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Effect of *Moringa oleifera* Leaves Powder (Sahajjan) on Physiochemical Properties of Chicken Bhujia

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ABSTRACT

The experiment was conducted during January–December, 2024 at the Dept. of Livestock Products Technology, College of Veterinary and Animal Science, RAJUVAS, Bikaner, Rajasthan, India to study the effect of *Moringa oleifera* leaf powder on shelf life and physico-chemical properties of chicken bhujia, Chicken, which contributes 48.96% to global meat production, is highly valued for its affordability and health benefits. However, processed chicken products are particularly susceptible to lipid peroxidation due to the conditions involved in their processing. While synthetic antioxidants have been traditionally used to prevent oxidation, concerns about their genotoxic effects have led to a growing interest in natural antioxidants derived from polyphenolic compound rich plant sources. This study aimed to evaluate the potential of *Moringa oleifera* leaf powder (MoLP) as a natural preservative to enhance the storage stability of chicken bhujia (MoLP) was incorporated at levels of 1.5% (T_1), 3% (T_2) and 4.5% (T_3), alongside control samples. The chemicals in moringa serve as potent antioxidants and growth inhibitors for bacteria and fungi. Phenolic chemicals, which are abundant in Moringa, have been shown to significantly reduce food oxidation The chicken bhujia formulated with 3% (MoLP) (T_2), which received the highest sensory scores were subjected to further analysis for pH, TBARS, tyrosine, free fatty acid characteristics during ambient temperature storage. The findings revealed that (MoLP) significantly improved the quality of chicken bhujia. It reduced pH, TBARS values, tyrosine value and free fatty acid value.

KEYWORDS: Chicken bhujia, *Moringa oleifera*, leaves powder, shelf life

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1. INTRODUCTION

Poultry contributes 48.96% of the total meat production in the country. The growth of poultry meat production has increased by 4.95 per cent. (Anonymous, 2024).

The addition of chicken meat, which is a rich source of polyunsaturated fats, frequently lowers the oxidative stability of food products that require the use of antioxidants (Bhat and Bhat, 2011a, 2011b, 2011c). Although the oxidation of lipids and proteins in food matrices can be effectively controlled by synthetic antioxidants, knowledgeable consumers strongly advise against using them (Kalem et al., 2017; Mahajan et al., 2016a; Noor et al., 2017; Noor, Bhat, Kumar, and Mudayanselage, 2018). As antioxidants and preservatives in food, plant extracts high in polyphenols and antimicrobials are very acceptable to consumers (Bhat et al., 2015b; Kumar, Bhat, and Kumar, 2013).

Due to lipid oxidation, synthetic antioxidants like butylated hydroxytoluene, butylated hydroxyanisole, etc. are added during the meat processing process; nevertheless, due to their potential toxicological effects, they have recently come under investigation (Choi et al., 2019; Ribeio et al., 2019).

Bioactive compounds are abundant in the leaves and seeds of *Moringa oleifera*, sometimes known as Moringa. In addition to their significant therapeutic benefits (Fuglie et al., 2001), the chemicals in moringa serve as potent antioxidants and growth inhibitors for bacteria and fungi. Phenolic chemicals, which are abundant in Moringa, have been shown to significantly reduce food oxidation (Keokamnerd et al., 2008; Sabale et al., 2008). Flavonoid (mainly flavonoid and glycoside: quercetin, rhamnetin, campferol, apigenin, and myricetin) and their derivatives (coumaroylquinic acids and their isomers, feruloylquinic and caffeoylquinic) (Rani et al., 2018) are found in *Moringa oleifera* leaves, along with 11 phenolic acids (Gallic acid, caffeic acid, chlorogenic acid, o-coumaric acid, p-coumaric acid, ellagic acid, gentisic acid, sinapic acid, and syringic acid).

Bhujia, a popular Indian deep-fried snack made from gram flour, is shelf-stable but prone to oxidation and rancidity due to its high fat content. Adding meat powder enhances its flavor and nutrition, while spices and condiments act as natural antioxidants, preserving quality and extending shelf life (Sarkar et al., 2020).

Protein, vitamins A, B, and C, as well as minerals like calcium and iron, are abundant in *Moringa oleifera* leaves. Leaves are a great source of vitamins A and C when consumed uncooked. They are a great source of vitamin B in addition to being high in plant minerals. Their leaves contain seven times as much vitamin C, ten times as much vitamin A and seventeen times as much calcium as oranges, carrots, and other fruits. Milk provides nine times the protein, bananas have fifteen times the potassium, and spinach has twenty-five times the iron of curd. As an antipyretic, antiepileptic, and anti-inflammatory for the urinary tract, in addition to their antibacterial properties, a number of plant components, including leaves, roots, seeds, bark, fruits, flowers, and immature pods stimulate the heart and circulatory system (Prasajak et al., 2021)

Moringa oleifera, also known as the horse-radish tree or drumstick tree, is a very profitable crop in many Southeast Asian countries. For a long time, the plant has been used because its components provide therapeutic benefits. Zeaxanthin, lutein, alpha- and beta-carotene, and chlorophyll are among the phytonutrients included in Moringa. According to Sarkar et al. (2022), phytonutrients have been demonstrated to enhance immunity, support the creation of new blood cells, improve liver function, and revitalize the body at the cellular level. Many plants' leaves and fruits are regarded as vegetables in their home countries. Moringa leaves include compounds that may be used as an antioxidant and antibacterial, including alkaloids, protein, quinine, saponins, flavonoids, tannin, steroids and glycosides (Bagheri et al., 2020). The objectives of the research were to study the effect of the effect of *Moringa oleifera* leaf powder on shelf life and on physico-chemical properties of chicken bhujia.

2. MATERIALS AND METHODS

The experiment was conducted during January-December, 2024 at Dept. of Livestock Products Technology, College of Veterinary and Animal Science, RAJUVAS-Bikaner (334 001), Rajasthan, India (28°02'13"N, 73°30'15"E) to study the effect of *Moringa oleifera* leaf powder of physic chemical properties of chicken bhujia, To conduct the experiment required broiler meat to be purchased from Aakash poultry farm in Bikaner, Rajasthan and at the lab, the deboning process was carried out by hand in Department of Livestock Products Technology, College of Veterinary and Animal Science Bikaner. Meat was packed in polyethylene bags and refrigerated overnight at 4°C to condition it after the fat and separable tissue were removed. It was then frozen at -18±1°C for eventual use. The spices, after removing extraneous matter, all spice ingredients were oven-dried at 50°C for 2–3 hours. The dried spices were ground using a grinder with a suitable blade and sieved through a fine mesh to obtain a uniform powder. The spice powders were combined in the specified proportions to create the spice mix and the moisture content was analyzed hourly until it stabilized. The prepared spice mix was incorporated into the formulation of chicken bhujia products. The Refined gram flour (RGF), table salt, refined soya bean oil (Fortune brand), sodium tri-poly phosphate

(STPP) were all Procure at nearby shops. For product examination, analytical-grade chemicals and media from reputable companies such as Sigma, Merck, SRL, and Hi-media, among others, were utilized.

2.1. Preparation of moringa oleifera leaves powder (MoLP)

Moringa leaves were procured from Pashu Vigyan Kendra Suratgarh. The leaves were washed with the help of tap water followed by distilled water to remove the dirt and dust or any other foreign material on its surface. After washing, leaves were dried in the hot air oven at 40-50°C for 6–8 hours till constant weight was obtained. Dried leaves were then powdered using a heavy Grinder Machine (Uno (mx-140), Group SEB India Pvt. Ltd, Maharaja white line) and sieved. The dried powder was packaged in LDPE pouches and stored at refrigeration at 4°C for further use.

2.2. Preparation of chicken bhujia

During early trials, the laboratory standardized the process for making shelf-stable chicken bhujia utilizing varying ingredient levels and processing parameters (Figure 1). The chicken mince meat (CMM) (40%) Refined gram flour (RGF) (50%), spice mixture (6%), table salt (2%), refined soya bean oil (Fortune brand) (1.5%), sodium tri-poly phosphate (STPP) (0.5%) and (40 ml) water were added to a bowl to make dough. The chicken mince meat (40%) was replacing *Moringa oleifera* leaves powder (MoLP) in the basic formulation viz T_1=1.5% *Moringa oleifera* leaves powder (MoLP), T_2=3% *Moringa oleifera* leaves powder (MoLP) and T_3=4.5% *Moringa oleifera* leaves powder (MoLP) respectively, and the rest of the ingredients were kept the same for the three treatments. Preliminary trial findings were used to determine these levels of incorporation. After the batter was put into a manual extruder, the uncooked bhujia were deep-fried in refined soya bean oil (Fortune brand). The bhujia were placed in laminate pouches made of polyethylene and aluminum with a 12-micrometer thickness after cooling, and they were kept for 90 days at room temperature (25±1°C). The air conditioners were used to regulate the laboratory's temperature for the duration of storage. The samples were assessed for a number of quality indicators after being collected on days 0, 15th, 30th, 45th, 60th, 75th and 90th day.

2.3. Analytical procedure

2.4. Physico-chemical parameters

2.4.1. pH

The pH of chicken bhujia was determined using a digital pH meter (LMPH-10, Labman benchtop) with a combined glass electrode, as per the method described by Trout et al. (1992). For the analysis, 10 g of the sample was homogenized with 50 ml of distilled water in homogenizer for 1 minute.

C= Control chicken bhujia

Chicken Bhujia with 3% *Moringa oleifera* leaves powder (MoLP)

Figure 1: Chicken bhujia incorporated with *Moringa oleifera* leaves powder (MoLP)

TBARS values were estimated by the procedure described by Witte et al. (1970), FFA% value was estimated as per Koniecko (1979) and tyrosine value was determined as per the method described by Strange et al. (1977).

2.5. Statistical analysis

The experiments in this study were repeated three times, with each sample being taken in duplicate. Data was analyzed using Statistical Software Packages (SPSS16.0) following the procedure of Snedecor and Cochran(1989).

Table 1: Effect of *Moringa oleifera* leaves powder (MoLP) incorporation on physico-chemical properties of chicken bhujia during ambient temperature storage (Mean±SE)

Days/Group	0	15	30	45	60	75	90	Treatment Mean±SE
pH								
C	6.37±0.12	6.09±0.21	6.36±0.01	6.43±0.00	6.47±0.004	6.55±0.004	6.61±0.01	6.41^{B}±0.04
T_2	6.12±0.00	6.17±0.00	6.24±0.00	6.28±0.00	6.33±0.01	6.43±0.01	6.51±0.01	6.30^{A}±0.02
TBARS								
C	0.20±0.02	0.40±0.05	0.51±0.03	0.66±0.04	0.76±0.03	0.81±0.03	0.92±0.07	0.61^{B}±0.04
T_2	0.16±0.01	0.27±0.03	0.39±0.03	0.56±0.04	0.65±0.03	0.70±0.03	0.75±0.04	0.49^{A}±0.04
Tyrosine value								
C	1.48±0.15	1.72±0.15	1.81±0.09	1.82±0.10	1.91±0.09	2.13±0.14	2.22±0.16	1.87^{B}±0.06
T_2	1.32±0.04	1.50±0.08	1.67±0.07	1.77±0.06	1.85±0.08	1.95±0.09	2.14±0.12	1.75^{A}±0.05
Free fatty acid (FAA) value								
C	0.28±0.06	0.38±0.05	0.35±0.07	0.38±0.08	0.41±0.09	0.45±0.08	0.49±0.06	0.39^{B}±0.03
T_2	0.15±0.00	0.25±0.04	0.29±0.05	0.32±0.05	0.36±0.06	0.41±0.08	0.46±0.08	0.32^{A}±0.03

Means bearing different superscript in a column (capital letter) and in a row (small letter) differ significantly; C: Chicken bhujia without *Moringa oleifera* leaves powder (MoLP); T_2 group: Chicken bhujia with 3% *Moringa oleifera* leaves powder (MoLP)

3. RESULTS AND DISCUSSION

3.1. Effect of Moringa oleifera leaves powder (MoLP) on the physico-chemical properties of chicken bhujia

3.1.1. pH

In this study, the overall mean of pH value of control and treated T_2 with (3%) *Moringa oleifera* leaves powder (MoLP) were (6.41±0.04) and (6.30±0.02) respectively. *Moringa oleifera* leaves powder (MoLP) had significantly (p<0.05) lower mean treatment value compared to control. This observation could be related to the elevated levels of antioxidants and bio-active ingredients present in *Moringa oleifera* leaves, which were incorporated into the chicken bhujia. T_2 had significantly lower (p<0.05) pH than control products throughout ambient storage period (Table 1).

The Moringa flower extract's inhibitory effects on protein and lipid oxidation, as well as some of the plant powder's antibacterial properties, may be the reason why the pH increased significantly (p<0.05) less in treated samples during the refrigeration period than in control samples (Dodiya et al., 2015).The overall mean pH values on days 0, 15th, 30th, 45th, 60th, 75th and 90th of ambient storage were significantly different (p<0.05), showing an increasing trend over time. Thereafter the pH value increased significantly (p<0.05) with the increase in storage period. The rise in pH is due to volatile nitrogen compounds like ammonia, formed during protein breakdown by enzymes or bacteria. These compounds are alkaline and increase the pH as proteins are degraded into amino acids and further processed by microbes. This was reported by Erkan et al. (2012). Both the control and treated mutton patties' pH levels rise when MOLE was added during storage, most likely as a result of microbes breaking down proteins into alkaline substances like ammonia (Mashau et al., 2021; Al-Juhaimi et al., 2016). Additionally, the outcomes matched the research published by other scholars (Khomola et al., 2021; Madane et al., 2020; Serdaroglu et al., 2021. This rise in pH is likely due to microbial metabolism and enzymatic reactions over time Duan et al. (2020), Wang et al. (2020).

Similar findings were reported in chicken nuggets incorporated with *Moringa oleifera* flower extracts Madane et al. (2019) and those containing gooseberry pulp and seed coat powder Goswami et al. (2020). Verma et al.(2020) goat meat nuggets treated with *Moringa oileifera* leaves flower, Kashif (2024) reported chicken burgers treated with *Moringa oleifera* leaves, Gomes et al. (2023) Yoghurt treated with *Moringa oleifera* leaves extract, Similar finding Mathu Kumar et al. (2014) ground pork patties incorporation of *Moringa oleifera* leaves extract.

The production of basic amino acids as a result of the proteolysis of meat proteins, which is brought on by microbial or enzymatic activity, is responsible for the pH rise during storage. The quality evaluation of vacuum-packaged chicken snacks kept at room temperature revealed similar results. Singh and colleagues (2011). For a number of meat products, the progressive rise in pH with increasing storage duration has also been well established (Kumar and Sharma, 2006; Bhat and Pathak, 2009). Saini et al. (2020) and Mishra et al. (2015) noted similar outcomes in chicken snack and chicken ring, whereas Sarkaret al. (2020) showed a similar tendency.

3.1.2. Thio-barbituric acid reactive substance value (TBRAS)

The overall mean of TBARS value of control and treated with T_2 group (3%) *Moringa oleifera* leaves powder (MoLP) were (0.61±0.04) and (0.49±0.04) respectively. *Moringa oleifera* leaves powder (MoLP) had significantly (p<0.05) lower mean value compared to control.

The TBARS (Thiobarbituric Acid Reactive Substances) values of chicken bhujia group (control and T_2) increased significantly (p<0.05) with the duration of storage (Table 1). A notable (p<0.05) increase in TBARS was observed within control and treatment group over time. However, the TBARS values were significantly lowest in the T_2 group, with the control (C) showing the highest levels. This indicates that the inclusion of *Moringa oleifera* leaves powder (MoLP) was more effective in inhibiting oxidative rancidity in chicken bhujia. Importantly, the TBARS values of all groups remained below the spoilage threshold (≥1 mg malonaldehyde/kg) throughout the storage period, highlighting the efficacy of the treatments in maintaining product quality.

Lipid oxidation, which results in the creation of volatile metabolites, is the cause of the rise in TBARS readings over the course of storage. The presence of oxygen during aerobic storage makes this process especially noticeable since it promotes oxidative processes. and al. Mashau (2021b).

Hazra et al. (2012) reported a significant (p<0.05) lower in TBARS values of ground buffalo meat treated with 1.5% *Moringa oleifera* leaves extract (MOLE) in comparison to other treated meat. The strong antioxidant ability of MOLE is due to the different polyphenolic compounds present in MOLE (Madukwe et al., 2013; Muthukumar et al. (2014), Shah et al. (2015).

Similar trends in TBARS values during shelf-life studies under refrigeration storage have been reported in various studies. Muthukumar et al. (2014) observed such trends in ground pork patties, while Mashau et al. (2021b) reported similar findings for mutton patties. Additionally, Shah et al. (2015) documented comparable results for modified atmosphere-packed raw beef incorporated with different levels of MOLE. A similar finding was reported by Al-Baidhani et al.(2024) who reported beef patties treated with *Moringa oleifera* leaves. Similar findings Al-Baidhani and Al-Mossawi (2019b).

Lipid oxidation was also significantly reduced by adding plant-based powders or extracts to beef, according to other research Khomola et al., 2021; Mashau et al., 2021). Furthermore, when compared to the control, Das et al. (2012) found that adding 0.1% MOL extract to cooked goat meat patties significantly decreased TBARS values.

3.1.3. Tyrosine Value (TV)

The overall mean of tyrosine value of control and treated with T_2 group (3%) *Moringa oleifera* leaves powder (MoLP) were (1.87±0.06) and (1.75±0.05) respectively. *Moringa oleifera* leaves powder (MoLP) had a significantly (p<0.05) lower mean value compared to the control. The tyrosine value of the T_2 group was found to be significantly lower (p<0.05) compared to control (C) during the storage study (Table 1). The results indicate that the incorporation of *Moringa oleifera* leaves powder (MoLP) effectively maintained significantly lower tyrosine values in chicken bhujia groups during storage compared to the control (C). This retardation of proteolysis activity in the final product is likely due to the antimicrobial properties of *Moringa oleifera* leaves, as described by Xiao et al. (2020). Gomkale (2023) observed a similar trend in tyrosine value in the *Moringa oleifera* leaves extract (MOLE)-treated chicken nuggets was significantly reduced with an increment of the amount of extract in the product.

The results of the study were in conformation with the findings of Koshle (2019) who observed a similar change in the tyrosine value of chicken sticks incorporated with custard apple pulp extract and Gadekar et al. (2014) who observed similar changes in the tyrosine values of restructured goat meat product treated with natural antioxidants.

Throughout the storage period, a consistent increase in tyrosine value was observed across treatments and control groups. Kasthuri et al. (2017) and Lonarkar et al. (2022) regarding the quality of chicken samosas mixed with custard apple peel powder. This increase can be attributed to the rise in microbial load and the enhanced production of proteolytic enzymes during the late logarithmic phase of microbial growth, leading to autolysis, as reported by Thomas et al. (2010) in pork sausage. This trend underscores the relationship between microbial activity and proteolysis during storage. Similar results were reported by Khare (2016) in chicken cut-up parts treated with carrageenan and paprika extract, respectively.

3.1.4. Free fatty acids (FFA)

The overall mean of the free fatty acid (FFA) value of control and treated with 3% *Moringa oleifera* leaves powder (MoLP) were (0.39±0.03) and (0.32±0.03) respectively. The T_2 group with *Moringa oleifera* leaves powder (MoLP) had significantly (p<0.05) lower mean treatment free fatty acid (FFA) value compared to the control. This might be due to the antimicrobial activity of Moringa leaf powder which causes a reduction in microbial growth and subsequent microbial lipolytic activity and generation of free fatty acids.

As refrigerated storage progressed, the Free fatty acid (FFA) percentage values increased significantly. This rise in FFA levels during storage could be attributed to microbial lipolytic activity (Table 1). In addition to their antibacterial and antioxidant properties, the data show that the extracts help extend the product's shelf life by inhibiting secondary lipid oxidation. The antioxidant properties of Moringa leaves play a significant role in this regard. For example, a study by Rahman et al. (2020) showed that adding Moringa leaf extracts to goat meat reduced the increase in chemical markers (POV, TBA and FFA) compared to a control group that neither included the extracts nor underwent storage.

Oleic acid is commonly used as a reference to express free fatty acids (FFA), an empirical indicator of hydrolytic rancidity in meat systems. FFAs are formed due to the catalytic activity of trace metals, microbes, or enzymes such as lipases. They are by-products of enzymatic or microbiological lipolysis of lipids, which significantly influence the flavor profile of meat (Vasu, 2023).

FFA values are consistently aligned with TBA values. Furthermore, free fatty acids are produced not only through enzymatic degradation but also through microbial degradation of lipids and fats Rehman et al. (2020). The results are consistent with the findings of Reddy et al. (2013) in restructured mutton slices Najeeb et al. (2014) in restructured chicken blocks, Vasu (2023) in pork sausage treated with finger millet and Moringa leaves powder, Similarly, Gadekar et al. (2014) observed a similar trend in FFA levels during storage in both restructured mutton and goat meat products.

Similar findings with prior studies on plant-extract beef patties (Ibrahim, 2018). Rahman et al. (2020), the results are satisfactory. Additionally, the findings of Al-Baidhani and Al-Mossawi (2019b) agree, showing that the values of TBA, and FFA increase as the storage duration. extends. A similar finding was reported by Al-Baidhani et al. (2024).

3.1.5. Effect of Moringa oleifera leaves powder (MoLP) incorporation on cooking yield of chicken bhujia

The statistical analysis revealed a significant (p<0.05) effect of incorporating *Moringa oleifera* leaf powder (MoLP) on the cooking yield of the product (Table 2). The cooking yields for Chicken Bhujia were as follows: 87.29±0.18% with 1.5% MoLP (T_1), 89.01±0.33% with 3.5% MoLP (T_2) and 91.08±0.32% with 4.5% MoLP (T_3), compared to 84.56±0.26% for the control. These findings indicate that increasing levels of MoLP significantly enhance the cooking yield of chicken bhujia.

The increase in the cooking yield of chicken bhujia treated with *Moringa oleifera* leaves powder (MoLP) is likely due to its strong capacity to retain moisture and fat within the meat matrix. The increase in cooking yield values is attributed to the retention of both fat, water and moisture maintenance in product during cooking processing Mahmoud et al. (2017). Similarly, Aleson-Carbonell et al. (2005) reported that the addition of lemon albedo to beef burgers, Alakali et al. (2010) reported that using bambara groundnut seed flour in beef patties improved cooking yield.

Table 2: Effect of *Moringa oleifera* leaves powder (MoLP) incorporation on cooking yield of chicken bhujia (Mean±SE)

Groups	Cooking yield (%)	Water holding capacity (%)
C	$84.56±0.26^a$	$38.63±0.34^a$
T_1	$87.29±0.18^b$	$45.93±0.29^b$
T_2	$89.01±0.33^c$	$51.77±0.32^c$
T_3	$91.08±0.32^d$	$56.17±0.23^d$

Overall means bearing different superscripts in the column (a, b, c, d) different significantly (p<0.05); n=6 (for each treatment), C: Chicken bhujia without *Moringa oleifera* leaves powder (MoLP); T_1 group: Chicken bhujia with 1.5% *Moringa oleifera* leaves powder (MoLP); T_2 group: Chicken Bhujia with 3% *Moringa oleifera* leaves powder (MoLP); T_3 group: Chicken bhujia with 3% *Moringa oleifera* leaves powder (MoLP)

Additionally, the enhanced cooking yield in treated patties may be attributed to the presence of dietary fibers in *Moringa oleifera* leaves powder (MOLE), which effectively bind both water and fat Cofrades et al. (2000). The incorporation of *Moringa oleifera* leaves powder (MOLE) contributes to forming a stronger meat matrix structure, enhancing the overall cooking performance of the patties (Essa and Elsebaie, 2018).

Similar results were reported by Mashau et al. (2021) where by the addition of *Moringa oleifera* leaves extract (MoLP) increased the cooking yield of mutton patties. The similar trend was observed by Al-Juhaimi et al. (2016), Ham et al. (2017), Kausar et al. (2018), Madane et al. (2021), Khomala et al. (2021), Mashau et al. (2021b), Ibrahim et al. (2022), Pathade et al. (2022). Similar finding was reported by Al-Baidhani et al. (2024) who observed that beef patties treated with *Moringa oleifera* leaves exhibited a comparable increase in cooking yield. Gomakle (2023) also observed similar results in chicken nuggets incorporated with *Moringa oleifera* leaves.

3.1.6. Effect of Moringa oleifera leaves powder (MoLP) incorporation on water holding capacity (%) of chicken bhujia

The statistical analysis revealed a highly significant (p<0.05) effect of incorporating *Moringa oleifera* leaf powder (MoLP) on the water-holding capacity (WHC) of the product. The WHC values for chicken bhujia were as follows: 45.93±0.29% with 1.5% MoLP (T_1), (51.77±0.32)% with 3.5% MoLP (T_2) and (56.17±0.23)% with 4.5% MoLP (T_3), compared to (38.63±0.34)% for the control. These results indicate that increasing levels of MoLP significantly improve the WHC of chicken bhujia.

The water holding capacity (WHC) of meat refers to its ability to retain added or its water during processing. It is an important quality attribute for determining whether the meat is suitable for use in processing meat products (Mahmoud et al., 2017). The water holding capacity of Chicken Bhujia incorporated with *Moringa oleifera* leaves powder (MoLP) was highly significantly (p<0.05) higher than the control. The control group had a lower water holding capacity, which could be attributed to the minor denaturation of sarcoplasmic proteins. This denaturation can affect the meat's ability to retain water during processing (Para et al., 2017).

Water holding capacity is the most important quality characteristic of fresh meat. It affects characteristics of cooked meat such as technological quality, appearance and sensory quality of the products (Kausar et al., 2018). Moreover, Muthukumar et al. (2012) stated that the addition of *Moringa oleifera* leaves extracts increased the water holding capacity of goat meat and raw pork patties.

Sharma and Yadav (2020) observed similar results whereby incorporation of plant-based ingredients enhanced the water holding capacity in various meat products. Studies have demonstrated that adding ingredients such as Pomegranate peel, Bagasse powder and their extracts can significantly increase the water holding capacity of products like chicken patties, goat meat, and pork patties. This improvement results in meat products that are more tender and juicier. The use of fruit and vegetable-derived components positively affects the meat's ability to retain water, thereby enhancing both texture and sensory quality.

Muscle proteins, like actomyosin, help meat bind water, which is a key function of muscle fibers. During steaming, water loss lightens beef patties. Incorporating *Moringa oleifera* leaves powder increases water holding capacity, with higher WHC indicating better water retention by fibers, which improves patty quality (Swatike et al., 2024).

Hayes et al. (2010) and Hazra et al. (2012) reported an increase in water holding capacity (WHC) (%) of beef patties treated with ellagic acid and clove oil extract and ground buffalo meat treated with 1.5% *Moringa oleifera* leaves extract (MOLE) in comparison to other treated meats. Similar findings were also reported by Mathukumar et al. (2012), Das et al. (2012), Shah et al. (2015), and Al-Juhaimi et al. (2016). A similar finding was reported by Al-Baidhani et al. (2024), who observed increased WHC in beef patties treated with *Moringa oleifera* leaves. Khomala et al. (2021) also reported similar results.

4. CONCLUSION

Incorporating *Moringa oleifera* leaf powder (MoLP) into chicken bhujia improved its functionality, quality, and antioxidant properties. Bhujia with 3% MoLP had the highest acceptance compared to control and other treatments. MoLP reduced TBARS, tyrosine, and free fatty acids, inhibiting lipid oxidation and lipolysis, thus extending shelf life. It also improved pH, enhancing stability. MoLP is a natural, safe, and cost-effective preservative, reducing foodborne risks. Its polyphenols made it highly effective, especially in preserving chicken bhujia.

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