Shelf-Stable and Safe Intermediate-Moisture Meat Products Using Hurdle Technology

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ABSTRACT

A number of ready-to-use shelf-stable intermediate-moisture (IM) spiced mutton and spiced chicken products were developed with a combination of hurdles (reduced moisture, vacuum packaging, and irradiation). The water activity of the products was reduced to about 0.80 either by grilling or by hot-air drying. These IM products were vacuum packed and subjected to gamma radiation processing at 0 to 10 kGy. Microbiological analyses revealed a radiation dose-dependent reduction in total viable counts and in numbers of Staphylococcus species. IM meat products that did not undergo radiation treatment showed visible mold growth within 2 months. The products subjected to irradiation at 10 kGy showed an absence of viable microorganisms and also retained high sensory acceptability for up to 9 months at ambient temperatures.

With rapid urbanization and socioeconomic change, there has been an increase in demand for convenient ready-to-cook and ready-to-serve meat products. A variety of types of products, such as kababs, tikkas, lollipops, fingers, patties, sausages prepared from mutton, chicken, pork, and beef, are available. Currently, these products are marketed frozen, since they have limited shelf lives at ambient temperatures (4). The market for these products is limited because of a lack of infrastructure in developing countries such as India. Furthermore, freezing does not eliminate pathogens and thus poses a potential health hazard (3). However, the risks from pathogens could be avoided and meat products could be made shelf stable by employing hurdle technology. Traditionally, intermediate-moisture (IM) meat products are prepared by partial dehydration and with the use of suitable humectants. All humectants that have been used so far are less than ideal, as they affect organoleptic qualities. A possible solution to this problem may consist in radiation processing of partially dehydrated meats without the use of humectants. At water activities of $<0.85$, virtually all bacterial growth will be arrested, but many yeasts and molds and a few kinds of bacteria may continue to grow in foods of neutral pH (8). Radiation processing can eliminate yeasts and molds, thus resulting in shelf stability for these foods and an improvement in microbiological safety through the destruction of pathogenic microorganisms. Therefore, the feasibility of preparing shelf-stable and microbiologically safe ready-to-serve meat products with a combination of hurdles (i.e., reduced water activity, vacuum packaging, and gamma irradiation) was tested.

MATERIALS AND METHODS

Preparation of IM meat products. Mutton kababs (20 to 22 g), an ethnic preparation, were made from minced meat. Various spices (turmeric, pepper, cardamom, and cinnamon) were added to the minced meat, which was then rolled into long fingers on skewers. The kababs were grilled for 30 min at 250°C (with an internal kabab temperature of 75°C) to reduce water activity to $\leq0.85$. Spiced chicken meat cubes (5 to 6 g each) were prepared by marinating boneless chicken meat cubes. The marinade consisted of paprika and a mixture of dry and wet spices. The product was steamed for 5 min and then partially dehydrated in a hot-air oven (60°C) for 4 h to obtain a water activity of $\leq0.85$.

After cooling, the IM meat products were vacuum packed in multilayered pouches (12 μM polyester, 12 μM metalized polyester, and 40 μM polyethylene).

Irradiation. The packed samples were subjected to gamma irradiation at 25°C at a dose of 3 kGy/h in a Package Irradiator (Nordion International Inc., Kanata, Ontario, Canada) with a $^{60}$Co source. The samples received minimal doses of 2.5, 5, and 10 kGy, with an overdose ratio of 1.3. Dosimetry was performed with a cerric-cerious dosimeter calibrated against Fricke’s dosimeter. Dosimetry intercomparison was carried out with national standards established by the Radiological Physics and Advisory Division of the Bhabha Atomic Research Centre in Mumbai, India. A nonirradiated lot served as a control. All samples were stored at ambient temperatures (30 ± 2°C).

Analyses. Analyses of both irradiated and nonirradiated samples were carried out at regular intervals of 2 or 4 weeks during storage at ambient temperatures. For microbiological analyses, a 10% homogenate was prepared in sterile saline with a Stomacher 400 (Seward Medical, London, UK). Serial dilutions were made, and appropriate dilutions were plated in duplicate. Plate count agar, Baird-Parker agar, violet red bile agar, sulphite polymyxin sulphadiazine agar, and potato dextrose agar were used to determine total viable counts, Staphylococcus spp. counts, coliform counts, sulphite-reducing Clostridia counts, and mold counts, respectively (6). The moisture content of a sample was estimated...
FIGURE 1. Moisture contents of meat products. Each data point represents the mean water activity of six samples.

FIGURE 2. Water activity of meat products. Each data point represents the mean moisture content of six samples.

by drying the sample at 100 ± 5°C for 16 h (1) and then measuring the water activity of the sample with an Aqua Lab CX2T water activity meter (Decagon Devices, Inc., Pullman, Wash.).

Sensory evaluations. After the IM meat products were rehydrated for 15 min in water and fried in hot cooking oil for 30 s, they were presented to trained panelists (6). Sensory evaluations of irradiated and nonirradiated samples were performed by a panel of six to eight staff members who were familiar with the characteristics of meat products. Panelists were asked to rate samples as “acceptable” or “nonacceptable” on the basis of appearance, odor, flavor, and taste on a 10-point scale, where 10 corresponds to the highest quality and 0 corresponds to the lowest quality. Scores of ≥6 were considered acceptable (6).

RESULTS

Dehydration of meat products. The moisture content and water activity of fresh mutton kababs and chicken cubes were found to be 62 to 65% and 0.97 ± 0.01, respectively. Upon grilling (mutton kababs) and hot-air drying (spiced chicken cubes), moisture content and water activity were reduced to 27 to 32% and 0.80 ± 0.05, respectively (Figs. 1 and 2). There was no significant change in moisture content or water activity during storage at ambient temperatures.

Microbiological assessment: IM mutton kababs. Results of the microbiological analyses of IM mutton kababs are shown in Table 1. For fresh mutton kababs, total viable counts ranged from 10^4 to 10^5 CFU/g and Staphylococcus spp. counts ranged from 10^2 to 10^3 CFU/g. One of the batches of fresh kababs tested positive for sulphite-reducing Clostridia. After grilling, samples had total viable counts ranging from 10^3 to 10^4 CFU/g and Staphylococcus spp. counts ranging from 10^1 to 10^2 CFU/g. Grilling at 250°C for 30 min raised the internal temperature of kababs to 75°C and resulted in a bacterial count reduction of at least 1 log.

TABLE 1. Results of microbiological analyses of intermediate-moisture mutton kababsa

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a Fresh product contained total viable counts of 10^4 to 10^5 CFU/g and Staphylococcus spp. counts of 10^2 to 10^3 CFU/g. Shown are the results of three independent experiments involving different batches of mutton kababs. All samples were devoid of coliforms. One control sample showed sulphite-reducing Clostridia. TVC, total viable counts; SC, Staphylococcus counts; FC, fungal counts; V, visual fungal growth seen; ND, not detected by the methods used; NCO, not carried out because visual fungal growth was observed.
Microbiological assessment: IM spiced chicken cubes. The results of microbiological analyses of the samples are presented in Table 2. Fresh products had total viable counts ranging from $10^4$ to $10^5$ CFU/g, while *Staphylococcus* counts for these products ranged from $10^2$ to $10^3$ CFU/g. For IM products, the total viable bacterial counts ranged from $10^4$ to $10^6$ CFU/g and the *Staphylococcus* spp. counts ranged from $10^2$ to $10^4$ CFU/g. During the drying process, there was no reduction in bacterial counts; rather, there was a slight increase. As it did for the IM mutton kababs, radiation treatment resulted in a dose-dependent reduction in total viable counts as well as in levels of *Staphylococcus* spp. Irradiated samples exhibited lower microbial counts than did nonirradiated samples throughout the storage period. The samples that did not undergo radiation processing were not shelf stable for long: visible mold growth was seen within 2 to 3 months of storage at ambient temperatures. No viable microorganisms were detected in samples subjected to irradiation treatment (10 kGy), and these samples were sensorially acceptable (Fig. 3).

**DISCUSSION**

In the present study, shelf-stable mutton and chicken meat products with good organoleptic qualities were developed with a combination of hurdles, including reduced water activity, vacuum packing in multilayered pouches, and irradiation treatment (10 kGy). Our results clearly establish the safety and stability of these products, as none of the microorganisms we looked for could be detected during storage at ambient temperatures for several months. Since the water activity of these products is <0.85, there is no risk posed by *Clostridium botulinum* (9) or by enterotoxin from *Staphylococcus* spp. (7). Under normal circumstances, a water activity of 0.85 or less is sufficient to prevent bacterial spoilage (8, 10, 11, 14). The heating required to partially dehydrate meat products also inactivates autolytic enzymes. Thus, there is no enzymatic deterioration when the meat products are to be stored at ambient temperatures for extended periods (12). Vacuum packing of...
these products controls oxidative chemical deterioration during storage (13). The water activity of the products is around 0.85 and is not sufficient to control mold growth without radiation processing. A dose-dependent reduction in the bacterial count was observed upon irradiation, and our results show a reduction to nondetectable levels at 10 kGy; as a result, these meat products are stable and safe. The use of irradiation to eliminate pathogenic microorganisms in foods of animal origin has been well documented (2, 5), and this documentation has resulted in further improvement in the microbiological safety of foods.

In addition to these products, a number of other ethnic products, such as spiced mutton cubes, chicken kababs, and chicken tikka, have been prepared using this process. This technology, which can give products shelf stability, will be of great economic and health significance. It will boost the demand for and enhance the distribution of such products in India and will also facilitate the exportation of these products.

REFERENCES