Quality characteristics of highly extended cook-in packaged ham as affected by replacement of sucrose by hydrolyzed corn starches and sorbitol

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Abstract— **The color and microbiological stability during storage and retail display is important to both meat processors and retailers.**

The objectives of the present study were to evaluate the effects of replacing sucrose from sugar cane by hydrolyzed corn starch and sorbitol on the pH, water activity, psychrophilic plate count and objective color parameters (L, a* and b*) in highly extended cook-in ham.

Ham muscles were injected to 170% of their initial weight, mechanically tenderized and tumbled for 4 h, after which they were vacuum packaged in extruded heat-shrinkable film and stored at 4ºC. The sugarcane sucrose (4,8%) in the brine of the control treatment (CTL) was replaced by hydrolyzed corn starch (HCS, Corn Products) with different dextrose equivalent (10DE, 40DE and 100DE) values and sorbitol (S), totaling five treatments (CTL, HCS10, HCS40, HCS100 and S). Water activity, pH value, moisture content and psychrotrophic plate counts were determined at 0, 30, 45, and 100 days storage of the whole pieces, while evaluation of discoloration was performed on slices of the abovementioned products packaged in PVC films based on the CIE L*, a* and b* measurements after 0, 6 and 24 hours exposure to light.

The lowest water activity and the highest pH values were detected in S, while HCS100 didn't differ from S and showed the highest moisture content and the lowest drip loss values among treatments. CTL had the lowest pH value. The highest color stability was exhibited by HCS40. The lowest psychrotrophic counts were obtained in S (1.6 log CFU/g), and were not significantly different from HCS100 (1.8 log CFU/g), whereas the other treatments presented counts above 2 log CFU/g.

Further studies with blends of HCS40, HCS100 and S might enhance the microbiological and color stability of this type of product.

Keywords— **Cooked ham, Dextrose equivalent, Sorbitol.**

INTRODUCTION

Cooked ham marketed in highly extended *cook-in* packages have gained a significant share of the Brazilian market of processed meat products, with a total annual production of 174.000 metric tons in 2010. Hams of this category are normally added with a red coloring (carmine) to produce the pink color demanded by the Brazilian consumer. For the most part, these products are sold as one whole piece, sliced at the retail level and packed in PVC film.

The color of meat products such as ham is of utmost importance to consumer acceptance. For that reason, color stability during storage and display in retail outlets is extremely relevant to both processors and retailers. In Brazil, the shelf life of this type of product is generally set at 90 days for the ham pieces in their original, unopened packaging.

The objective of this study was to evaluate the technological performance of three corn starch hydrolysates with different degrees of hydrolysis, and sorbitol in *cook-in* ham, as compared to the traditional product made with saccharose, based on the determination of water activity, moisture content, pH value and growth of psychrotrophic microorganisms throughout 100 days storage of the whole ham pieces.

MATERIAL AND METHODS

Formulations and processing

This study was conducted using a standard ham formulation yielding an end product weighing 170% of the raw material used, in this case pork leg meat. The different ham muscles obtained from the pork leg were injected with a brine solution and subsequently tenderized and followed by massaging in a tumbler for

12 hours. Next, they were vacuum-packed (3kg-pieces) in a food-grade vacuum sealing machine using a co-extruded film (TO60B CRYOVAC®, Brazil) for the bottom and a laminated heat-shrinkable film (BH035B CRYOVAC®) for the top. The different ham pieces were cooked in water tanks at a commercial meat processing plant. The pieces were transported to CTC/ITAL where they were kept in a cold storage room at 4ºC until analysis. The formulations of the different treatments investigated are shown in Table 1.

Table 1 Percentage composition of the *cook in* cooked ham formulations with a 170% yield.

Raw materials and Ingredients/additives	Treatments				
	CTL	HCS 10DE	HCS 40DE	HCS 100DE	S
Leg of pork meats	58,3	58,3	58,3	58,3	58,3
Water	33,5	33,5	33,5	33,5	33,5
Soy protein isolate	2,0	2,0	2,0	2,0	2,0
Salt	1,5	1,5	1,5	1,5	1,5
Seasonings (50% salt)	1,2	1,2	1,2	1,2	1,2
Sugar cane (sucrose)	2,0	-	-	-	-
Carrageenan	0,5	0,5	0,5	0,5	0,5
Sodium Polyphosphates	0,5	0,5	0,5	0,5	0,5
Hydrolyzed Corn Starch 10DE [1]	-	2,0	-	-	-
Hydrolyzed Corn Starch 40DE [2]	-	-	2,0	-	-
Hydrolyzed Corn Starch 100DE [3]	-	-	-	2,0	-
Sorbitol [4]	-	-	-	-	2,0
Curing salt (ppm)	150	150	150	150	150
Monosodium Glutamate	0,09	0,09	0,09	0,09	0,09
Sodium erythorbate	0,1	0,1	0,1	0,1	0,1
Carmime coloring	0,02	0,02	0,02	0,02	0,02

[1]Mor-rex 1910®, [2]Mor-rex 1940®, [3]Cerelose02020®, [4]RD750®, Corn Products, Brazil

Objective color

The objective color of slices from each of the treatments was evaluated based on the measurements taken using a portable spectrophotometer (Minolta, model CM 508d), with readings for lightness (L*), red/green (a*), yellow/blue (b*) performed and expressed according to the CIELab system, using the D65 illuminant, standard observation angle of 10º and lens opening 8mm in diameter, specular included. Thirty days after processing, the pieces were unpacked, sliced, placed in polystyrene trays, wrapped in PVC film and placed in a refrigerated display case (4ºC) under direct light (270 lux). Instrumental color readings were taken on the sliced products at the following intervals: immediately after slicing (0h), and 6 and 24h after exposure to light. All analyses were performed in triplicate for each treatment.

Determination of pH and Water Activity values

The pH values were determined using a pH-meter (Digimed model DM21) with a puncture electrode (Digimed model DME-CF1).

Five pH measurements taken from three samples of each treatment were used to calculate the mean pH of each treatment. The pH was measured upon completion of processing (0 days) and after 30, 75 and 100 days refrigerated storage.

Three water activities readings were taken from three samples per treatment. Water activity was determined with an Aqualab water activity meter (model CX-2), at a temperature of 25ºC A_w measurements were made throughout refrigerated storage at 48h (zero), 25, 45 and 90 days after processing.

The moisture content was determined in triplicate in three samples of each treatment, according to AOAC Method 950.46 (Horwitz, 2005) [2]. The readings were taken at 0, 25, 45, 75 and 90 days after processing during refrigerated storage of the finished product.

Microbiological evaluations

Total psychrotrophic counts were performed in triplicate on three samples of each treatment after 48h, 25, 45 and 90 days after processing during refrigerated storage of the finished product, according to the method described by Dowes and Ito (2001)[1]. The results are expressed in log CFU/g.

Statistical Evaluation

The results of the analyses performed on the whole pieces throughout refrigerated storage, along with the readings obtained for objective color of the sliced products were subjected to analysis of variance (MANOVA) to evaluate the effect of the treatments,

storage time and the treatment X time interaction. The difference between the mean values was evaluated by Tukey´s test at the 95% confidence level.

RESULTS AND DISCUSSION

Objective Color of the sliced ham

There were significant effects of treatment, storage time, treatment X time interaction on all the objective color parameters studied (Table 2).

Table 2 Objective color of sliced ham packaged in polystyrene trays wrapped in PVC film and kept in a display counter at 4ºC for 24 under direct light (270 lux).

Storage time (days)		Treatments				
		CTL	HCS 10DE	HCS 40DE	HCS 100DE	S
L	0h	62,7 ^{aA}	57,3 ^{bB}	59,1 ^{bB}	57,1 ^{b,B}	63,1 ^{aA}
	6h	65,1 ^{aA}	56,1 ^{bD}	61,1 ^{abC}	62,0 ^{aB}	62,4 ^{aBC}
	24h	64,9 ^{aA}	63,1 ^{aAB}	61,6 ^{aB}	61,0 ^{aB}	62,8 ^{aAB}
a*	0h	9,6 ^{aB}	11,5 ^{bA}	10,4^{aB}	10,3^{aB}	9,7^{aB}
	6h	8,6 ^{aC}	13,8 ^{aA}	10,8^{aB}	10,4^{aB}	9,9^{aB}
	24h	8,5 ^{aAB}	7,7 ^{cBC}	8,8^{bA}	9,3^{bA}	8,8^{bAB}
b*	0h	9,9^{bB}	11,1^{bA}	10,0^{bB}	9,8^{aB}	9,9^{aB}
	6h	10,7^{aB}	12,2^{aA}	10,9^{aB}	9,9^{aB}	9,1^{bC}
	24h	10,4^{abA}	10,2^{cA}	8,4^{cB}	9,8^{aA}	10,5^{aA}

CTL – sugarcane (sucrose); HCS10DE – Hydrolyzed corn starch Mor-rex1910® Corn Products; HCS40DE Mor-rex1940® Corn Products; HCS100DE Cerelose02020® Corn Products; S – sorbitol – RD750 Corn Products

Different lowercase letters in the same column for the same parameter indicate significant difference between the means by Tukey´s test ($p<0,05$)

Different uppercase letters in the same row for the same parameter indicate significant difference between the mean values of the treatments by Tukey´s test ($p<0,05$)

The significant effect ($p<0,05$) of the interaction between treatment and storage time (Table 2) evidenced that among the freshly sliced products (0h), the treatments with the highest L* values were CTL and S, which did not differ from each other. After 6h exposure to light, the lowest L* value was that of treatment HCS 10DE, a value that did not vary within this period. After 24h exposure, the CTL treatment exhibited the highest L* value and treatments HCS 40DE and HCS100DE the lowest, while the other treatments (HCS10DE and S) presented intermediate values which did not differ among each other. Slices of the HCS10DE treatment did not show any change in L* value after up to 6 hours exposure to light, standing out as the product with the lowest value within this period. The S treatment, which, among the treatments with intermediate values for the L* parameter, did not show any variation within this period. The changes in the L* value were more pronounced in the first 6h of treatment HCS100DE.

Water activity, pH value and Moisture content

There were significant effects of treatment, storage time and treatment X time (Table 3) on the water activity of the cooked hams.

Table 3 Effect of the treatment X time interaction on the water activity levels of *cook-in* hams kept under refrigeration (4ºC).

Effects	Storage time (days)			
Treatments	0	30	75	100
CTL	0,974^{aA}	0,974^{aA}	0,970^{bA}	0,973^{aA}
HCS10DE	0,973^{aA}	0,972^{abA}	0,970^{bA}	0,970^{bB}
HCS40DE	0,975^{aA}	0,972^{abA}	0,970^{bA}	0,970^{bB}
HCS100DE	0,972^{aA}	0,971^{aA}	0,970^{aA}	0,970^{aB}
S	0,972^{aA}	0,971^{aA}	0,970^{aA}	0,970^{aB}

CTL – sugarcane sucrose; HCS10DE – Hydrolyzed corn starch Mor-rex1910® Corn Products; HCS40DE Mor-rex1940® Corn Products; HCS100DE Cerelose02020® Corn Products; S – sorbitol – RD750 Corn Products

Different lowercase letters in the same column for the same parameter indicate significant difference between the means by Tukey´s test ($p<0,05$)

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With regard to the effect of the treatment on the water activity, the treatments HCS100DE and S exhibited the lowest water activity and did not differ from each other. The HCS10DE and HCS40DE treatments did not differ from each other throughout the storage period investigated. The significant effect of storage time on the water activity clearly showed that changes in the levels of water activity only occurred up to 75 days storage. The interaction

indicated that the HCS100DE and S treatments significantly reduced the water activity of the hams and that the water activity level did not change throughout storage.

There was a significant effect of the treatment ($p<0,05$) and storage time ($p<0,05$) on the pH values, but the treatment X time interaction was not significant ($p=0,06026$).

The significant effect of the treatment indicated that the treatments HCS100DE and S had the highest mean pH values (6,27) which did not differ between each other, while treatments HCS10DE and HCS40DE presented intermediate values, 6,21 and 6,20, respectively, which also did not differ from each other. Treatment CTL had the lowest pH value (6,09) among the treatments investigated. The reduction in pH may reflect an increase in the acidity of the product, which is generally associated with the growth of lactic bacteria during storage, especially in vacuum-packed products.

There was a significant effect of the treatment ($p<0,05$) on the moisture content of the hams, much although storage time and the treatment X time interaction were not significant ($p>0,05$). Treatment HCS100DE exhibited the highest moisture level (77,1%), whereas HCS10DE had the lowest (76%).

Microbiological evaluations

Although no significant effect has been observed on the counts at the interval of confidence established (95%), the results suggest that, at a confidence interval of 90% ($p=0,07$), treatment HCS10DE presented the highest count (2,5 log CFU/g) and treatment S the lowest (1,6log CFU/g), with the latter not being different from the count determined for the HCS100DE treatment (1,7log CFU/g).

The results relative to the total count of psychrotrophic microorganisms throughout storage of the ham pieces indicates that the S treatment followed by the HCS100DE treatment had the greatest retarding effect on microbial growth in the *cook-in* ham investigated (Table 4).

Table 4 Effect of the treatment ($p=0,07$) on psychrotrophic counts (Log CFU/g) in whole pieces of *cook in* ham kept under refrigeration (4ºC).

Treatments	Log CFU/g
Control	$2,08^{ac}$
HCS 10DE	$2,53^{a}$
HCS 40DE	$2,38^{ab}$
HCS 100DE	$1,80^{c}$
S	$1,60^{c}$

CTL – sugarcane sucrose; HCS10DE – Hydrolyzed corn starch Mor-rex1910 Corn Products; HCS40DE Mor-rex1940 Corn Products; HCS100DE Cerelose02020 Corn Products; S – sorbitol – RD750 Corn Products

Different lowercase letters in the same column parameter indicate significant difference between the means by Tukey´s test ($p<0,05$).

CONCLUSIONS

The present study allowed to conclude that treatment HCS 40DE favors color stability throughout exposure to light, while HCS 100DE reduces the water activity and S does not favor microbial growth. Treatment HCS 10DE was found to be inadequate for use in *cook in* ham.

The use of blends of HCS 40DE, HCS 100DE and S, in replacement of saccharose probably may produce marked improvements in terms of appearance - particularly that of the sliced product - and reduction of the water activity, in addition to providing increased microbiological stability and reduction of exudation.

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