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Effect of Rice Beer and Phyto-Ingredients on Proximate Composition, Texture, Colour, and Sensory Evaluation of Vacuum-packaged Marinated Duck Meat

Pompi Rani Boro [a*], Saurabh Kumar Laskar [a], Ankur Das [a] and Naba Jyoti Deka [b]

[a] Department of Livestock Products Technology, College of Veterinary Science, Assam Agricultural University, Khanapara, Guwahati Pin: 781022, Assam, India.
[b] Department of Veterinary Biochemistry, Assam Agricultural University, Khanapara, Guwahati Pin: 781022, Assam, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This research investigates the impact of rice beer and phyto-ingredients on vacuum-packaged marinated duck meat quality. Ducks aged 9 to 12 months were sourced, slaughtered, and dressed, followed by marination in four formulations: a control (meat + spice paste), T1 (meat + rice beer +

**Corresponding author: Email: pompi8420@gmail.com;*

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spice paste), T2 (meat + phyto-ingredients + spice paste), and T3 (meat + rice beer + phyto-ingredients + spice paste). After marination, the samples were vacuum-packaged and refrigerated for 24 hours, with quality assessments conducted at 5-day intervals. Results showed that T3 had significantly higher moisture content than the control, while the control had higher levels of crude protein, ether extract, and total ash. Colour analysis indicated no significant differences in lightness, but a decrease in redness and yellowness was noted across samples. Texture analysis revealed T3 had reduced hardness, with significant differences in springiness and chewiness compared to the control. Sensory evaluation showed no significant differences in appearance, colour, flavour, or tenderness but notable differences in juiciness and overall acceptability.

Keywords: Meat; Phyto-ingredients; marination; fermented beverages.

1. INTRODUCTION

Meat contains water, proteins, lipids, minerals, and a trace amount of carbohydrates and vitamin B complex. It plays a vital role in the human diet by supplying all the nutrients needed for development and health. Meat and meat products are important providers of essential lipids, minerals, soluble vitamins, and considerable protein with high biological value. Each of these elements contributes differently to our physiological processes. Poultry is the most important source of meat, accounting for around half of the total amount of meat produced. Duck meat, which makes up a significant amount of the 851.81 million tonnes of poultry meat produced in India, is the second-highest contributor among the poultry types. In Assam and other coastal Indian states, duck rearing—especially that of the Pati duck (*Anas platyrhynchos domesticus*)—has special importance since it allows tiny and marginalized farmers to profit from the marshy and wet environment. (Kalita and others, 2009) Duck meat is unique because it combines the qualities of red and white meat, and some areas have more red fiber than chicken. Duck meat is becoming more popular because of its intermediate meat category status and high content of phospholipids and monounsaturated fatty acids like oleic and linoleic acids (George et al., 2014). But even though duck meat is popular in Assam, people still eat it traditionally, and there are not many processed duck meat items available on the market compared to chicken.

Marination is an essential step in meat product preparation. Marinating meat tenderizes it, speeds up maturation, and adds unique tastes. Acidic ingredients that alter the structure of the meat are frequently used to improve this process. Marinades have been widely used to enhance flavour, colour, juiciness, tenderness, and cooking yield of the meat products. The components of marinades determine how effective they are. For example, salt and phosphate are frequent ingredients in most marinades. Salt improves flavour, facilitates the extraction of proteins, increases the absorption of marinades, and retains moisture better during storage and further processing.

Alcohol and natural acids found in fermented drinks have the capacity to preserve food, especially meat. In northeastern India, traditional rice beer is distinctive in its manufacturing process and flavour profile, and it is deeply ingrained in tribal life on a cultural and religious level. This traditional beverage is made from fermented rice starch that bacteria have converted to sugars. Because of their volatile oils and oleoresins, spices derived from plant materials are essential for flavouring, tenderizing, and preserving food.

Furthermore, natural antioxidants can be added to meat through active packaging, surface application, or dietary absorption to improve meat quality. Green tea extracts are well-known for their beneficial effects on microbial growth and lipid oxidation because they contain high amounts of antioxidant polyphenols. Native to places like Northern India and Iran, pomegranates have anti-inflammatory, antibacterial, and antioxidant qualities. Citrus fruits are valued for their varied contents, which include fiber, carotenoids, flavonoids, polyphenols, and essential oils. Bamboo shoots are known for their potential as health foods since they contain dietary fibre, proteins, amino acids, and vitamins. The current study aims to create a standard marinade utilizing rice beer, phyto-ingredients, and spice extracts to make duck meat products, considering the advantages of rice beer as a marinade. The study aims to investigate the physicochemical characteristics marinated duck meat.

2. MATERIALS AND METHODS

2.1 Collection and Preparation of Marinated Duck Meats

Local Ducks known as Pati Duck of the age group of 9-12 months, irrespective of their sexes, were procured from the local Beltola market of Guwahati city, Assam, India. The ducks were slaughtered in a semi-mechanized poultry dressing unit of the Department of Livestock Products Technology and properly dressed hygienically. After slaughter, the carcasses were packed in medium-density food-grade polythene bags and kept in a refrigerator at 4±1ºC until further use. Locally made rice beer was collected from the Bodo community and prepared at the Amtola village, Raha, District Nagaon. The rice beer is known as "Jou" in the local Bodo language. Glutinous Rice (Bora saul) is boiled first, then cooled and allowed to dry up partially. A mixed starter culture containing dry cake, locally known as "Angkhu," is added to rice, mixed properly, and kept overnight at room temperature. The rice mix is then kept in earthen pots with little water for 3-4 days at room temperature for fermentation. The peculiar "alcoholic" smell indicates the ripening of the mixture. The semi-liquid "alcoholic mass" is filtered to get the "Rice beer" liquor in this work. Rice beer is bottled in an air-tight amber-coloured glass bottle, brought to the laboratory, and stored at refrigeration temperature until further use. Good quality spices (Cumin, Coriander, Turmeric, Black pepper, Paprika) were collected from the local market, washed, and dried. The spices were made into powder using a conventional grinder mixer and packed in food-grade MDPE packets at room temperature until use. Fresh condiments (Garlic and Ginger) were collected from the local markets. Raw condiments were washed, cut into small pieces, and ground into a paste using a conventional grinder mixer. The paste was collected in a beaker and stored in a refrigerator at 4±1ºC until use.

2.2 Marination and Packaging of Meat Samples

The wholesale breast cut was used for the present study. The cut was separated from the whole duck carcass. Marinades were prepared and applied to the breast meat samples. The marinated meat samples were then grouped as follows:

Control: Meat + Spice paste.

Treatment 1: Meat + rice beer+ Spice paste.
Treatment 2: Meat + Phyto-ingredients+ Spice paste.
Treatment 3: Meat + Rice beer+ Phyto-ingredients + Spice paste.

2.3 Packaging

The marinated samples were vacuum and aerobically packed. The packets were marked and stored at refrigeration temperature (4±1ºC) for 24 hours. After this period, the samples were subjected to various quality assessments. Proximate composition, texture profile, colour profile, and sensory evaluation were analyzed at the intervals of 1st, 5th, 10th, and 15th days for vacuum-packed samples.

2.4 Proximate Composition

The Moisture, Crude Protein (CP), Ether Extract (EE), and Total Ash (TA) contents of the control and treated products were estimated as per the standard procedure (AOAC, 2005).

2.5 Texture Profile

The texture profile of the product (Hardness, Fracturability, Springiness, Cohesiveness, Chewiness and Resilience) was determined with the help of a texture analyzer (TAHD plus, Stable micro systems, UK) (Reese et. al., 2025).

2.6 Colour Profile

The colour (L*, a*, b*) of the product was evaluated with the help of a UV-Visual Spectrophotometer (Cary 100 bio) using the solid sample holder. The L*.a*, b* values were recorded on the day of preparation of the product (Ainur et al., 2020).

2.7 Sensory Evaluation

The sensory evaluation of the control and the treated samples was carried out by serving the products to a 7-member panel of semi-trained judges of different age groups and sexes. All the product samples were evaluated for appearance, colour, flavour, tenderness, juiciness, and overall acceptability using a 9- point hedonic scale card as described by Ingham et al. (2002).

2.8 Statistical Analysis

Data obtained in the study were analyzed statistically on the "SPSS-16.0" software package as per standard methods (Snedecor and Cochran, 1995). Five batches of the products were prepared and used as replicates in this study.

Table 1. Formulation of Marinated Duck Meat

SL. No.	Ingredients	Control (%)	Treatment 1 (%)	Treatment 2 (%)	Treatment 3 (%)
1.	Duck Breast meat	93	90	88	85
2.	Assamese rice beer	-	3	-	3
3.	Phyto-ingredients (Tea extract, Pomegranate, Lemon, Bamboo shoot extract)	-	-	5	5
4.	Salt	1.5	1.5	1.5	1.5
5.	Sodium tripolyphosphate	0.5	0.5	0.5	0.5
6.	Spices (Cumin, Coriander, Turmeric, Black pepper, Paprika)	1.5	1.5	1.5	1.5
7.	Condiments (Garlic, Ginger)	3.5	3.5	3.5	3.5
	Total	100	100	100	100

Permission to use poultry birds, such as ducks, for research was obtained from the Institutional Animals Ethics Committee (IAEC), AAU, Khanapara, Guwahati, Assam.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition

The mean percent proximate composition of marinated duck meat for vacuum-packaged samples is presented in Table 2.

The mean values of moisture percent revealed highly significant (P<0.01) differences between the control and treated samples under vacuum packaging. There was an increase in moisture percent in T1, T2, and T3 samples compared to control samples. The comparatively higher moisture content recorded in the treated meat samples might be due to the addition of aqueous extract of phyto-ingredients and rice beer. Lopez et al. (2012) also found a greater moisture percentage (P < 0.05) in the marinated products when compared with the control. Kumar et al. (2015) reported that the marination of spent hen breast fillets with lemon juice and ginger extract significantly (P<0.05) increased moisture content compared to the control, and they concluded that the increase in the moisture content might be attributed to the marinade absorption.

In the current study, the average protein content values exhibited a gradual and significant decrease (P<0.01) from the control samples to the T1, T2, and T3 samples. This trend could be attributed to a progressive reduction in the percentage of lean meat with higher protein content, as the levels of phyto-ingredients increased in the treated formulations, resulting in formulations with substantially lower protein content. Such a decrease in protein percentage in the marinated chicken breast fillets was also reported by Lopez et al. (2012). Kumar et al. (2017) also reported decreased protein content in spent hen breast fillets due to marination and opined that a decrease in the protein content could be due to increased moisture content. The mean values for percent ether extract revealed significant (P<0.01) differences among the control and treated samples for vacuum packaging systems. A gradual decrease in ether extract was recorded for T1, T2, and T3 as compared to control samples. Kumar et al. (2017) also observed significantly (P<0.05) lower fat content in spent hen breast fillets marinated with lemon juice and ginger extract compared to the control. They also reported that the fat content significantly (P<0.05) differed among treatments. The decrease in fat content in the treatment groups might be due to the absorption of marinade solution. In the present study, the replacement of the fat content of the duck meat by the increased levels of phyto-ingredients might have contributed to the overall decreased fat percentage in the treated meat samples.

The ash percent of the treatment products was found to be lower compared to the control sample. The mean values for percent total ash content revealed significant (P<0.01) differences between the control and T3 samples. Kumar et al. (2015) noticed that the lemon-marinated (LM) and ginger-marinated (GM) chicken tikkas had lower protein, fat, and ash levels than the control. The washout of sarcoplasmic fluids in the marinades was the cause of the lowering of these nutrients in the marinated solutions. Rahman et al. (2023) concluded that the results on the nutritional parameters of marinated products differed according to the different marinades. In the present study, the results of the proximate composition showed that overall proximate composition was better in control samples than in treated samples.

3.2 Colour Profile

The results of mean colour values of control and treated samples for vacuum-packaged marinated duck meat products are presented in Table 3.

Table 2. Effect of rice beer and phyto-ingredients of marinated vacuum packaged on proximate composition of duck meat products at refrigeration temperature (mean ± s.e)

Treatment	Moisture	Protein	Ether Extract	Total ash
Control	73.06±0.01^{A}	20.45±0.18^{A}	1.90±0.01^{A}	0.90±0.01^{A}
Treatment 1	73.17±0.01^{B}	20.28±0.07^{B}	1.83±0.01^{B}	0.85±0.02^{B}
Treatment 2	74.53±0.01^{C}	19.54±0.24^{C}	1.82±0.01^{B}	0.84±0.01^{B}
Treatment 3	76.13±0.00^{D}	19.23±0.48^{D}	1.81±0.00^{B}	0.83±0.01^{B}

n=5, VP=Vacuum Packaging

Means with different superscripts within a column differ significantly

Table 3. Effect of rice beer and phyto-ingredients of marinated vacuum packaged on colour profile duck meat products (mean ± se)

Treatments	Lightness (L)	Redness (a*)	Yellowness (b*)
	VP	VP	VP
Control	80.98 ±0.38	28.60 ±0.24	26.72 ±0.20
Treatment 1	81.04 ±0.30	27.30 ±0.01	27.21 ±0.05
Treatment 2	80.72 ±0.20	27.17 ±0.01	27.19 ±0.03
Treatment 3	80.33 ±0.13	27.25 ±0.03	27.02 ±0.01

n=5, VP=Vacuum packaging
Means with different superscripts within a column differ significantly

The lightness values showed no significant differences for all the control and treated samples. The L*(colour) value was lower for treated products than for control products. It might be due to the addition of rice beer and phyto-ingredients, which lower lightness values. Augustyn et al., (2019) also reported no significant differences (P > 0.05) in the brightness parameter L∗ between the marinades used in the pheasant breast muscles were found. The brightening of the colour of marinated in acidic marinades could be due to a decrease in its pH and a higher amount of extracellular water introduced into the meat during marinating.

The mean redness values showed no significant differences between the control and treated samples. Redness (a*) followed a decreasing trend in all the treated products and control products. A decrease in a* value indicates the change in colour from red to brown, which could be due to the formation of metmyoglobin due to the oxidation of myoglobin pigment. Redness is used as an indicator of colour stability in meat and meat products and showed pronounced fading with the increase in storage period for samples (Gogoi et al., 2020).

The mean yellowness value showed no significant differences in all the control and treated samples. A slight decrease in yellowness might be due to the addition of antioxidant-rich phyto-ingredients and rice beer, which imparted a lower colour reaction between oxygen and muscle pigments. The findings of the present study compared with the reports of (Lopez et al. 2012), who reported that yellowness was lower (P< 0.05) in the treatments marinated with various concentrations of salt when compared with the control.

3.3 Texture Analysis

The results of the texture profile of control and treated samples under vacuum-packaged marinated duck meat products are presented in Table 4.

In the present study, it was shown that marinating had a beneficial effect on the reduction of the hardness (P < 0.01) of marinated duck meat samples compared to the control. The hardness values showed a decreasing trend in the treatments compared to control samples. The acid breaks the transversal bounds of collagen, leading to the unstable structure loss of this connective tissue protein (Cholan, 2008).

The mean values for springiness scores for control and treated samples revealed highly significant differences (P<0.01) among the control and treated samples. The T2 had the highest, and T3 had the lowest springiness value among all the treated and control samples.

The cohesiveness scores for control and treated samples revealed non-significant (P>0.05) differences among all the treated samples. Cohesiveness followed an increasing and decreasing trend, which might be due to products having gotten tougher initially and followed by softer consistency due to the loss of integrity of the muscle cells and, thus, the muscle tissue losing its regaining capacity to its original form.

The mean values for chewiness score revealed a highly significant (P<0.01) difference between the control and treated samples. There is a decreasing trend of chewiness values from control to treated samples. This might be due to the offering of higher resistance by the control, T1, and T2 samples compared to T3 samples during chewing. The T3 samples offered less resistance during chewing because of the loss of cell integrity and disruption of muscle fiber. The mean values for resiliance scores for control and treated samples revealed non-significant (P>0.05) differences among all the control and treated samples. Marination decreased cohesiveness, hardness, and chewiness (P< 0.05) and increased juiciness (Maxwell et al. 2018).

Table 4. Effect of rice beer and pyto-ingredients of marination of vacuum packaged on texture profile of duck meat products at refrigeration temperature (mean ± se)

Treatments	Hardness (kg/cm)	Springiness (cm or mm)	Cohesiveness (ratio)	Chewiness (kg/cm/or mm)	Resiliance (cm/ or mm)
Control	4118.16 ±254.63^{A}	0.59 ±0.03^{A}	0.414 ±0.02	1705.81 ±30.32^{A}	0.136 ±0.00
Treatment 1	3148.58 ±285.41^{B}	0.62 ±0.00^{AB}	0.4064 ±0.03	1686.18 ±29.18^{A}	0.132 ±0.19
Treatment 2	2680.20 ±212.10b^{C}	0.64 ±0.01^{B}	0.418 ±0.01	1716.28 ±69.14^{A}	0.131 ±0.00
Treatment 3	2571.00 ±103.23^{C}	0.47 ±0.04^{C}	0.4238 ±0.03	1491.19 ±22.47^{B}	0.129 ±0.00

n=5, VP=Vacuum packaging

Means with different superscripts within a column differ significantly.

Table 5. Effect of rice beer and phyto-ingredients on sensory evaluation of marinated vacuum packaged duck meat products (mean ± se) at refrigeration temperature

Treatments	Appearance	Colour	Flavour	Tenderness	Juiciness	Overall acceptability
	VP	VP	VP	VP	VP	VP
Control	6.80 ±0.12	6.60 ±0.18	6.90 ±0.18	6.70 ±0.12	6.60 ±0.19^{A}	6.70 ±0.07^{A}
Treatment 1	6.90 ±0.10	6.90 ±0.10	6.90 ±0.10	6.60 ±0.10	6.60 ±0.10^{A}	6.80 ±0.04^{A}
Treatment 2	6.80 ±0.12	6.90 ±0.10	7.00 ±0.22	7.10 ±0.18	6.90 ±0.10^{AB}	6.90 ±0.05^{AB}
Treatment 3	7.20 ±0.12	7.00 ±0.00	7.10 ±0.24	7.30 ±0.20	7.30 ±0.20^{C}	7.30 ±0.20^{B}

n=5, VP=Vacuum packaging

Means with different superscripts within a column differ significantly.

3.4 Sensory Evaluation

The results of the sensory evaluation of control and treated samples for vacuum-packaged marinated duck meat products are presented in Table 5. The sensory evaluation of the control and the treated samples was performed 1 day after marination. The different sensory quality traits were evaluated by scorecard methods employing semi-trained panelists.

The mean appearance score revealed no significant differences (P>0.05) among the control and treated samples. The colour scores did not differ significantly between the control and treated samples. However, the panelist offered a marginally higher score for colour in T3 samples. This might be due to the portion of the reduction in conversion of oxy myoglobin to met-myoglobin due to the use of phyto-ingredients and rice beer.

The flavour scores did not differ significantly (P>0.05) between the control and treated samples. The study recorded marginally higher non-significant scores in T3 samples compared to other treated samples. Contrary to the present findings, Maxwell et al. (2018) reported that marination enhanced the flavour and aromatic sensory attributes of chicken breast fillets measured in their study.

The mean juiciness scores revealed significant differences (P<0.05) among the control and treated samples. The highest juiciness scores in T3 samples as compared to the control samples were found. This might be due to the addition of rice beer and phyto-ingredients, which contributed to higher retention of moisture in the meat samples as well as the taste of juiciness among the test panelists (Kyriakopoulou et al.,2021].

The mean tenderness scores revealed no significant differences (P>0.05) among the control and treated samples. The marginally higher tenderness score was offered by the panelist for T3 samples. The mechanism by which marinade influences meat tenderization appears to involve several factors including weakening of structures due to meat swelling, an increase in proteolysis caused by cathepsins, and an increase in the conversion of collagen to gelatin at a low pH during cooking (Ertbjerg, et al., 1999).

3.5 Overall Acceptability

The mean overall acceptability scores revealed significant differences (P<0.05) between the control and the treated samples. It has been observed from overall acceptability scores that the panelist offered the highest scores in T3 samples. Augustyn et al., (2019) recorded that the use of marinade has improved the sensory characteristics of pheasant breast muscles compared to the control group. It was shown that the muscles marinated with whey and buttermilk were characterized by significantly higher juiciness and tenderness and lower odour desirability than the muscles marinated using lemon juice. Kim et al., (2011) also stated that the use of acid whey for marinating beef improved the tenderness and juiciness of the product compared to the control group.

4. CONCLUSION

The marination of duck meat with a marinade composed of rice beer, phyto-ingredients, and spice paste would be a beneficial approach to the development of duck meat products, as indicated by the aforementioned findings. It was evident that the marinade formulated by combining all of the ingredients had a substantial impact on the sensory evaluation, texture profile, colour profile, and proximate composition. Based on the combined impact of rice beer, phyto-ingredients, and spice paste as marinating ingredients in duck meat during refrigeration storage, it may be recommended that this technology has the potential for commercial exploitation.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

DISCLAIMER (ARTIFICIAL INTELLIGENCE

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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