Scientific Contributions

Shelf stable beef snack foods and applications for beef in the health food market

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Background and Introduction

In 1980, the Province of Alberta and the Prefecture of Hokkaido signed an agreement of cooperation in education, culture, sport, and economics, and the 20th anniversary of this agreement saw close cooperation between research institutions. This project is a result of the importance that Alberta and Hokkaido have placed on advancing knowledge of value-added meat processing.

The Japanese snack food market is saturated with potato chips, extruded corn and wheat puffs of various flavours, and salted/dried seafood products. The Japanese meat processing industry has lagged behind in new product development, preferring instead to use qualifiers such as "Superior Quality", "Made in Japan", "Exceeds Safety" to attract consumers. Recently, however, major meat processors have been energetic in their development of consumer-friendly processed meats for retail and food service markets. In North America, snack food sales are increasing and AC Nielson category numbers for all supermarkets, mass merchandisers, and drug outlets showed meat snack sales up 44% to $243.9 million US in 2001.

Meat snacks can provide increased variety while addressing alternative consumer requirements. The popularity of low carbohydrate, high protein diets has influenced interest in meat snacks and increased demand is expected to continue. The current meat snack market consists mainly of sliced or formed beef jerky and meat sticks that are produced using traditional smoking and air-drying methods. By pursuing new applications of these historical technologies in conjunction with the development of novel methods to produce room temperature shelf-stable beef products, new meat snacks could be developed to meet the growing demand for "healthy snacking" and "functional foods". This would include beef snacks with easy digestibility and defined protein and mineral contents, and those formulated with specific health factors such as cancer-reducing agents.

This report represents a portion of the initial developmental research into innovative beef processing technologies, and investigation of the free radical trapping activity of beef extract compounds conducted jointing between Alberta and Hokkaido. It is important to note that some of the ingredients and pH/ water activity combinations may not comply with current Canadian regulations.

Development of soft beef jerky by traditional drying with sugar infusion

Beef jerky is classified as an intermediate moisture, shelf stable meat product. Shelf stable classification requires either a water activity (Aw) value d" 0.85, or Aw d" 0.9 combined with a pH of d" 5.3, or a pH d" 4.6 without concern about Aw. Achieving low Aw (d" 0.85) by traditional methods generally requires long drying periods resulting in undesirable hardening and darkening of the final product. With a target of Aw d" 0.9 and pH d" 5.3 prototypes were produced to evaluate the effects of pH adjustment with lemon juice, citric acid, or glucono-delta lactone (GDL) and sorbitol and dextrose for Aw adjustment. The advantage of using acidifiers and Aw modifiers is an increased production turnover as a result of decreased cooking time, and an increased yield with the use of low-cost polysaccharides.

Beef outside round was combined with a commercial spice mix, tumbled under vacuum, and processed in a smokehouse for a 2.3 hour cycle of reddening, smoking, and drying. Initial results indicated that although citric acid and lemon juice adjusted the pH to 5.3, both had a negative influence on the appearance of the product. The surface was matte with a "velvet-like" appearance, probably caused by an initial rapid drop of surface pH resulting in denaturation of surface proteins. Excessive addition of sorbitol (> 8%) caused the product to have a wet appearance, while excess dextrose made the product sticky. Both results were caused by the agglomeration of long chain carbohydrates on the meat surface, although prolonged tumbling and proper adjustment of polysaccharide concentrations may eliminate these problems. The best results are compiled in Table 1 and demonstrated in Figure 1.

Development of string beef by osmotic drying with sugar infusion

The concept of string beef was based on two existing snack products familiar to Canadian and Japanese consumers, respectively: string cheese and shredded (pulled) dried squid. The basic concept was to dry the muscle fibres by osmosis with a liquid which had low water activity and to replace lost water with sugar through infusion to assure a soft texture and water activity Aw d" 0.9. Acidifiers were used to assist in water release from protein and to maintain a final pH d" 5.3.

Beef outside round was injected to 30% with a sugar solution containing a polydextrose, glycerol, or sorbitol – polysaccharides known for their ability to remain liquid at high concentrations. Following injection and vacuum-tumbling, the meat was cut along the grain into pieces of approximately 10 cm x 4 cm x 4 cm and immersed in the injection solution for 48 hours. Saturated product was pressured cooked with injection liquid for 30 minutes at 118 – 120 °C to gelatinize collagen, then cooled, peeled, and packaged.

All three sweeteners resulted in similar products, but glycerol had an unacceptable sweetness not usually associated with meat, while the polydextrose was relatively expensive. The optimum formulations are presented in Table 2. The sorbitol solution was selected for final sample preparation because of its wide acceptance as a mild sweetener and its lower cost (around $1.50/kg). Attention to uniformity of injection was critical since the fluid, with ~50% sorbitol, did not disperse well and improper injection led to uneven product drying. During the process development stage, it was also observed that both prolonged immersion for 3 – 4 days and extended cooking time over-dried the product and the fibres became brittle. The finished product (Figure 2) had good colour and flavour, with a soft texture and meat fibres that separated easily from the surrounding collagen. A possible application of the string beef process is in the production of a shelf-stable ginger-beef product.

Development of crunchy candy meatballs with trehalose

The majority of beef snacks manufactured in Canada and Japan have a salty, savoury taste. In this part of the project, an attempt was made to manufacture a novel confectionary-type (candy) snack using a combination of beef and low-calorie sugars. In addition to raw ground beef, each formulation contained ground beef that was previously cooked by boiling in 0.1% citric acid or an equal part sugar.

All ingredients (Table 3) were mixed together and formed into balls, then coated with breadcrumbs and deep-fried.

After frying (Figure 3), the products had a crunchy surface and a soft interior; however, when left at room temperature for 24 hours, the product became overly soft. This situation was improved slightly by short, successive frying; however, after holding at room temperature, the product again lost its crunchy texture, likely resulting from moisture migration from the soft interior to the exterior due to the humectant properties of the sugars. In a final test, the product was deep fried for 90 seconds at 180°C and dried overnight in a vacuum oven at 70°C. The resulting product was crunchy and had good flavour but was hard to chew. After one day at room atmosphere, the texture of the product became acceptable.

Development of shelf stable beef meatballs

Beef meatballs are common and well accepted as a main entrée and are usually served in sauce accompanied by pasta or potatoes. They are normally sold freshly ground and formed as a frozen entrée, and are also a frequent component in home meal replacements. In Japanese supermarkets and convenience stores, meatballs are typically skewered and coated with sauce and sold by the piece in the ready-to-eat section. In Europe, a number of companies are producing sauced meatballs in retorted, semi-rigid modified atmosphere packages, and have a declared shelf life of up to 18 months. With the exception of frozen and retorted products, meatballs have a short shelf life, ranging from 2 – 3 days for freshly ground to 1 – 2 weeks for a cooked and chilled product. Development of shelf stable beef meatballs with Aw d" 0.9 and pH d" 5.3 could expand their present applications to include lunch box users, whose access to proper refrigeration is limited.

Process development was conducted in three segments. A formula with a reasonable low Aw was first prepared. This formula was then modified to achieve the required pH, and based on these results samples from a final formula were produced (Table 4). Beef (75% - 80% lean) was ground and combined with the remaining ingredients in a mixer until a proper bind was achieved. Meatballs were then formed and deep-fried in canola oil to an internal temperature of 72°C.

The initial formula provided an acceptable product, however addition of glucono-delta lactone (GDL) at a much higher level than anticipated was required to reduce pH to 5.3. It was suspected that the skim milk powder had a very strong buffering effect and was removed from subsequent formulas. Furthermore, it was observed that while GDL addition lowered pH, it had an adverse effect on product texture and bind. In order to improve texture, corn syrup solids were replaced with breadcrumbs in the final formulation (Figure 4). Additional refinement of the formula is required, with the addition of a minimum level of sodium nitrite to meet Canadian regulations and, possibly, an encapsulated GDL to reduce the negative impact on product bind and texture.

Development of deep-fry vacuum-dried beef

Freeze-drying is a common method of food preservation, particularly where the structure of material is to be maintained. The most common application in the meat industry is in the manufacture of dried meat cubes for instant soups. Depending on the dryer's capacity to remove water, however, the process may require several days. Deep-fry vacuum-drying was investigated as an alternative method due to its short processing time and the use of relatively low temperatures that aid in nutrient retention. The influence of various temperatures, times, cut directions, and the initial product state (fresh versus frozen) on the appearance, texture, and Aw of beef was examined. Drying took place under -74 mm Hg vacuum. In preliminary testing excessive shrinkage and shape distortion of raw beef was observed, so subsequent evaluations focussed only on frozen (-27ºC) meat that tended not to shrink and retained better colour and shape.

Cooking to approximately 85ºC resulted in products with a natural reddish/pink colour, and good, crisp texture. Beef cooked for 10-12 minutes had a jerky-type texture. Samples of meat cut across the grain and cooked for 40 minutes were crisp like potato chips but with a fresh meat flavour, and had a very light texture and a reddish/pinkish colour (Figure 5a, 5b). The meat broke down easily during mastication, however residual collagen was detectable. Additionally, deep-fried vacuum-dried beef has a slightly spongy texture upon re-hydration, due to its collagen content; however, pre-treatment of beef with proteolytic enzymes is expected to alleviate residual connective tissue problems. Spiced meat did not have the flavour intensity expected based on the amount of spice used, and this was likely due to topical spices being blown off by the steam generated during frying. Use of oleoresins or water-soluble spices for meat chip-type products could resolve this problem.

The production procedures for deep-fried vacuum-dried meat products are relatively simple and further development work could be reasonably expected to lead to commercial application. For example, preliminary testing with ground meat resulted in a "popcorn"-type product (Figure 6) that could be incorporated into chip and nut snack mixtures to boost protein content.

Extruded, puffed, low fat beef snacks

Extrusion of various beef mixtures was tested as a method of production of a healthy, high protein/low carbohydrate/low fat snack product. Lean (90%) ground beef was combined in a silent cutter with one or two of the following ingredients: corn flour, potato starch, skim milk powder, soy protein isolate, or sodium caseinate. To achieve product puffing without the addition of oil, superheated steam was produced by the application of pressure and high temperature to the ingredient mixture in the extruder. Upon exit from the die, the release of pressure caused rapid boiling of the water in the mixture and the resultant steam expanded the product to produce a puffed chip (Figure 7) similar to "pork rinds", but with virtually no fat.

Evaluation of antioxidant effect of beef extract and amino acids by Comet Assay

It is well known that DNA damage by active oxygen is the first stage in the mechanism of cancer development. Reports have suggested that several peptides and low molecular weight components of food can suppress DNA damage by catching free radicals and superoxides, and promoting DNA repair. Peptides from enzyme-processed beef muscle may have similar DNA protective activity and could be incorporated into snack products for the health food market. This study was focussed on water-soluble nitrogen compounds in beef and their effect on DNA damage suppression in HL60 cells – a human promyeolocytic leukemia cell line with a pronounced susceptibility to DNA damage by hydrogen peroxide (H_2O_2) and lipid hydroperoxides due to the lack of a self-repairing mechanism.

Cells were cultured then treated as follows: negative control (no H_2O_2), positive control (treated with 10 ppm H_2O_2), and test samples (treated with 10 ppm H_2O_2 *and* beef compounds at levels from 1 to 10,000 ppm). After incubation under treatment conditions, cells were ruptured and damaged DNA flowed out of the cells during gel electrophoresis, developing a trailing "tail" - hence the name "Comet Assay". Gels were stained and photographed and a computerized imaging system was used to evaluate the "tail moment" representing the total amount of DNA that was damaged and leaked from the cell. The results of treatment with meat extract are shown in Figure 8. Results of various other compounds, including carnosine, taurine, alanine, are available in a separate publication.

Results indicate that some beef extracts had a strong protective effect, particularly carnosine and meat extract at 10 ppm. It should be noted that all compounds were tested against radical levels present at much higher than those found *in vivo*. Further work to identify the amino acid composition of the meat extract and to determine its most effective fractions would be valuable. This type of knowledge could be put to use in enzymatic meat processing in order to increase levels of protective free amino acids and peptides in nutritionally-enhanced beef products manufactured especially for the elderly and people with gastric ailments.

Conclusion

This project represents investigative development work on a number of technologies and processing conditions to produce novel, shelf-stable beef snacks that could be acceptable in Japanese or North American markets. Most of the technologies and products are experimental at this point, but with further refinement could have application in the value-added beef industry. Further work could also be conducted on the use of proteolytic enzymes in meat processing. Besides the obvious benefits of texture and flavour enhancement, enzymes could assist in boosting the antioxidant activity and anti-carcinogenic potential of meat products through the incorporation of peptides and free amino acids.

Table 1. Optimum formulations for soft beef jerky

	No added sugars	Sorbitol and dextrose	Dextrose
Ingredient (kg)			
Beef	4.5	4.5	4.5
Jerky spice	0.27	0.315	0.27
GDL	0.03375	0.03825	0.03825
Sorbitol	-	0.3	-
Dextrose	-	0.225	0.002
Finished product			
Yield (%)	54.2	60.6	60.4
Aw			
Thin slice	0.864	0.882	0.875
Thick slice	0.922	0.915	0.891
pH	5.33	5.36	5.23

Table 2. Optimum formulations for string beef

	With 60% polydextrose	With 70% sorbitol
Ingredient (%)		
Salt	7.0	1.4
Citric acid	0.2	0.2
Dextrose	-	5.0
Soy sauce		20.0
Hydrolyzed plant protein		5.9
After injection		
Aw	0.87	0.751
pH	2.10	4.35
After cooking		
Aw	0.91	0.834
pH	5.08	5.25

Table 3. Formulation of crunchy candy meatballs

	Product 1	Product 2	Product 3
Ingredient (kg)			
Raw ground beef	50	50	100
Citric acid boiled beef	100	50	-
Sugar boiled beef	100	150	150
Trehalose	150	150	100
Sugar	40	40	-
Sodium caseinate	8	-	-
Bread crumbs	-	10	30
Orange flavour	0.06	0.06	0.06

Table 4. Typical formulas used in the development of shelf stable meatballs

	Formula 1	Formula 2	Formula 3
Ingredient (g)			
Beef, 70-80% lean	508	500	1000
Soy protein isolate	30	40	80
Soy flour	30	40	80
Corn syrup solids	50	60	
Salt	15	15	30
Garlic powder	1	1	3
Onion powder	2	2	5
Pepper	3	3	7
GDL		6	13
Bread crumbs		50	80
Mustard powder		-	20
Skim milk powder	20		
Dextrose	-	-	120
Aw	0.92	0.91	0.91
pH	5.8	5.2	5.2

Table 5. The effect on appearance, texture, and Aw of beef after various temperature/time combinations of deep-fried vacuum-drying combinations

Temperature (°C)	Time (min)	Cut*	Aw	Appearance	Texture
70	10	W	0.963	red	raw
	20	W	0.887	red	chewy
	20	A	0.795	red	tough
	40	A	0.253	brown/red	crisp
85	10	W	0.908	red	chewy
	20	W	0.747	red	chewy
	20	A	0.962	red	chewy
	40	W	0.246	red	crisp
	40	A	0.171	red	crisp
105	10	W	0.913	red	chewy
	10	A	0.830	red	chewy
	20	A	0.132	brown/red	crisp
	35	A	0.108	brown	crisp

*W = sample was cut with the grain (parallel to fibre direction); A = sample was cut against the grain (perpendicular to fibre direction)

Figure 1. Soft beef jerky with sorbitol and dextrose

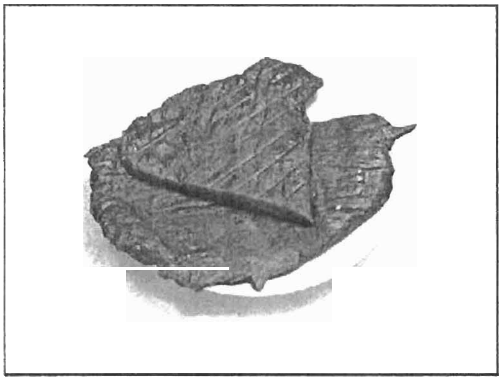

Figure 2. String beef with sorbitol

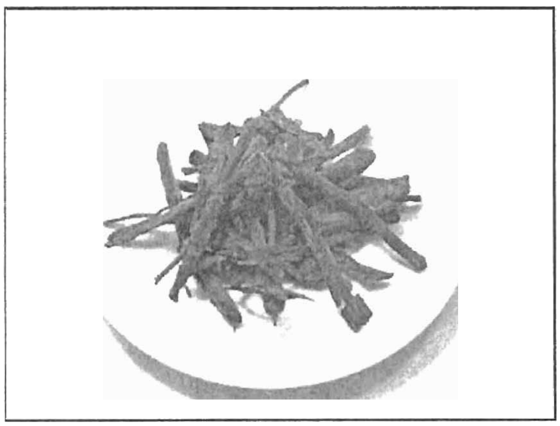

Figure 3. Crunchy candy meatballs

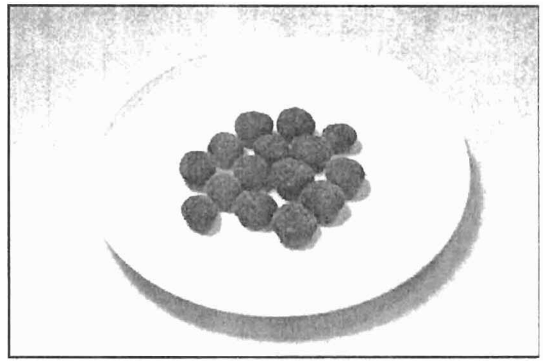

Figure 4. Shelf stable meatballs

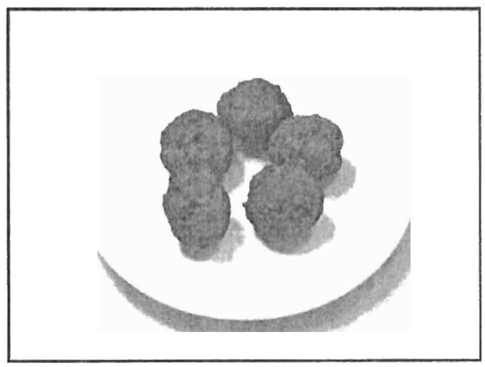

Figure 5. Deep-fried vacuum-dried beef cut with the grain (a) or across the grain (b

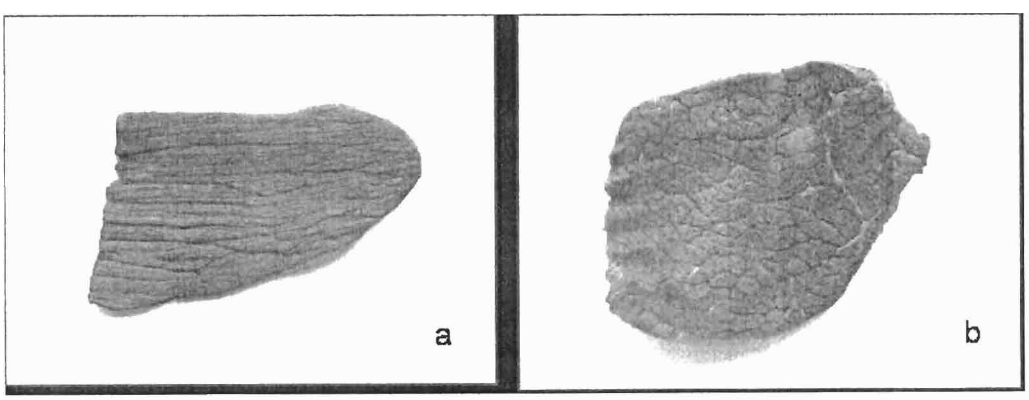

Figure 6. Deep-fried vacuum-dried "popcorn" beef

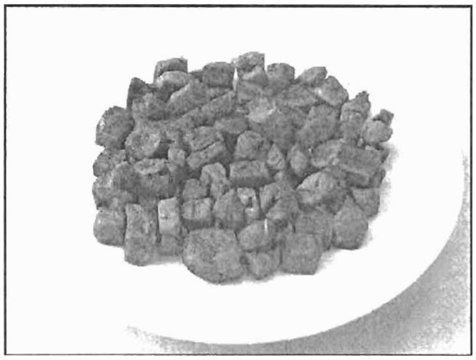

Figure 7. Extruded, puffed, low fat beef snacks

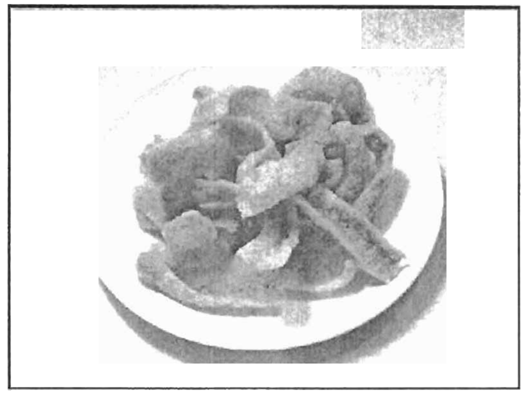

Figure 8. Influence of meat extract on damage to cellular DNA by hydrogen peroxide. Bars on the left of the figure indicate undamaged cells. Moving towards the right, "tail moment" increases indicating greater DNA damage.