbonate conical centrifuge tube, and centrifuged at 222g for 10 min at 4°C. The amount of supernatant released from the mayonnaise was decanted, weighed, and calculated as a percentage of the original weight.

Emulsion stability

For determination of emulsion stability of mayonnaise, 15 g of mayonnaise samples (F1) were taken in centrifuge tubes. The tubes were tightly sealed with plastic caps and stored at 50°C for 48 h then centrifuged for 10 min at 3000 rpm (Khan *et al.*, 2014). The weight of the precipitated fraction (F2) was noted, and the stability of emulsion or stability ratio (SR) was calculated by following formula-

$$\text{Emulsion stability} = \frac{F2}{F1} \times 100$$

Antioxidant activity

The antioxidant activity of oyster mushroom powder and mayonnaise variants was measured using 2,2-diphenyl-1-picrylhydrazyl (DPPH) dye, as per the procedure described by Shimada *et al*. (1992)

Peroxide Value and Acid value

For determination of acid value, 10 g of mayonnaise was dissolved in 50 ml of the neutral solvent (ethanol) in a 250 ml conical flask. Few drops of phenolphthalein indicator were added and titrated the content against 0.1N potassium hydroxide with constant shaking until the pink color, which persists for fifteen seconds, was obtained (Gaikwad *et al.,* 2020). Acid value of sample was calculated using following formula-

$$\text{Acid Value} \left(\frac{\text{mg KOH}}{\text{g}} \right) = \frac{\text{Titra value} \times 0.1\text{N KOH} \times 56.1}{\text{weight of sample}} \times 100$$

Hydrogen ion concentration (pH) and Titratable Acidity

Mayonnaise sample (1g) was diluted with 10 ml of distilled water, and the pH of mayonnaise variants was estimated by pH meter (Eutech instruments pH700) at room temperature. Titratable acidity of mayonnaise was estimated by titrating against alkaline solution (Tyl and Sadler, 2017). Mayonnaise sample (5g) was diluted to set volume with distilled water.

An aliquot of the sample was titrated with 0.1N sodium hydroxide solution to a phenolphthalein endpoint. From the volume of alkali used, acidity was calculated, and results were expressed as % Acetic acid.

$$\text{Acidity (\%)} = \frac{\text{Titre vol. (ml) x Normality of alkali x milli equivalent factor of acid x vol. made (ml)}}{\text{weight or volume of sample (g or ml)}} \times 100$$

Milliequivalent factor of acetic acid = 0.08

Viscosity

The viscosity of mayonnaise variants was measured with Anton Paar Rheometer MCR 301 with a PP50 probe. Mayonnaise sample (2 g) was placed on rheometer's platform and analyzed. The data of the rheological measurements were analyzed with the supporting rheometer software. A strained control amplitude steep was run at room and refrigerated temperatures.

Sensory evaluation

Mayonnaise samples were subjected to the sensory evaluation soon after its preparation by a panel of ten semi-trained or non-trained judges using 9-point hedonic scale.

Storage study

Vegan mayonnaise and its oyster mushroom variant were stored in glass bottles of 200g size at 28°C and refrigerated temperature (4°C) and analyzed for titratable acidity, pH, acid value, peroxide value, viscosity, antioxidant value and microbial quality at an interval of 15 days by following the methods as described above.

Statistical Analysis

All the experiments were performed in triplicates. The data in the present investigation were subjected to a two-way analysis of variance (ANOVA) with DMRT (Duncan Multiple Range Test) techniques using KAU GRAPES 1.0.0 software based on R and analyzed according to one factorial and two factorial completely randomized designs (CRD) wherever needed. The critical difference value at the 5% level was used to compare different treatments during storage.

RESULTS AND DISCUSSION

Various gums including xanthan, guar, karaya and arabic gums (1% w/v) were used for preparation of oyster mushroom mayonnaise and the developed product was evaluated for sensory properties. As per sensory scores (Fig. 1), arabic gum scored poorly among mayonnaise variants for consistency, texture, and overall acceptability. However, incorporation of mushroom powder while preparing these variants improved the consistency and texture of product. It indicated that the oyster mushroom powder had thickening properties. Through the sensory evaluation, mushroom mayonnaise made with xanthan gum and

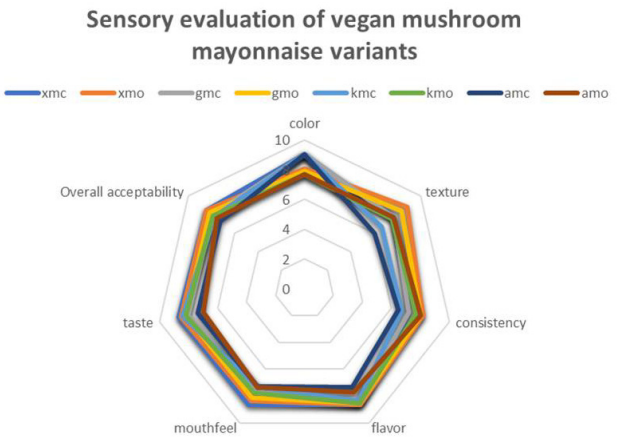

Fig. 1. Sensory evaluation of vegan mayonnaise variants. xmc = vegan mayonnaise variant made with xanthan gum, xmo = vegan mayonnaise (xanthan) with 10% oyster mushroom powder, gmc = vegan mayonnaise variant made with guar gum, gmo = vegan mayonnaise (guar) with 10% oyster mushroom powder, kmc = vegan mayonnaise variant made with karaya gum, kmo = vegan mayonnaise (karaya) with 10% oyster mushroom powder, amc = vegan mayonnaise variant made with arabic gum, amo = vegan mayonnaise (arabic) with 10% oyster mushroom powder

guar gum turned out to be better than other blends. During the trials, guar gum mayonnaise variants exhibited more syneresis and less emulsion stability compared to xanthan gum mayonnaise variants. So, xanthan gum mayonnaise variants are taken for storage studies on the basis of sensory scores, with XMO (oyster mushroom) scored slightly higher than its control (XMC) variant.

The addition of oyster mushroom powder led to a significant change in nutritional composition in vegan mayonnaise (Table 2). Mayonnaise variants with oyster mushroom powder exhibited lower fat and moisture content while higher protein, crude fiber, and ash content as compared to control sample of vegan mayonnaise. It has been reported that increasing the level of mushroom powder in soup mix resulted in correspondingly increased protein, crude fibre and ash content while decreased moisture and fat content in the final product (Srivastava *et al.,* 2019). These changes in nutritional profile of mushroom powder incorporated vegan mayonnaise could be attributed to the high protein and fibre content and low-fat content of mushroom powder.

Table 2. Physicochemical, rheological and colour properties of vegan mayonnaise variants

Parameter	M	MO
Fat content (%)	51.51±0.25[a]	41.52±0.23[b]
Moisture content (%)	42.59±0.49[a]	36.55±0.43[b]
Protein (%)	0.68±0.05[b]	3.08±0.16[a]
Crude fiber(%)	5.74±0.07[b]	0.39±0.01[b]
Ash content (%)	6.53±0.12[a]	0.83±0.01[a]
Viscosity (Pa.s)	10.00±1.0[b]	33.90±0.10[a]
TA (%)	0.59±0.02[b]	0.78±0.04[a]
pH	4.49±0.02[b]	5.03±0.02[a]
AV (mg KOH/g)	0.13±0.04[a]	0.13±0.04[a]
PV (meq/kg)	2.56±0.03[a]	2.56±0.03[a]
Syneresis (%)	0.52±0.03[a]	-
ES (%)	96.10±0.12[a]	97.00.±0.14[a]
L	96.47±0.663[a]	83.72±0.701[b]
a	4.32±0.03[b]	5.68±0.07[a]
b	52.967±0.07[b]	8.30±0.62[a]

All values are mean of triplicate determinations ± standard deviation of mean. Values within same row with different letters are significantly different (pd"0.05). M = vegan mayonnaise variant made with xanthan gum, MO = vegan mayonnaise (xanthan) with 10% oyster mushroom powder.

Mayonnaise variants showed good emulsion stability, with slight increase in viscosity, titratable acidity and pH due to oyster mushroom powder (Table 2). Results have shown that oyster mushrooms had good emulsifying properties and acted as a thickener. Oyster mushroom powder increased the viscosity and consistency of mayonnaise variants. Because of good emulsifying properties, it successfully replaced part of the emulsifier. Studies showed that oyster mushroom flour exhibited more emulsifying properties than protein concentrates (Cruz-Solorio *et al.,* 2018). The slightly increased titratable acidity and pH of mayonnaise variants with oyster mushroom powder were due to the acidity of mushroom powder. Mushroom flour properties obtained by hot air drying has been studied and noted that the pH of the mushroom was 6.06 and the titratable acidity was 0.228 % citric acid (Uribe *et al.,* 2023). The good emulsion stability of samples may be due to the small oil droplet size and good binding capacity of stabilizers. Vegan mayonnaise sample showed little syneresis 0.52%, which may be due to high moisture. Vegan mayonnaise was whiter in colour than mushroom powder added variant. Decreased lightness and increased redness value could be attributed to the slightly darker colour of oyster mushroom powder that could be due to browning of mushroom during drying.

Storage study

Mayonnaise variants exhibited changes in physicochemical and microbial parameters during storage at room and refrigerated temperatures. Titratable acidity, pH, acid value and peroxide value

underwent changes during the storage period (Fig. 2). Antioxidant activity decreased while viscosity of mayonnaise samples increased during storage (Table 3).

Mayonnaise variants containing oyster mushroom powder showed a little higher pH than those without mushroom powder. Disregarding the mayonnaise variant, pH content decreased significantly during the

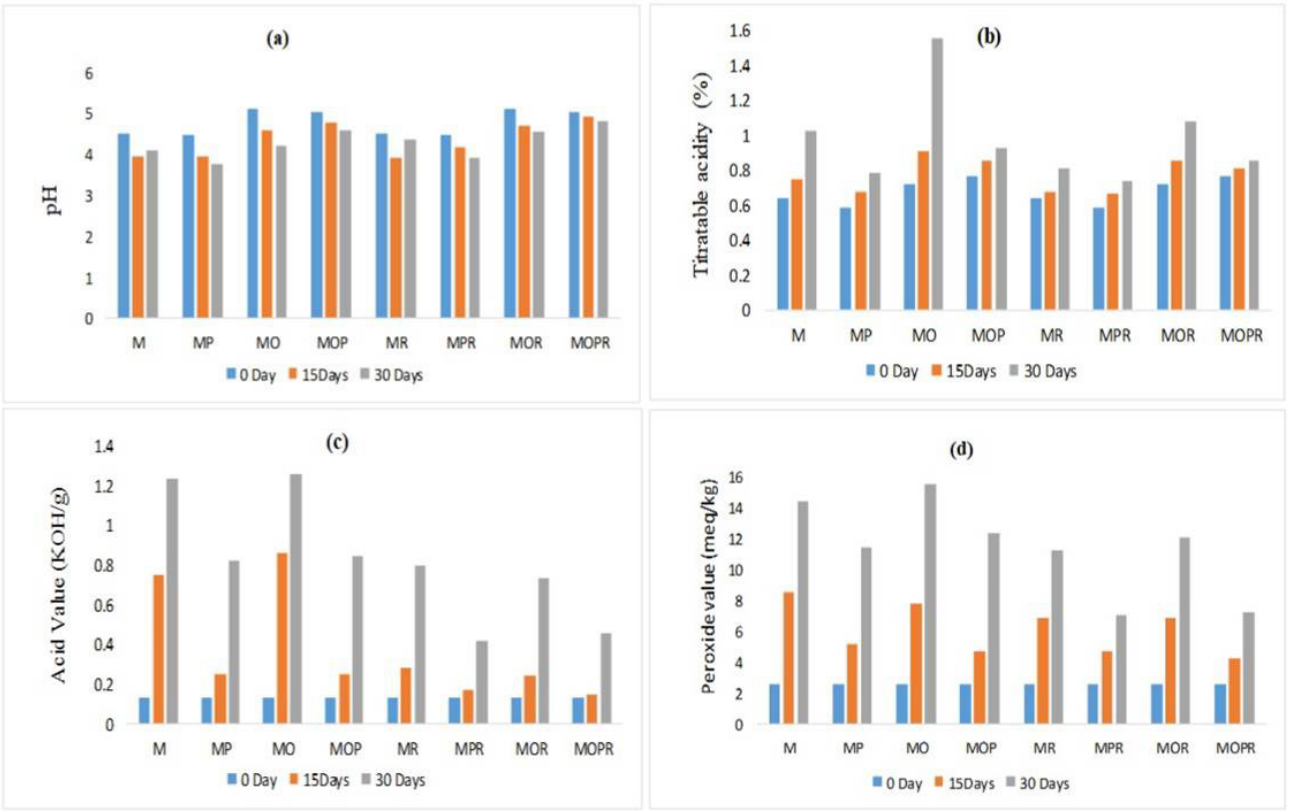

Fig. 2. Effect of storage on pH, titratable acidity, acid value and peroxide value of vegan mayonnaise variants. M = vegan mayonnaise stored at room temperature, MP = M+ preservatives; MO = M + oyster mushroom powder; MOP = MO+ preservatives; MR = vegan mayonnaise stored at refrigeration temperature; MPR=MR + preservatives; MOR = MR + oyster mushroom powder; MOPR = MOR + preservatives

Table 3. Effect of storage on Viscosity (Pa.S.) and Anti-oxidant activity (% inhibition of DPPH) of mayonnaise variants

Storage		Viscosity (Pa.S)				% Inhibition of DPPH			
Temp	**Period**	**M**	**MP**	**MO**	**MOP**	**M**	**MP**	**MO**	**MOP**
RT	**0**	7.36±0.01^{j}	10.00±1.0^{h}	33.90±0.10^{e}	35.90±0.10^{c}	14.57±0.28^{h}	16.91±0.64^{f}	20.48±0.44^{d}	27.69±0.26^{a}
	15	8.86±0.01^{i}	11.34±0.29^{g}	34.20±0.1^{de}	36.70±0.10^{b}	10.04±0.08^{j}	13.58±0.31^{i}	19.07±0.33^{e}	25.76±0.23^{b}
	30	11.52±0.01^{g}	12.23±0.01^{f}	34.70±0.10^{d}	40.10±0.10^{a}	6.34±0.13^{l}	7.45±0.19^{k}	15.26±0.29^{g}	21.20±0.29^{c}
RFT	**0**	7.36±0.01^{j}	10.00±1.00^{i}	33.90±0.10^{e}	35.90±0.10^{d}	14.57±0.28^{f}	16.91±0.64^{e}	20.48±0.43^{c}	27.69±0.26^{a}
	15	10.10±0.10^{i}	11.30±0.10^{h}	36.40±0.10^{d}	37.30±0.10^{c}	14.57±0.28^{f}	16.91±0.64^{e}	20.13±0.18^{c}	27.69±0.26^{a}
	30	12.10±0.10^{g}	14.70±0.10^{f}	38.20±0.10^{b}	40.60±0.10^{a}	10.89±0.11^{h}	12.43±0.34^{g}	18.22±0.22^{d}	24.86±0.14^{b}

All values are mean of triplicate determinations ± standard deviation of mean. Values of each parameter within the table with different letters are significantly different (pd"0.05). M = vegan mayonnaise (control sample); MP = vegan mayonnaise with preservatives, MO= vegan mayonnaise with oyster mushroom powder; MOP= vegan mayonnaise with oyster mushroom powder and preservatives; RT= Room Temperature, RFT = Refrigerated Temperature

storage period. Refrigerated samples showed slightly less decrement in pH compared to room temperature samples. Mayonnaise variants containing mushroom powder showed little higher titratable acidity compared to those without mushroom powder and an increasing trend of titratable acidity was noticed in all mayonnaise variants during storage period. Refrigerated samples showed slightly less increment in titratable acidity compared to room temperature samples.

The intrinsic properties of mayonnaise, dressings, and sauces that most influence the growth and survival of pathogenic bacteria are their acidity and followed by salt and sugar content. However, sugar and salt interact with vinegar's acetic acid to inhibit the growth of foodborne pathogens. Mayonnaise's antimicrobial effect is partly due to its lower pH and the lysozyme in the egg white used in its preparation. The persistent production of acid and growth of lactic acid bacteria during storage might be the reason for increased titratable acidity and decreased pH value during storage (Uluko *et al.,* 2015). The hydrolysis of triglycerides and subsequent rise in free fatty acids (FFA) are also responsible for increased acidity during storage (Kishk and Elsheshetawy, 2013) The slightly increased titratable acidity and pH of mayonnaise variants with oyster mushroom powder were due to the higher pH and acidity of mushroom powder. Uribe *et al.* (2023) studied mushroom flour properties obtained by hot air drying. According to them, the pH of the mushroom was 6.06, and the titratable acidity was 0.228 % citric acid. Acid value and peroxide value of mayonnaise samples increased significantly during the storage period at room and refrigerated temperatures but refrigerated samples showed slightly less increment compared to room temperature samples. Similar trends in acid value and peroxide value values were observed by in earlier investigation (Kishk & Elsheshetawy, 2013; Uluko *et al.,* 2015). The measurement of lipid hydrolysis that leads to the formation of free fatty acids is known as acid value. Peroxide value indicates early oxidation and onset of rancidity. Therefore, a high peroxide value in product indicates the occurrence of rancidity.

Viscosity is resistance of liquid to flow. The mayonnaise's viscosity has a big impact on its quality. The flavour, appearance, and overall acceptability of mayonnaise can be impacted by its texture. Therefore, it is important factor while making mayonnaise to ensure desired consistency and texture. Viscosity enhancement in mayonnaise was observed due to presence of chemical preservatives in both the variants - with and without oyster mushroom powder. It was also observed that viscosity of all mayonnaise variants increased significantly during the storage. Oyster mushroom added in the form of powder might have continuously absorbed water from the emulsion that resulted in a thicker paste during storage. Researchers showed similar results in their study on storage's impact on the rheological and viscoelastic characteristics of mayonnaise emulsions with various oil droplet sizes and noted that viscosity increased during a storage period of one month (Katsaros *et al.,* 2020). The viscosity of low-fat mayonnaise samples increased after four weeks and stated that it was due to xanthan gum taking four weeks to attain its maximum viscosity (Bergecliff, 2016).

The term "antioxidant activity" describes a substance's capacity to inhibit free radicals and avoid oxidative cell damage. By scavenging free radicals and lowering oxidative stress, antioxidants can aid in preventing such damage. Antioxidant activity of fresh mayonnaise variants ranged from 14.57% to 27.69% inhibition of DPPH. Mayonnaise variants with oyster mushroom powder showed more antioxidant activity than their variants without oyster mushroom powder. As mushroom contains phenols and antioxidant properties, the samples with mushroom powder showed more antioxidant activity. Earlier studies showed similar results addition of phenols to

mayonnaise increased antioxidant activity of mayonnaise (Romeo *et al.,* 2021). Disregarding the mayonnaise variant, antioxidant activity decreased significantly during the storage period. Refrigerated samples showed slightly less antioxidant activity decrement than room temperature samples that can be attributed to slower oxidative changes at lower storage temperature.

CONCLUSION

This study explored the potential of mushroom to be used as an ingredient in the most trending food products like spreads. Xanthatn gum proved to be an appreciable substitute of egg in the development of mayonnaise. The incorporation of oyster mushroom (*Pleurotus ostreatus*) powder into vegan mayonnaise produced a novel value-added product with acceptable sensory score, good physicochemical and rheological properties. It can be concluded that low fat, high fibre and protein vegan mayonnaise can be the next option for health conscious consumers of present age. The exploration of other nutrition ingredient and innovative techniques in mayonnaise research can add to the continuous evolution of this popular condiment.

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