PREDICTION OF FINAL YIELD (%) IN BACON MANUFACTURE USING DIFFERENT PHYSICAL AND CHEMICAL MEASUREMENTS

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INTRODUCTION

Manufacture of a consistent and uniform product out of non-uniform raw material has been a common goal for the bacon industry in the past. Nowadays, bacon manufacture continues to be a challenge. An early study by Schroder and Rust (1974) showed significant differences in belly composition between pigs. The same study reported non-significant differences between paired bellies of an animal, but highly significant differences from anterior to posterior ends of the belly. This inherent belly variability has prompted the bacon industry to recognize the use of selection and process control to minimize variation (Paul, 1978). Process control plays a very important role in bacon manufacture. Many variables have been reported to affect the process of converting green bellies into bacon. Thus, the objectives of this research were (1) to study the effects of preprocessing belly temperature, belly thickness and pump pressure on bacon final yield (%), pumped yield (%) and % residual salt; and (2) to formulate equations to predict bacon final yield (%) using different physical and chemical measurements.

MATERIALS AND METHODS

Experiment I

Experiment I consisted of a 4X4 factorial design. The experiment was replicated three times. For replicate one, 16 pork bellies from normal slaughter weight barrows and gilts were purchased from a local packing plant. Bellies were selected and sorted into four groups according to their thicknesses (1.27 cm, 2.54 cm, 3.81 cm and 5.08 cm). Belly thicknesses were measured at the shoulder end using a metal ruler. Bellies were skinned with a Townsend skinner Model 7900 (Townsend Engineering Company, Des Moines, IA) and trimmed according to standard industry procedures. Skinned bellies were individually-vacuum packaged. These bellies were used to calibrate the brine injector. The 16 bellies grouped by thickness were randomly assigned to four preprocessing temperature groups: 1.67°C, 7.22°C, 12.78° and 18.33°C. Each group of 4 bellies was placed in separate temperature-controlled chamber until the internal belly temperatures equilibrated to the respective chamber temperature. A Townsend injector Model 1450 (Townsend Engineering Company, Des Moines, IA) was used to inject the bellies. Brine injector was calibrated at a target of 12% pump. The 16 treatments were randomly injected. Belly weights were recorded before and after injection. Pump yield was calculated as a percentage of green weight. Injected bellies were cooked and smoked to an internal temperature of 57.2°C. Heat- processed bellies were chilled overnight and weighed. Final yield was calculated as a percentage of green weight. Two slices of 2.5 cm width per bacon slab (Nusbaum *et al*. 1976) were collected and analyzed for fat, moisture and protein. Fat and moisture were determined according to AOAC official methods (AOAC Official Methods of Analysis, 1990). Protein was determined using a nitrogen analyzer (Model FP-428, LECO corporation, St. Joseph, MI). pH was measured using a pH meter (Accumet 925 pH/Ion Meter, Fisher Scientific).

Experiment II

Experiment II consisted of a 3X2 factorial design. This experiment was replicated two times. For replication one, 30 pork bellies from normal slaughter barrows and gilts were skinned, trimmed and vacuum packaged as described in experiment I. The 30 bellies were randomly assigned to two preprocessing temperatures, either 1.67°C or 12.78°C. Each group of 15 bellies was placed in a separate temperature-controlled chamber until internal temperatures equilibrated to the respective chamber temperature. After temperature equilibration, the 15 bellies from each temperature group were randomly assigned to three pumping pressures: 35 psi, 45 psi and 65 psi (241.3 Kpa, 310.2 Kpa and 379.1 Kpa) and injected with curing brine containing 12.8% salt (NaCl). All bellies were injected using the same brine injector as in experiment I. Belly weights were recorded before and after injection. Pump yield was calculated as a percentage of green weight.Injected bellies were cooked and smoked to an internal temperature of 57.2°C. Heat processed bellies were chilled overnight and weighed. Final yields was calculated as a percentage of green weight.Samples were collected as in experiment I and % residual salt was determined according to AOAC procedure (1984, 24.011) using Quantab® chloride titrators (Environmental Test Systems, Inc., Elkhart, IN).
Data for both experiments were subjected to analysis of variance and LSD were used to separate means (SAS, 1991).

RESULTS AND DISCUSSION

Experiment I

No significant effects were observed for belly thickness, preprocessing belly temperature and their interaction on the final yield. However, a significant effect was found for the replication factor. No significant differences were found among treatment means (Table 1). A study by Nusbaum et al. (1978) found no significant differences among treatments on final yield when preprocessing belly temperatures were lower than 21.1°C. Replication and preprocessing belly temperature factors showed a significant effect on pumped yield. Comparison among treatment means showed significant differences (Table 1). Pumped yield values at preprocessing belly temperatures of 1.67 and 7.22°C were lower when compared to preprocessing temperatures of 12.78 and 18.33°C ($p<0.05$). Nusbaum *et al.* (1978) also found that higher levels of pumped yield could be attained at higher preprocessing temperatures. The authors also reported that higher processing losses occurred at processing belly temperature of 21.1°C. Significant effects were found for % fat, % moisture and % protein because of changes of the level of belly thickness. Replication had a significant effect on % fat values and on pH. Treatment means differed significantly among belly-thickness values of 1.27, 2.54 and 3.81 cm for % fat, % moisture and % protein (Table 1, $p<0.05$). However, no significant differences were found between 3.81 cm and 5.08 cm treatment means ($p>0.05$). In general, levels of fat increased and levels of protein and moisture decreased as levels of belly thickness increased (Table 1). Comparison among treatment means for pH values showed some differences (Table 1). pH-mean value for a belly thickness of 1.27 cm differed significantly from the higher belly thickness pH- mean values ($p<0.05$). This difference could be attributed to the changes in compositional values of bellies. It is expected that a thinner belly will have a better buffering capacity because of its higher content of protein. Linear regression analyses were performed on final yield and pumped yield using % fat, % protein and % moisture as dependent variables. Non significant linear relationships were found when final yield (%) was regressed against % fat, % protein and % moisture ($p>0.05$). Linear equations were modeled as an attempt to predict final yield (%) using compositional values (Table

2). However, because of the low correlation values of these equations, they should only be used to estimate final yield % values in the bacon industry.

Experiment II

Replication and pump pressure had a significant effect on final yield %. Preprocessing belly temperature again did not have a significant effect on final yield %. Nusbaum *et al.* (1978) reported that belly temperature had a significant effect on final yield, however, the authors observed that significant differences among belly temperature groups were primarily due to the 21.1°C temperature group. Comparisons among treatment means for pumping pressure, regardless of belly temperature, differed significantly on final yield only between 35 and 55 psi (Table 3). Nusbaum *et al.* (1985) reported that bellies pumped at 70 psi retained greater amounts of brine before and after thermal processing, but they also sustained greater losses during thermal processing when compared to bellies pumped at 50 psi. A significant interaction was found between pump pressure and preprocessing belly temperature. Pumping pressures of 45 and 55 psi more effectively increased the final yield (%) for 12.78°C group when compared to 1.67°C group. No additional gain in final yield was observed whether 45 or 55 psi was used for the 12.78°C group. Increasing the pumping pressure from 35 to 45 psi did not increase the final yield (%) for 1.67°C group. Replication, preprocessing belly temperature and pump pressure had a significant effect on pumped yield (%) and % salt. Pumped yield (%) and % salt values were significantly higher for 12.78°C temperature groups when compared to 1.67°C temperature groups ($p<0.05$, Table 3). Nusbaum *et al.* (1978) reported that elevated preprocessing belly temperatures allow the belly to retain more cure after injection and thermal processing and ultimately result in a higher percentage of residual salt. Comparisons among treatments means for pumped yield (%) and % salt values revealed significant differences for 35, 45 and 55 psi pump pressures, regardless of belly temperature ($p<0.05$, Table 3). In general, pumped yield (%) and % salt values increased when pump pressure increased from 35 to 55 psi. Gains in final yield (%) can be partly attributed to the increase in % salt in finished product. A significant two way interaction was found for % salt between pump pressure and preprocessing belly temperature. Pumping pressure of 35 psi did not seem to affect the % salt level for 1.67° and 12.78°C temperature groups. Regression equations were formulated to predict final yield (%), pumped yield (%) and % salt by using pumped yield (%), % salt and pump pressure as dependent variables (Table 4). These equations can be used as a practical guidance by the bacon processors to target certain levels of final yield on finished product while still attaining an acceptable level of residual salt. However, further testing should be conducted to determine processing conditions that will not exceed the maximum allowed level of nitrite.

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TABLE 1.
TREATMENT MEANS FOR FINAL YIELD (%), PUMPED YIELD (%), % FAT, % MOISTURE, % PROTEIN AND pH[a]

Temperature °C	Thickness (cm)	Observa-tions	Final yield (%)	Pumped yield (%)	(%) Fat	(%) Moisture	(%) Protein	pH
1.67		3	101.5 c	10.2 c	53.1 c	32.7 c	8.9 c	6.3 c
7.22		3	103.9 c	12.9 c	52.6 c	33.5 c	9.1 c	6.3 c
12.78		3	102.4 c	17.9 d	48.9 c	36.1 c	9.7 c	6.3 c
18.33		3	97.4 c	19.8 d	49.8 c	34.5 c	9.6 c	6.3 c
SEM[b]			(4.0)	(2.8)	(3.2)	(2.1)	(0.8)	(0.1)
	1.27	3	96.9 z	14.8 z	39.9 z	41.4 z	12.3 z	6.2 z
	2.54	3	101.6 z	16.1 z	46.9 y	36.2 y	10.0 y	6.3 zy
	3.81	3	105.1 z	15.1 z	56.1 x	31.2 x	7.9 x	6.4 y
	5.08	3	101.5 z	14.9 z	61.2 x	27.9 x	7.0 x	6.4 y
	SEM		(4.0)	(2.8)	(3.2)	(2.1)	(0.8)	(0.1)

a Means followed by the same letter in the same column are not significantly different at $p<0.05$

b Pooled standard error for the overall means

TABLE 2.
REGRESSION EQUATIONS FOR THE USE OF % FAT, % MOISTURE AND % PROTEIN IN PREDICTING FINAL YIELD (%)

Predicted value (%)	Intercept		Regression coefficient and dependent variable[a]	r
Final yield =	85.27	+	0.313 (% fat)	0.35*
Final yield =	111.44	-	1.089 (% protein)	-0.30*
Final yield =	116.80	-	0.454 (% moisture)	-0.32*

a Range of values (minimum-maximum): % fat (26.1-68.3), % protein (5.3-16.6) and % moisture (23.1-52.5)

* $p<0.05$

TABLE 3.
TREATMENT MEANS FOR FINAL YIELD (%), PUMPED YIELD (%) AND % SALT[a]

Temperature °C	Pressure (psi)	Observa-tions	Final yield (%)	Pumped yield(%)	% Salt
1.67		30	99.5 c	15.1 c	2.12 c
12.78		30	100.8 c	19.1 d	2.84 d
SEM[b]			(0.48)	(0.70)	(0.053)
	35	20	98.9 z	11.7 z	1.48 z
	45	20	100.1 zy	16.2 y	2.10 y
	55	20	101.5 y	23.5 x	2.36 x
	, SEM		(0.59)	(0.86)	(0.064)

a Means followed by the same letter in the same column are not significantly different at $p<0.05$

b Pooled standard error for the overall means

TABLE 4.
REGRESSION EQUATIONS FOR THE USE OF PUMPED YIELD (%), % SALT AND PRESSURE IN PREDICTING FINAL YIELD (%), PUMPED YIELD (%) AND % SALT

Predicted value(%)	Intercept		Regression coefficient and dependent variable	r
Final yield (%) =	94.01	+	0.360 (pumped yield, %)[a]	0.73
Final yield (%) =	90.63	+	4.810 (%salt)[a]	0.74
Pumped yield (%) =	-1.67	+	0.388 (pressure)[b]	0.58
% Salt =	0.84	+	0.067 (pumped yield, %)[a]	0.88

a Range of values for predicting equation (minimum - maximum): pumped yield ,% (4.59-50) and % salt (0.82-3.75)

b Pressure values for predicting equation (minimum - maximum): 35 psi - 55 psi