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A study on the effect of ageing pork at varying time, temperature and packaging combinations on its color

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Abstract
The color of the meat is one of the essential factors for enhancing the preference of consumers at the point of sale. The decision of adopting a tenderization or packaging technique should consider the factor of maintaining acceptable color of meat. The objective of the current study was to determine the effect of ageing time and temperature combinations on color of fresh pork obtained from adult animals. The pork was kept for ageing in two different packing conditions i.e., Aerobic and Vacuum at two different temperatures i.e., 4 °C and 7 °C. The sampling was done for assessment on 0, 6 and 12 days. The different attributes of color that we studied were *L** (lightness), *a** (redness), *b** (yellowness), *c** (Chorma) and *h** (hue angle), We found that the ideal pH falling in the range of 5.7 to 6 was observed in vacuum packed samples both at 4 °C and 7 °C. From our study it can be concluded that among all the attributes the redness varied significantly with all types of treatments in the study whereas the chroma varied with days of ageing only. It can be concluded from our study that the packaging types under study affect the color of meat but not to the extent of drastically affecting consumer preference.

Keywords: Pork, meat color, ageing, aerobic packaging, vacuum packaging

Introduction
The colour of the meat is an essential appearance factor for consumer preference and meat discoloration decreases its desirability at the point of sale (Brewer *et al*., 2001) [3]. The concentration of oxymyoglobin and carboxymyoglobin primarily determine cherry red color of fresh meat whereas the deoxy myoglobinis responsible for purplish red in vacuum packaged meat (Suman and Joseph, 2014) [28]. The oxidation of aforementioned three ferrous Mb forms to ferric metmyoglobin meads to discoloration of meat (Suman and Joseph, 2014) [28]. (color due to the presence of the heme protein's redox forms. Several inherent factors (sex, endogenous antioxidants, animal age, muscle, source, and pH) and external factors (postmortem aging, temperature, light, and packaging) influence color stability (Suman *et al*., 2014; Mancini and Hunt, 2005) [18, 28].
Postmortem wet aging (in vacuum packaging) is a common meat industry practice to improve tenderness and palatability, and beef sub primal are aged/stored for an average of 20 days in retail establishments (Guelker *et al*., 2013) [9]. The cellular and biochemical mechanisms that govern the meat quality attributes undergo changes during postmortem aging. As aging time increases, there is decreased competition from mitochondria for oxygen, thereby improving myoglobin oxygenation, resulting in improved blooming (MacDougall, 1982; Mancini and Ramanathan, 2014) [16, 18]. Aging can also influence cellular mechanisms (such as reducing enzymes, oxygen scavenging enzymes, and mitochondria) responsible for meat color stability, resulting in lower color stability during subsequent retail display (King *et al*., 2012; English *et al*., 2016: Ponnampalam *et al.,* 2016) [4, 15, 22]. Pommier *et al.,* (1987) [21] showed that the amount of free cathepsin D (152 K D aspartic protease) increased during ageing, which they attributed to a fall in pH and lysosomal rupture, but concluded that this did not affect tenderization.
The object the study was to assess the effect of aging time and temperature combinations on fresh pork qualities obtained from adult animals in terms of color under variable packaging conditions.

Material and Methods
Colour
Pork latissimus dorsi muscle samples were collected hygienically at local market under Malpura municipality immediately after slaughter from each carcass and placed in polyethylene

bags and shifted to the laboratory under chilled condition for various analyses. After that samples cut in pieces weighed over digital balances model (SIMADUZU) with maximum calibration of 220 grams and kept in high density laminated polyethylene pouches with 80-micron thickness. Later pouches were labeled for aerobic and vacuum at 4 °C and7 °C with 0, 6, 12 days. Vacuum pouches were sealed with vacuum packing machine (DZQ-400) set at vacuum time at 30seconds, aeration time of two seconds and sealing time set at 2.5 seconds.

Later samples were stored in domestic refrigerator at 4C and 7 °C. Muscle colorimetric parameters were evaluated by a colorimeter (Minolta CR400, Konica Minolta, Japan) was used to measure meat color coordinates (*L**, *a** and *b**) of the muscles 24 h after slaughter. Fresh cut slices of latissimus dorsi muscles of around 2.5 cm thick were left on a polystyrene tray at 4 °C for 1h to allow blooming prior to color measurement.

Color coordinates were calculated using the CIE-LAB system under light source D65 (Daylight), 8 mm diameter measurement area and 10° standard observer. The same colorimeter was calibrated daily according to the standard manual of the manufacturer specifications. For that, the calibration was performed by using standard white tiles (Y = 93.58, x = 0.3150, and y = 0.3217) prior to color determination. *L** (lightness) is measured from 0 (black) to 100 (white), *a** (redness) has a negative value for green and a positive value for red and *b** (yellowness) values have a negative value for blue and a positive value for yellow. Chroma (*C**), related to the intensity of color (higher when *a** of *b** are high), and hue angle (*h**), related to the change of color from red to yellow. Hunter L (lightness), a (redness) and b (yellowness) values were measured by placing over the camera of spectrophotometer on to Latissimus dorsi muscle cross section surfaces. Measurements were made after the newly cut surface was exposed to ambient air.

Statistical analysis

Data were analyzed using Statistical Software Packages (SPSS 16.0) following the procedure of Snedecor and Cochran (1994). Multiple ANOVA Means between periods of storage, between groups and within groups were compared.

Results and Discussion

Table 1: Effect of varying temperature and packaging type on pork color on different days

Color	Aerobic packing						Vacuum packing						SEM	*P* Value		
	4 °C			7 °C			4 °C			7 °C						
	0 d	6 d	12 d	0 d	6 d	12 d	0 d	6 d	12 d	0 d	6 d	12 d		P	T	D
L	50.84	35.62	45.82	50.84	46.71	52.88	50.84	47.47	45.71	50.84	50.70	42.19	0.56	0.314	0.334	0.384
a	11.49	13.12	11.75	11.49	11.46	9.64	11.49	11.60	9.97	11.49	10.04	9.24	0.22	0.045	0.048	0.019
b	12.93	10.52	11.41	12.93	13.77	11.91	12.93	11.48	130.78	12.93	11.04	9.98	9.99	0.337	0.330	0.403
c	17.34	14.29	15.65	17.39	17.72	14.63	17.40	15.05	14.2	17.40	15.57	14.91	0.28	0.417	0.250	0.001
h	48.76	48.39	44.41	48.76	50.63	55.78	48.76	49.98	47.47	48.75	49.26	40.27	0.62	0.073	0.400	0.164

(n = 10, P- packing, T- temperature, D- days, $P < 0.01$) - significant, SEM- standard error of mean)

Meat colour is important aspect for consumer acceptability and it is determined chromatically by pigment content and achromatically by scattering of light by the microstructure. Whereas the former is measured by hue and chroma, the latter is measured by lightness (Hughes *et al*., 2019) [11]. In our study we examined the parameters affecting meat colour in different kinds of meat packing and storage techniques during ageing. Meat color stability is also impacted by storage time (Harsh *et al*., 2018) [10], loss of water (Kim *et al*., 2018) [14], and freezing rate (Kim *et al*., 2018) [14]. The results are presented in table 1.

With respect to lightness (L) no significant difference was observed in either packaging type or temperature of ageing and the results are in agreement with previous observations wherein it was established that contribution of pigment to the lightness is much smaller (Hughes *et al*., 2019) [11]. With regard to the redness (a), there is significant difference ($P<0.05$) between both packaging types and temperatures. In aerobic packaging, the value was significantly higher in aerobic packaging on 6th and 12th day at both 4 ^{0}C and 7 ^{0}C. The results are in agreement with previous studies with respect to fading of brightness with time after 4 days (Segato *et al*., 2003) [24]. Vacuum packaging time has been shown to reduce the ability to bloom and subsequent colour stability of meat (Robertson *et al*. (2007) [23]. However another important factor determining the redness is the extent exposure of meat to air before vacuum packaging. A study in beef showed that exposure over 6 h did not negatively influence brightness of meat stored 7d (Segato *et al*., 2003) [24]. In our study, the exposure was for two hours before subjecting it for vacuum packaging which might be the reason for fading of redness on day 6 itself. Also, the studies proved that the lower pH muscles with more spaces between cells and muscle bundles in the structure have a greater ability to undergo oxidation, resulting in greater browning closer to the surface of the muscle (Hughes *et al*., 2019) [11]. In our study too, the pH decreased in vacuum packaged meat during ageing on day 6 (Ambedkar *et al*., 2021) [1] which might have resulted in decrease in redness on day 6.

Regarding 'b' i.e., yellowness, there is significant difference between the treatment groups indicating that treatment in our study had no much influence on yellowness. High redness and low yellowness values are better for consumer choice because decreased redness is associated with rancidity and increased yellowness of the fat is assumed to be due to lipid oxidation (Hur *et al*., 2013) [13].

With respect to Chroma (c) the significant difference could be noticed among days of ageing in both types of packaging at two temperatures in study. Chroma is also known as "saturation index" and it is useful to indicate intensity of hue of the product with larger values indicating more saturation of the hue (AMSA, 2012). Therefore, it can be said in our study that with increasing days of storage, in both aerobic and vacuum types, the chroma decreased.

Hue angle represents the meat color change from red to yellow and it has a strong correlation with visual color. It represents the meat colour change from red to yellow and a larger hue angle value generally indicates a shift to lower redness and higher yellowness (Brewer *et al*., 2001) [3]. In our study there is no significant change observed in hue angle

indicating that there is no change in color of meat from red to yellow which is further justified by 'b' values that did not vary significantly too in our study.α-actin was responsible positively with lightness and negatively with red, yellow, chroma, and hue and overly responsible for meat color (Gagaoua *et al*., 2017a, b; Gagaoua *et al*., 2015; Hwang *et al*., 2005; Polati *et al*., 2012) [7, 8, 20].

Conclusion

It can be concluded from our study that, vacuum tenderization of meat at 4 and 7 °C for 6 – 12 days did not adversely affect the meat appearance parameters and maintained desirable meat aspects from consumer point of view.

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