KINETICS OF BEEF CARCASS AGING

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SUMMARY: The objective was to study the kinetics of beef carcass aging with respect to its postmortem quality characteristics. The influences of the type of packaging and chilling; and fat cover thickness as function of aging time on colour, water holding capacity, pH, press juice and cooking loss were assessed. Longissimus dorsi muscle from 8 steers, for with less than 4mm fat cover and 4 with more than 6 mm fat cover, and either slow chilled (7°C for 4 h and then stored at 2°C for 16 d) or fast chilled (stored at 2°C for 16 d) were used. The time history plots of the measured quality parameters as a function of experimental variables were developed. Total colour difference of aged meat was shown to follow zeroth order kinetics with the rate of constant dependent on the fat cover thickness and packaging time. Similarily, the rate constants of brightness difference, hue difference, Hunter colour L and b values, and pH were dependent on fat cover thickness and the types of chilling and packaging. The pH and brightness difference obeyed the zeroth or second order kinetics. The L and b showed a second order kinetics. Similarly, hue difference followed zeroth, 0.5th and 2nd order kinetics depending on the experimental variables.

INTRODUCTION: Aging is the holding of meat at varying periods under controlled temperature and relative humidity conditions. The mechanism by which cooler conditions improves tenderness is unclear and inconclusive despite the extensive studies. Lanari et al. (1987) reported the variation of tenderness of vacuum-packaged semi-tendinosus muscles for 20 d aging period at different storage temperatures (0, 4, 10 and 13°C). Tensile and Warner-Bratzler shear measurements were used to determine the tenderness of raw and cooked beef. They developed an exponential decay equation to quantify changes in beef tenderness during aging: $\ln(F/F_o)=k(t_o-t)$, where F and F_o are forces at time t and at the end of the aging process (t_o), respectively, and k is the rate constant.

Thus, the objective of the study was to study the kinetics of beef carcass with respect to its postmortem quality characteristics. The influences of the type of packaging and chilling; and fat cover thickness as function of aging time on textural profile and stress relaxation parameters, colour, water holding capacity, pH, press juice and cooking loss were assessed.

MATERIALS AND METHODS:

Carcass Chilling and Packaging: Eight steers which ranged in age from 14 to 24 months were obtained from the Animal and Poultry

Science's beef herd. The animals were maintained at the same ration prior to slaughter. They were conventionally slaughtered at different time intervals at the University's abattoir. The *longissimus dorsi* muscle between the first and fourteenth ribs were used. The carcasses were divided into two groups: four with 4 mm or less of subcutaneous fat thickness (low fat cover) over the *longissimus dorsi* at the 12th rib, and the other four with 6 mm to 8 mm subcutaneous fat (high fat cover). Two replications were used. Slow and fast chilling processes were employed. For the fast chilling treatment, the carcass, after slaughter was cooled at 2°C. For the slow chilling, the carcass was first cooled at 7°C for 4 h, and then cooled at 2°C up to aging time of 16 d.

After 24 h of fast or slow chilling, the *longissimus dorsi* muscle of one side of the carcass was removed. It was then divided into six sections and vacuum-packaged in ethylene/vinyl acetate copolymer poly-vinylidene-chloride (PVDC) 400 mm X 800 mm laminate bags. The packaged meat samples were kept in the cooler at 2°C for 16 d. The other half side of the carcass was aged on the carcass in the same cooler at 2°C, whereby samples of about 12 cm were cut from it on days 0 (24 h postmortem), 2, 4, 8, 12 and 16. The left and right sides of the carcasses were selectively alternated for either no packaging (carcass aging) or vacuum packaging for the 8 carcasses.

Colour: The colour parameters of 'L', 'a' and 'b' were determined by using a Spectrogard colour system (model 96, Pacific Scientific Co.). The operating conditions of the instrument were: observer at 2°, large area specular reflectance included, Hunter Lab Colour Scale and average daylight illumination. Two 3 cm thick slices of the meat were cut from the muscle, and left to stand for 20 min in light before recoding the data. Four reading were taken for each sample.

The measured Hunter Colour Values (L, a, b) sere used to calculate changes in total colour, brightness, hue angle and saturation (Moore, 1988) based on the following equations:

$$\text{Total colour difference (TCD)} = [(L_o-L_x)^2 + (a_o-a_x)^2 + (b_o-b_x)^2]^{0.5}$$

$$\text{Brightness difference (BD)} = [\Sigma(L_o-L_x)^2]^{0.5}$$

$$\text{Hue angle difference (HD)} = [\tan^{-1}(a_x/b_x)-\tan^{-1}(a_o/b_o)]^{0.5}$$

$$\text{Saturation difference (SD)} = (a_x^2 + b_x^2)^{0.5} - (a_o^2 + b_o^2)^{0.5}$$

Where L_o, a_o, b_o are at time zero, and L_x, a_x, b_x are at time x. Brightness measures the light scattering, or greyness of the meat, while saturation measures the depth of the dominant hue.

pH: Ten grams of a meat sample was macerated in 90g deionized water in a Waring Blender at 21,000 rpm for 60s. The slurry was then filtered through a coarse filter paper (Whatman, medium). The pH of the filtrate was determined by using a digital Piccolo ATC pH meter. The test was replicated three times.

Press juice: One half gram of the meat sample used for the colour determination was placed between two aluminum foils (80 mm X 80 mm) and then sandwiched between two filter papers (Whatman, medium). The resulting composite were then placed between two pieces of plexiglass (150 mm X 150 mm X 5 mm) and compressed using a Carver Lab Press (Model C) at a force of 57.8 kN for 60 s. Five readings were taken for each period. The press juice was calculated as the juice lost divided by the initial mass of the sample.

Water-holding capacity: Five grams meat sample used for the colour determination was cut and placed in a Fisher Vacuum Oven in an aluminum cup. It was subjected to a pressure of 0.5906 Pa at room temperature for 4 h, after which it was weighted. It was then placed in an oven preheated to 100°C for 24 h to determine its moisture content. Five determinations were carried out. The WHC was calculated dividing the moisture left by the initial sample moisture.

Cooking loss (CKL): Three centimeters thick meat sample of about 30 g was taken in an aluminum container, and placed in a preheated oven at 170°C and heated until its geometric centre reached 70°C. The meat sample was weighed before and after the roasting. Five repetitions were done. Cooking loss was the loss in mass during cooking divided by the cooked mass.

Data Analysis: A mainframe computer (IBM Model 3081) was used for the statistical analysis system's (SAS, 1987) general linear model (GLM) procedure to perform a covariate split-plot analysis with age as a covariate. Response variable were analyzed by the analysis of variance for a split-split-plot designed experiment. The model included: (i) whole plot effects for fat cover thickness and chilling rate with the interaction fat x chill as the whole plot error; (ii) sub plot effects for packaging and aging time; (iii) the two-way interaction time x packaging; and (iv) residual variations (subplot errors) (Steal and Torrie, 1980). Duncan's Multiple range test was used for the means separation.

Since the split-split-plot ANOVA model was completely specified, the residual mean sum of squares for error was zero. Hence, the error term chilling x replication x fat was used in Duncan's mean test analysis for replication, fat cover thickness and chilling; error term chiling x replication x fat x packaging for the type of packaging; error term chilling x time x replication x fat for time. SAS - CORR procedure was used to correlate the response variables. Mean values of each dependent variable of two replicates were used in the analysis. Regresion models of response variables as fucntion of aging time, packaging, fat cover thickness and their interactions were fitted using the stepwise regression and GLM procedures at 15% significance level.

The kinetics data was analyzed by using the NLIN (non-linear) procedure of the SAS to determine the reaction order and the rate constant of the kinetic equation:

$$dP/dt = -kP^n$$

Where dP/dt = change of P w.r.t. time
k = rate constant
P = property parameter of the meat at time t
n = order of reaction

RESULTS AND DISCUSSION:

1. Colour: The 'L' positively correlated ($P < 0.001$) with chilling rate, aging time and fat cover thickness. A positive correlation existed between 'a' and aging time ($P < 0.05$). The 'b' had a strong positive correlation ($P < 0.001$) with the chilling rate, fat cover thickness and aging time. Morover, TDC, HD and SD had a positive correlation ($P < 0.001$) with aging time. The change in hue angle reflects the degree of change in meat redness. Saturation difference (SD) is an indication of the depth of the dominant hue (redness). The ANOVA showed that aging time influenced 'L', 'b', TCD, BD and HD. Packaging type affected 'L',; and 'b' and TCD changed by the interaction fat x chilling x packaging. 'a' was not changed by any of the variables.

TCD followed a zero order reaction but the rate constants were dependent on fat cover thickness and packaging type (Table 1). BD also exhibited a zero order reaction with rate constant of 0.31 1/day dependent on chilling, 0.5th order reaction with rate constant of 0.054 1/day dependent on fat cover thickness and second order reaction with rate constant of 0.019 day^{-1} dependent on packaging. 'L' followed a second order reaction but was influenced by fat cover thickness and chilling rate. The fat cover thickness dependent rate constant and chilling dependent rate constant for 'L' were 2.6E-4 and 2.8E-4 day^{-1}, respectively. Similarily, 'b' followed a second order reaction which was dependent on packaging and chilling types with 9.1E-4 and 0.001 day^{-1} rate constants, respectively. HD exhibited a zero order reaction but dependent only on packaging. The rate constant was 0.0106 day^{-1}.

TCD followed zeroth order kinetics with rate constant dependent on fat cover thickness and type of packaging. BD showed a similar behavior except that the rate constants were dependent on chilling rate and the type of packaging; and also exhibited 0.5th order reaction with fat cover thickness dependent rate constant. Parameters 'L' and 'b' followed second order reaction whereby the rate constants depended on fat cover thickness and chilling rate; and the types of packaging and chilling, respectively.

WHC, Press Juice, pH and Cooking Loss: WHC was negatively correlated ($P < 0.05$) with chilling rate and positively ($P < 0.001$) with aging time. Press juice negatively correlated with fat cover thickness ($P < 0.05$). Positive correlation existed between pH and packaging type ($P < 0.05$) and aging time ($P < 0.001$), and negatively correlated ($P < 0.001$) with fat cover thickness. Cooking loss was positively correlated with chilling rate and aging time ($P < 0.001$), and negatively with fat cover thickness ($P < 0.001$).

ANOVA indicated that aging time significantly influenced beef pH and cooking loss, however, interaction fat x chilling x time affected press juice. pH also influenced by vacuum packaged aging.

None of the hydration properties followed any kinetics order. However, pH followed zeroth and second order reaction kinetics (Table 1). A zero order reaction with fat cover thickness dependent rate constant of 0.01 day^{-1} was followed by pH. Also pH showed a second order reaction with packaging and chilling types dependent rate constants of 2.7E-4 and 2.9E-4 day^{-1}, respectively.

Table 1: Kinetics of Colour Parameters During Beef Aging

Parameter	Rate Constant (day^{-1})	Dependent Factor	Mean Sum of Square of Error	Reaction Order
L	2.6E-4	Fat cover thickness	1.41E-6	2
L	2.8E-4	Chilling type	1.73E-6	2
b	9.1E-4	Packaging type	1.20E-5	2
b	0.001	Chilling type	1.31E-5	2
BD	0.019	Packaging type	0.008	2
BD	0.054	Fat cover thickness	0.24	0.5
BD	0.31	Chilling type	1.58	0.0
TCD	0.297	Fat cover thickness	3.48	0.0
TCD	0.298	Packaging type	1.30	0.0
HD	0.011	Packaging type	0.003	0.0
pH	0.01	Fat cover thickness	0.003	0.0
pH	2.7E-4	Packaging type	2.E-6	2.0
pH	2.9E-4	Chilling type	1.5E-6	2.0

CONCLUSIONS: BD, HD and TCD followed zeroth-order reaction, whereby their rate constants depend on chilling and packaging types, and fat cover thickness. BD, 'b' and 'L' also followed the second order kinetics. The rate constant of BD affected by packaging type; and of 'L' influenced by fat cover thickness and chilling type. The rate constants of 'b' depended on packaging and chilling types. pH followed zeroth and second order kinetics during beef aging.

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