Original Research Article

Extension of shelf life of Roasted Duck by combination of Vacuum Packaging and Low Temperature Storage

ABSTRACT

A study was conducted to assess the shelf life of roasted duck under aerobic and vacuum packaging and in refrigerator (4±1° C) and freezer (-18±1° C) storage. The samples were analyzed for moisture content, pH, Thiobarbituric Acid (TBA) Value, Tyrosine value, Total Plate Count (TPC), Total Psychrophilic Count (TPSC), Yeast and Mould Count (YMC), colour, flavour and tenderness. The products showed an increasing trend in pH, TBA value, tyrosine value, TPC, TPSC and YMC during the storage period in refrigerated and freezer temperatures irrespective of the packaging methods i.e. aerobic and vacuum, whereas, the moisture content, colour, flavor and tenderness of the product followed a declining trend during storage. Though the sensory parameter scores declined during storage, but these changes were less in the vacuum packed and frozen products. The study showed that the aerobically packed roasted duck was acceptable upto 7th day and vacuum packed roasted duck was acceptable upto 14th day in the refrigerated storage. The freezer storage extended the shelf life of the roasted duck till 40th day in aerobic packaging while the combination of freezer storage and vacuum packaging extended the shelf life of the roasted duck till 60th day. These findings have significant implications for the food industry, enabling the development of strategies to extend the shelf life of roasted duck and reduce food waste.

Keywords: *Roasted Duck, vacuum packaging, laminate of metalized PET/Poly, microbial quality, sensory quality, lipid oxidation, freezer storage, shelf-life.*

1. INTRODUCTION

As a valued member of poultry family, duck, often categorized as “poor man’s companion bird” and is gaining importance to savour the palate of the consumers. Duck meat is highly nutritious, a good source of protein and also contain higher quantity of fat than chicken. It is liked in many countries because of its typical flavour, but ready to eat duck meat products are not produced at large scale. Processed duck meats have a good potential for providing nutrition to the consumers and income to the duck producers and processors.

Due to changing life styles, food habits and increasing purchasing power of the consumers, there is an ever-increasing demand for convenience foods, especially ready to eat foods. As a ready to eat meat product, Tandoori chicken is very popular in India, especially in the northern region. A similar kind of product, roasted duck is gaining popularity in the urban markets and the consumers prefer this product as delicacy. As roasted duck is highly perishable and prone to microbial and chemical changes during long storage period, its storage is challenging to the processors, retailers and consumers. Its sensory quality also gets affected by rancidity because of its fat content. Thus, the processors and retailers should focus on proper storage condition and delivery of such convenient food items to the consumers in consumers' friendly packages in order to maintain the quality of the products nearest to its originality. The selection of packaging material, packaging method and storage condition play vital role in extension of shelf life of any commodity. Proper packaging and storage can prevent/reduce product deterioration and food waste caused by moisture loss, microbial spoilage and chemical changes.

As the research work in the shelf life study of roasted duck is very scrappy, this study was conducted to extend the shelf life of the roasted duck under a combination of packaging and storage condition.

2. MATERIALS AND METHODS

2.1 Roasted duck preparation: Dressed ducks from the same source and age group were used for preparation of roasted duck. Dressed duck carcass was marinated with a mixture of lemon juice, food colour, salt, and spice mixture (chili powder, cumin powder, and coriander) for 30 minutes. Then it was marinated with mixture of yogurt and ginger-garlic pastes for 4 hours. The marinated duck was brushed with little oil and roasted in an oven (preheated to 500°F) for about 1 hour. The duck was turned and brushed with oil intermittently. Freshly prepared product was considered as control for the experiment.

2.2 Packaging and storage: For storage study, roasted ducks were packaged in laminate of metalized (aluminium) PET and low density polyethylene of 200 gauges thickness under two different methods of packaging i.e., aerobic and vacuum packaging. The samples were stored for studies on 7^{th}, 14^{th} and 21^{st} day of refrigerated storage (4±1° C) and were kept in freezer (-18 ±1° C) for subsequent analysis on 20^{th}, 40^{th}, 60^{th} and 80^{th} day of storage.

2.3 Analysis: Samples were analyzed for physico-chemical properties i.e. moisture content (AOAC, 1990), pH (Trout, 1992), TBA (Thiobarbituric Acid) value (Tarladgis *et al*., 1960), Tyrosine Value (Strange *et al*., 1977); and microbiological qualities i.e. Total Plate Count (TPC), Total Psychrophilic Count (TPSC) and Yeast and Mould Count (YMC) by the methods described by APHA, 1984. The sensory qualities i.e. colour, flavor and tenderness were evaluated by using 9 point Hedonic scale where 9 is extremely desirable and 1 is extremely poor (Keeton, 1983). In the present study six trials were conducted. The data were analyzed by the statistical method using General Linear Model of SPSS software package (Snedecor and Cochran, 1994) and Duncan's Multiple Range test (Duncan, 1955).

3. RESULTS AND DISCUSSION

3.1 Physico-chemical properties of roasted duck

The results of the physico-chemical properties of roasted duck stored at refrigeration temperature (4±1°C) and freezer temperature (-18±1°C) are presented in the table no. 1 and 2 respectively.

Moisture content: The results showed that the moisture content of the freshly prepared roasted duck was 57.44% which decreased significantly ($p<0.01$) throughout the storage period in both the aerobic and vacuum packaging and in under both the storage conditions (refrigerated and freezer), though the decrease in the vacuum packed sample was not significant till 20^{th} day of the freezer storage. This result could be substantiated with the results of Pavankumar *et al.* (2003) who also reported the same trend in chicken tandoori. In both the storage temperatures, vacuum packaging resulted in better retention of moisture of the product.

pH: The samples in aerobic and vacuum package showed significant increase in pH after 7 days of refrigerated storage. In freezer storage, pH increased significantly after 20 days and 40 days in aerobic and vacuum packed samples, respectively. Such increment of pH with the advancement of storage period was possibly due to accumulation of alkaline metabolites from action of bacteria in the product. This result could be supported with the observation of Sinhamahapatra *et al,* (2013) and Indumathi & Arun (2017) who reported the same trend in some other meat products. The change in pH of vacuum packed samples was slower than the aerobically packed samples and the changes in freezer storage was slower than that of refrigerated storage because of the advantageous effect of vacuum condition and low temperature in arresting the microbial activity, respectively.

TBA value: The TBA value is considered as an essential quality indicator of food as it indicates the extent of oxidative rancidity in fat-containing food and it is highly correlated with taste panel scores for oxidized and warmed over flavour in meat. The minimum threshold value of TBA is 0.5-1.0 mg malonaldehyde/kg of meat (Tarladgis *et al.* 1960). The TBA value of the roasted duck increased significantly ($p<0.01$) during refrigerated and frozen storage both in case of aerobic and vacuum condition. This increasing trend in TBA value during storage indicates more oxidation of unsaturated fatty acids of the product (Patterson *et al.,* 2004). TBA value of samples exceeded 0.5 mg malonaldehyde/kg of meat on 14th and 21stday of refrigerated storage in aerobic and vacuum packaging, respectively. In frozen storage, TBA value of roasted duck exceeded the minimum threshold value on 60th day and on 80th day in case of aerobic and vacuum packaging, respectively. Therefore, the samples were not analyzed for TBA value after the day of exceeding the threshold value. The rate of increase in TBA value was slower in freezer than refrigerator storage because of slower enzymatic catalysis and lipid oxidation at comparatively lower temperature. Absence of oxygen in vacuum pouches resulted in better prevention of lipid oxidation and oxidation dependent volatile production than aerobic packaging (Fig. 1 and 2). The observations of Nam & Ahn, (2003), Indumathi & Arun (2017) and Bernardez-Morales et al. (2024) were congruent with the result of the present study.

Tyrosine value: The Tyrosine value indicates the extent of proteolysis and it can be used to monitor the meat quality during storage. The tyrosine value of roasted duck increased significantly ($p<0.01$) in both the storage temperatures irrespective of the packaging conditions (Fig. 3 and 4). This trend was also observed by Sinhamahapatra *et al,* (2013) and Indumathi & Arun (2017) ; and it could occur due to increased microbial activity and production of proteolytic enzymes by the microbes. The comparatively slower rate of changes in tyrosine value of frozen samples might be due to reduced rate of microbial growth and proteolysis during frozen storage. The samples under vacuum packaging showed a lower tyrosine value than those in aerobic pouches because vacuum packaging reduced microbial growth and proteolysis. Sinhamahapatra *et al,* (2013) and Indumathi & Arun (2017) reported similar effects of vacuum packaging on the tyrosine value of meat products.

Table No.1: Mean±SEM value of Moisture Content, pH, TBA and Tyrosine value of Roasted *Duck* stored at Refrigeration Temperature (4±1°C). (N=6)

Parameters	Type of Packaging	0day	7days	14days	21days	Significance (P)
Moisture content (%)	Aerobic	57.44^{a} ±0.38	55.88^{b} ±0.2	54.35^{c} ±0.26	ND	**
	Vacuum	57.44^{a} ±0.38	56.85^{b} ±0.27	55.32^{c} ±0.29	54.51^{d} ±0.22	**
pH	Aerobic	6.03^{b} ±0.03	6.16^{b} ±0.02	6.32^{a} ±0.05	ND	**
	Vacuum	6.03^{c} ±0.03	6.08^{bc} ±0.01	6.19^{ab} ±0.03	6.33^{a} ±0.04	**

TBA value	Aerobic	0.130^{c} ±0.004	0.247^{b} ±0.05	0.546^{a} ±0.03	ND	**
	Vacuum	0.130^{d} ±0.004	0.202^{c} ±0.009	0.355^{b} ±0.004	0.532^{a} ±0.004	**
Tyrosine value	Aerobic	0.112^{c} ±0.005	0.241^{b} ±0.005	0.427^{a} ±0.002	ND	**
	Vacuum	0.112^{d} ±0.005	0.173^{c} ±0.003	0.277^{b} ±0.006	0.411^{a} ±0.004	**

(*Means bearing different superscripts within row differ significantly. ND means not done.*

**=P<0.01)

Table No.2 : Mean ± SEM value of Moisture Content, pH, TBA and Tyrosine value of Roasted *Duck* stored at Freezer Temperature (-18±1°C) . (N=6)

Parameters	**Type of Packaging**	**0 day**	**20 Days**	**40 days**	**60 days**	**80 days**	**Significance (P)**
Moisture content (%)	Aerobic	57.44^{a} ±0.38	56.45^{b} ±0.19	55.30^{c} ±0.22	53.82^{d} ±0.21	ND	**
	Vacuum	57.44^{a} ±0.38	56.88^{a} ±0.25	56.10^{b} ±0.21	55.03^{c} ±0.30	53.68^{d} ±0.26	**
pH	Aerobic	6.03^{c} ±0.03	6.16^{bc} ±0.03	6.26^{ab} ±0.03	6.39^{a} ±0.04	ND	**
	Vacuum	6.03^{c} ±0.03	6.06^{c} ±0.06	6.15^{bc} ±0.05	6.27^{ab} ±0.05	6.40^{a} ±0.10	**
TBA value	Aerobic	0.130^{d} ±0.004	0.298^{c} ±0.005	0.416^{b} ±0.003	0.555^{a} ±0.003	ND	**

	Vacuum	0.130^{e} ±0.004	0.260^{d} ±0.002	0.311^{c} ±0.01	0.449^{b} ±0.003	0.584^{a} ±0.004	**
Tyrosine value	Aerobic	0.112^{d} ±0.005	0.233^{c} ±0.003	0.331^{b} ±0.006	0.440^{a} ±0.002	ND	**
	Vacuum	0.112^{e} ±0.005	0.206^{d} ±0.007	0.272^{c} ±0.01	0.326^{b} ±0.008	0.428^{a} ±0.009	**

(*Means bearing different superscripts within row differ significantly. ND means not done.* **=P<0.01)

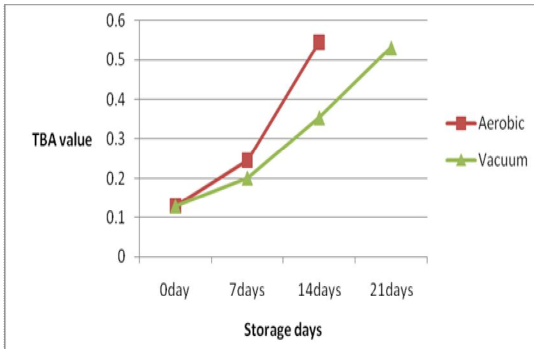

Fig. 1: TBA value of Roasted duck stored at refrigerated storage

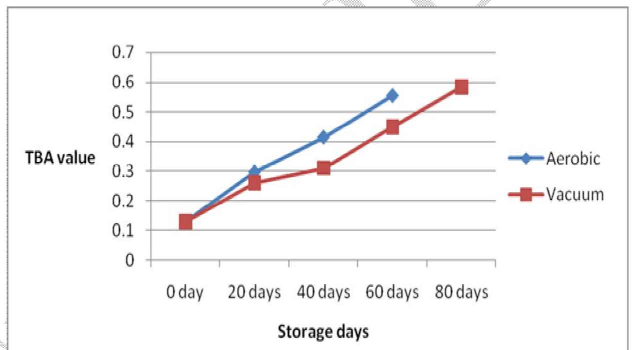

Fig. 2: TBA value of Roasted duck stored at freezer storage

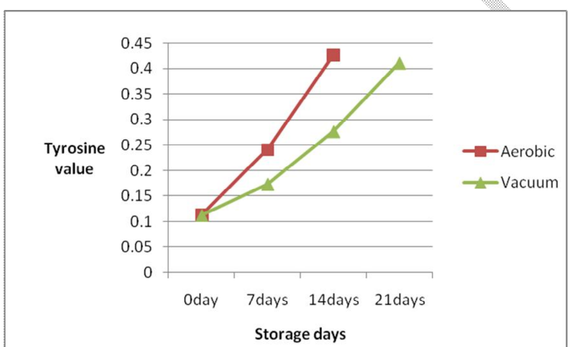

Fig. 3: Tyrosine value of Roasted duck stored at refrigerated storage

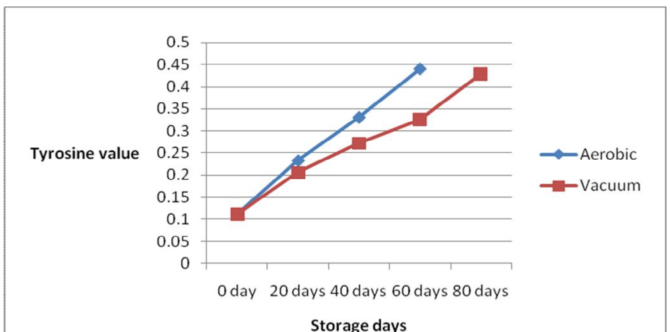

Fig. 4: Tyrosine value of Roasted duck stored at freezer storage

3.2 Microbiological qualities of roasted duck

The results of the microbiological qualities i.e. Total Plate Count (TPC), Total Psychrophilic Count (TPSC) and Yeast and Mould Count (YMC) of roasted duck stored at refrigeration temperature (4±1°C) and freezer temperature (-18±1°C) are presented in table no. 3 and 4, respectively. TPC, TPSC and YMC are expressed as log cfu/gm of sample.

Total Plate Count (TPC): In refrigerated storage, aerobic and vacuum packed samples showed significant increase in TPC throughout the storage period. The decrease in TPC of samples during first phase of freezer storage was due to effect of cold shock on microbes. After that a significant increment in TPC occurred due to adaptability of microbes to freezer temperature. TPC of frozen samples increased at slower rate than refrigerated samples due to reduction of microbial cell and extension of lag phase of microbial growth caused by cold shock in freezer. Again, oxygen transmission rate of packaging material decreased with lowering temperature (Patterson *et al.,* 2004), thus freezer temperature reduced growth rate of microbes in the samples to a greater extent. Fig. 5 and 6 showed that the samples in vacuum packaging had lower TPC than those in aerobic pouches because vacuum packaging arrested the proliferation of the aerobic microorganisms. The similar trend was reported by Bhattacharyya *et al. (*2013), Mathew *et al.* (2016) and Indumathi & Arun (2017) in some other vacuum meat products. The limit of aerobic plate count in cooked meat is 4 log cfu/gm as per the microbiological standards prescribed by the FSSAI (2011). In the present study, the TPC of the samples crossed this limit on 14^{th} and 21^{st} days of refrigerated storage of aerobic and vacuum packed samples, and 60^{th} and 80^{th} day of freezer storage in case of aerobic and vacuum packaging respectively.

Total Psychrophilic Count (TPSC): The changes in the TPSC of the samples also showed the same trend as of TPC. TPSC increased throughout the storage period in both the temperature except insignificant decrease in aerobic packed and significant decrease in vacuum packed sample in the first phase of storage. The slower rates of increase in TPSC in freezer temperature and in vacuum packed samples were due to retarded microbial growth in comparatively lower temperature and in absence of oxygen, respectively.

Yeast and Mould Count (YMC) : The YMC of the roasted duck meat samples gradually increased with the advancement of the storage period in refrigerated and freezer storage. The samples were acceptable in terms of YMC throughout the storage period as it was within the limit for the cooked meat i.e. 2 log cfu/gm (FSSAI, 2011). The YMC of samples in freezer storage increased at slower rate due to reduction of microbial cell and extension of lag phase of microbial growth caused by cold shock in freezer. Again, the oxygen transmission rate of packaging material decreased with lowering temperature, thus freezer temperature reduced microbial growth to a greater extent. The samples under vacuum showed lower YMC than those in aerobic pouches because vacuum packaging arrested the proliferation of the aerobic microorganisms.

Table No.3: Mean±SEM value of TPC, TPSC and YMC of Roasted *Duck* stored at Refrigeration Temperature (4±1°C) . (N=6)

Parameters	Type of Packaging	0day	7days	14days	21days	Significance (P)
TPC (log cfu/gm)	Aerobic	2.71^{c} ±0.07	3.42^{b} ±0.06	4.51^{a} ±0.07	ND	**
	Vacuum	2.71^{d} ±0.07	3.15^{c} ±0.05	3.68^{b} ±0.06	4.61^{a} ±0.06	**
TPSC (log cfu/gm)	Aerobic	2.10^{c} ±0.06	2.84^{b} ±0.04	3.65^{a} ±0.05	ND	**
	Vacuum	2.10^{d} ±0.06	2.59^{c} ±0.06	3.17^{b} ±0.04	4.05^{a} ±0.06	**
YMC (log cfu/gm)	Aerobic	0.90^{b} ±0.03	1.38^{b} ±0.04	1.82^{a} ±0.06	ND	**
	Vacuum	0.90^{c} ±0.03	1.10^{bc} ±0.03	1.72^{ab} ±0.04	1.95^{a} ±0.05	**

(*Means bearing different superscripts within row differ significantly. ND means not done.* **=P<0.01)

Table No.4:Mean ± SEM value of TPC, TPSC and YMC of Roasted *Duck* stored at Freezer Temperature (-18±1°C) . (N=6)

Parameters	Type of packaging	0 Day	20 Days	40 days	60 days	80 days	Significance (P)
TPC	Aerobic	2.71^{c} ±0.07	2.50^{c} ±0.08	3.14^{b} ±0.09	4.12^{a} ±0.1^{a}	ND	**
	Vacuum	2.71^{c} ±0.07	2.43^{d} ±0.07	2.74^{c} ±0.06	3.47^{b} ±0.08	4.28^{a} ±0.03	**
TPSC	Aerobic	2.10^{c} ±0.06	1.87^{c} ±0.06	2.18^{b} ±0.05	3.23^{a} ±0.04	ND	**
	Vacuum	2.10^{c} ±0.06	1.75^{d} ±0.08	2.11^{c} ±0.06	2.62^{b} ±0.04	3.27^{a} ±0.05	**
YMC	Aerobic	0.90^{c} ±0.03	0.80^{c} ±0.03	1.25^{b} ±0.04	1.58^{a} ±0.06	ND	**
	Vacuum	0.90^{c} ±0.03	0.79^{c} ±0.04	0.92^{bc} ±0.04	1.23^{b} ±0.03	1.83^{a} ±0.04	**

(*Means bearing different superscripts within row differ significantly. ND means not done.* **=P<0.01)

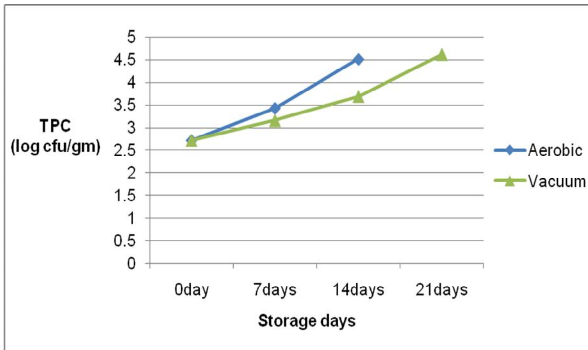

Fig. 5: TPC of Roasted duck stored at refrigerated storage

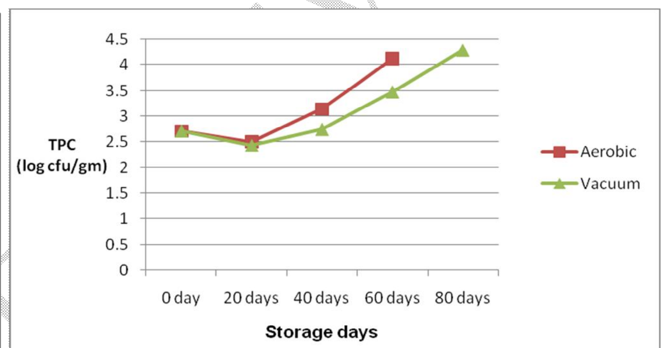

Fig. 6: TPC of Roasted duck stored at freezer temperature

3.3 Sensory qualities of roasted duck

The results of the sensory qualities i.e. colour, flavour and tenderness of roasted duck stored at refrigeration temperature (4±1°C) and freezer temperature (-18±1°C) are presented in table no. 5 and 6 respectively.

Generally, the consumers judge sensory quality of roasted meat products by its colour, flavour and tenderness, and these parameters are greatly affected by the storage conditions. The scores of colour, flavor and tenderness of freshly prepared roasted ducks were above 7 in the 9 point Hedonic scale, but they gradually decreased during storage in both the storage temperatures (Table no. 5 & 6; Fig. 7 & 8). The decrease in all the sensory qualities throughout the storage period might be due to moisture loss from product, increased lipid oxidation and proteolysis.

Better maintenance of sensory qualities in freezer storage than in refrigerator might be due to lesser degree of dehydration, slower microbial growth and reduced lipid oxidation. Vacuum packaging preserved sensory qualities better because anaerobic condition maneuvered dehydration, proteolysis and rancidity (Fig. 7 and 8). Better retention of sensory qualities in the vacuum packed meat products were also reported by Pavankumar *et al. (*2003), Sinhamahapatra *et al.(*2013), Indumathi & Arun (2017) and Bernardez-Morales *et al. (*2024).

The samples were not evaluated for flavour after 14th day and 21st day in aerobic and vacuum packaging respectively during refrigerated storage as the flavour score of the samples reached to the level below 4.50 on the corresponding days (score below 4.5 is disliked as in 9 point hedonic scale). So the products were acceptable in terms of flavour upto 7th and 14th day of refrigerated storage in aerobic and vacuum packaging, respectively. Similarly, the aerobically and vacuum-packed samples were acceptable upto 40th day and 60th day of frozen storage. As the off-flavour is associated with product's rancidity which is also reflected by the TBA value, the present study showed that the storage day when the samples became unacceptable in terms of the flavour , these were also unacceptable according to the TBA value. When the samples were unacceptable in terms of flavour, these were not offered for evaluation of tenderness.

Table No.5: Mean±SEM value of sensory qualities of Roasted *Duck* stored at Refrigeration Temperature (4±1°C) . (N=6)

Parameters	Type of Packaging	0day	7days	14days	21days	Significance (P)
Colour	Aerobic	7.45^{a} ±0.21	6.70^{a} ±0.31	5.83^{b} ±0.24	ND	**
	Vacuum	7.45^{a} ±0.21	6.90^{ab} ±0.27	6.33^{bc} ±0.33	5.70^{c} ±0.22	**
Flavour	Aerobic	7.40^{a} ±0.26	6.15^{b} ±0.20	4.23^{c} ±0.29	ND	**
	Vacuum	7.40^{a} ±0.26	6.55^{b} ±0.29	5.45^{c} ±0.19	4.17^{d} ±0.26	**
Tenderness	Aerobic	7.50^{a} ±0.25	6.50^{b} ±0.27	ND	ND	**
	Vacuum	7.50^{a} ±0.25	6.75^{a} ±31	5.67^{b} ±0.26	ND	**

(*Means bearing different superscripts within row differ significantly. ND means not done.* **=P<0.01)

Table No.6: Mean ± SEM value of sensory qualities of Roasted *Duck* stored at Freezer Temperature (-18±1°C). (N=6)

Parameters	Type of packaging	0 day	20 Days	40 days	60 days	80 days	Significance (P)
Colour	Aerobic	7.45^{a} ±0.21	6.70^{b} ±0.17	5.90^{c} ±0.24	5.15^{d} ±0.30	ND	**
	Vacuum	7.45^{a} ±0.21	6.90^{ab} ±0.25	6.33^{bc} ±0.33	5.75^{cd} ±0.17	5.10^{d} ±0.27	**
Flavour	Aerobic	7.40^{a} ±0.26	6.50^{b} ±0.27	5.45^{c} ±0.31	4.10^{d} ±0.23	ND	**
	Vacuum	7.40^{a} ±0.26	6.95^{ab} ±0.22	6.33^{b} ±0.33	5.25^{c} ±0.19	4.00^{d} ±0.25	**
Tenderness	Aerobic	7.50^{a} ±0.25	6.50^{b} ±29	5.45^{c} ±0.26	ND	ND	**
	Vacuum	7.50^{a} ±0.25	6.95^{ab} ±0.19	6.00^{bc} ±0.18	5.17^{c} ±0.33	ND	**

(*Means bearing different superscripts within row differ significantly. ND means not done.* **=P<0.01)

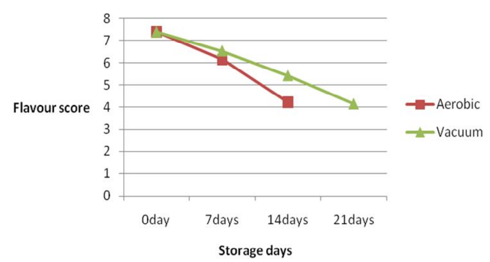

Fig. 7: Flavour score of Roasted duck stored at refrigerated storage

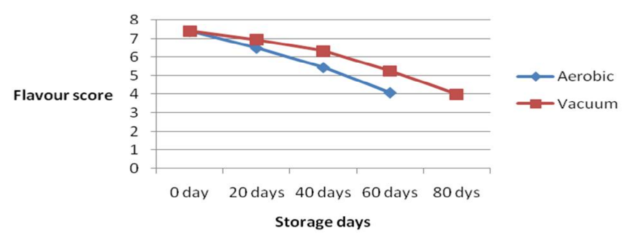

Fig. 8: Flavour score of Roasted duck stored at freezer temperature

4. CONCLUSION

It is evident from the results that considering the TBA value, TPC and flavour score of the roasted duck, the product was acceptable for human consumption till 7th and 14th day of refrigerated storage in case of aerobic and vacuum packaging respectively and till 40th day and 60th day of freezer storage in aerobic and vacuum packaging, respectively. Therefore, it can be concluded that vacuum packaging extended further the shelf life of the roasted ducks by 7 days in refrigerated storage and 20 days in freezer storage than the aerobic packaging. The roasted duck meat was also acceptable in terms of other parameters like pH, moisture content, Tyrosine value, TPSC, YMC , colour and tenderness during these storage life. Further, the vacuum packaging maintained all the desirable qualities of the products and prevented the undesirable changes in a better way than the aerobic packaging. The best combination for storing roasted duck was vacuum packaging and freezer temperature. It increased the shelf life of roasted duck more than 8 times if it is compared with combination of aerobic packaging and refrigerated storage (i.e. 60 days vs. 7 days). Thus, the meat processors and consumers may adopt combination of vacuum packaging and freezer storage (-18°C) for long term storage of roasted meat products without much quality deterioration and food waste. Future researches may be conducted to explore further extension of shelf life of roasted duck by application of active packaging (use of antimicrobial/antioxidant agents in package). Freshness or quality indicators may also be included in vacuum packages in future studies to help the consumers to check whether the product is suitable for consumption or not.

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 the writing or editing of this manuscript.

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