ORIGINAL RESEARCH

Analysis of Different Thermal Processing Methods of Foodstuffs to Optimize Protein, Calcium, and Phosphorus Content for Dialysis Patients

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Objective: To analyze how different thermal processing methods affect the protein, calcium, and phosphorus content of hospital food served to dialysis patients and to generate recommendations for preparing menus that optimize nutritional content while minimizing the risk of hyperphosphatemia.

Design and Methods: Standard Official Methods of Analysis (AOAC) methods were used to determine dry matter, protein, calcium, and phosphorus content in potatoes, fresh and frozen carrots, frozen green beans, chicken, beef and pork, frozen hake, pasta, and rice. These levels were determined both before and after boiling in water, steaming, stewing in oil or water, or roasting.

Results: Most of the thermal processing methods did not significantly reduce protein content. Boiling increased calcium content in all foodstuffs because of calcium absorption from the hard water. In contrast, stewing in oil containing a small amount of water decreased the calcium content of vegetables by 8% to 35% and of chicken meat by 12% to 40% on a dry weight basis. Some types of thermal processing significantly reduced the phosphorus content of the various foodstuffs, with levels decreasing by 27% to 43% for fresh and frozen vegetables, 10% to 49% for meat, 7% for pasta, and 22.8% for rice on a dry weight basis. On the basis of these results, we modified the thermal processing methods used to prepare a standard hospital menu for dialysis patients. Foodstuffs prepared according to the optimized menu were similar in protein content, higher in calcium, and significantly lower in phosphorus than foodstuffs prepared according to the standard menu.

Conclusions: Boiling in water and stewing in oil containing some water significantly reduced phosphorus content without affecting protein content. Soaking meat in cold water for 1 h before thermal processing reduced phosphorus content even more. These results may help optimize the design of menus for dialysis patients.

Introduction

IN-HOSPITAL NUTRITION PRESENTS numerous challenges because it must cater to diverse populations with special dietary restrictions and requirements. For patients on dialysis, the goals for nutrition therapy are to meet nutritional requirements and prevent malnutrition while minimizing the risk of uremia and complications associated with chronic kidney disease, such as cardiovascular disease, anemia, and secondary hyperparathyroidism.[1] Malnutrition among dialysis patients ranges from 10% to 70%,[2-4] and hyperphosphatemia can occur if the phosphorus content of the diet is not strictly controlled. Hyperphosphatemia is an independent risk factor for cardiovascular mortality in individuals with chronic kidney disease[5-7]; indeed; both hyperphosphatemia and malnutrition are associated with increased morbidity and mortality in these individuals.[5,8-10] To minimize risk of hyperphosphatemia and malnutrition, several methods have been developed to maintain calcium and phosphorus levels within the normal range.

Healthy individuals typically take in 1,425 to 2,070 mg of phosphorus in their daily diet, although some geographical variability may exist.[11] Dialysis patients, however, must reduce their daily intake to 800 to 1,000 mg per day to prevent hyperphosphatemia.[12] The problem with a low-phosphorus diet is that it also has lower protein content, increasing the risk of malnutrition.[13] Some low-phosphorus functional foods have been developed for people with renal diseases to reduce phosphorus content[14,15]; one example is DairyDelicious Milk (Delicious Milk Company, New York, NY), a reduced-fat milk product low in phosphorus and potassium, and another example is whey protein concentrate low in phosphorus and potassium. Unfortunately, these functional foods are not yet widely available. Another approach to reduce phosphate absorption is administration of phosphate binders, but these can only bind approximately 200 to 300 mg of phosphorus on a daily basis, making restriction of dietary phosphate intake key for phosphate control in dialysis patients.[16,17]

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Because restriction in dietary phosphate may compromise protein intake,[18] another approach to optimizing foodstuffs for dialysis patients may lie in modifying their thermal processing as different types of food processing can significantly alter the composition of the final product.[19-24] These changes in composition can occur through leaching of minerals and proteins from inside the food into the processing medium or through the absorption of materials from the processing medium into the food.[25,26] Indeed, fresh and frozen fruits and vegetables initially show negligible differences in nutritional composition but storage and processing conditions can lead to significant differences.[25] Moist heat food processing, that is, boiling and stewing, lead to the dissolution of monosaccharides and disaccharides, as well as of some vitamins and minerals. To what extent these substances transfer into the cooking medium depends on the details of the thermal processing.[26]

In general, the greatest losses of nutritional substances occur as a result of prolonged cooking, the use of water, and high cooking temperatures. Modifying these parameters can substantially improve nutrient stability and final product quality. For example, processing foodstuffs at different temperatures along the preparation pathway can lead to a product with much higher nutritional value than the same product prepared at constant temperature.[27] Roasting or frying foodstuffs can reduce the leaching of water-soluble minerals into the cooking medium.[19] Processing foodstuffs in hard water can increase the content of calcium and other minerals; indeed, this is the reason why vegetables usually show similar calcium content regardless of whether they are fresh, frozen, or canned.[25] In the same way, thermal processing methods can be modified to reduce mineral content in the final product. For example, double boiling—that is, boiling foodstuffs, changing the water, and then boiling again—can reduce potassium content much more than simple boiling.[20]

Thermal processing alters the structure of proteins, leading to their denaturation and coagulation, but it does not affect their nutritional value as it merely mimics the initial stages of proteolysis that occur in the digestive tract.[28] In fact, thermal processing improves the digestibility of proteins and starch because it increases their accessibility to enzymatic attack. For example, proteins and starch in leguminous plants are most easily digested after being cooked for 10 minutes at 121°C.[29]

Given that thermal processing can cause extensive changes in protein and mineral composition of foodstuffs, food preparation for special populations like hospital patients should be designed with these changes in mind.[30] However, chemical composition tables routinely used by dieticians and nutritionists often do not take into account processing-dependent changes in foodstuff composition. This is particularly important for dialysis patients, for whom standard hospital menus are expected to provide a daily energy intake of 30 to 35 kcal/kg body mass and a daily fluid intake in the amount of 1,000 mL + the urinary output in a day. The diet should also provide a daily intake of 1.2 g/kg body mass of protein, 1,000 to 1,500 mg of sodium, 40 to 70 mEq of potassium, 8 to 17 mg/kg body mass of phosphorus, and up to 1,500 mg of calcium (or up to 2,000 mg if the patient is receiving calcium-based phosphorus binders).[31]

The present study aims to examine systematically how thermal processing methods commonly used in hospitals affect the protein, calcium, and phosphorus content of foodstuffs for consumption by dialysis patients. Our aim is to provide the groundwork for rational design of diets with optimal nutritional value and minimum phosphorus content to avoid hyperphosphatemia and malnutrition.

Material and Methods

Samples

The effect of various thermal processing methods was assessed on dry matter, protein, calcium, and phosphorus content of 9 types of foodstuffs: potatoes, carrots, green beans, chicken, beef, pork, fish, rice, and pasta. Foodstuffs were selected because of their frequent use in hospital diets and the fact that they are always processed thermally.

All foodstuffs were bought from a local producer and prepared in the hospital kitchen using the same standard protocols and conditions normally used to prepare food for hospital patients (e.g., tap water was always used). Foodstuffs were thermally processed in the following ways: boiling in water (at 100°C), steaming (100°C), frying in oil (170°C), roasting in oil (air 180°C), or stewing in oil (100°C) to which water was gradually added. Foodstuffs were boiled or stewed in tap water. Water for cooking was salted. Edible refined sunflower oil was used for stewing and roasting. Thermal processing was carried out in Inox dishes. Boiling in water and frying were performed on a gas stove, whereas steaming was done inside a RATIONAL vapor or convection oven. All food was prepared until its consistency and other characteristics were judged suitable for consumption based on the standard practices in the hospital kitchen, and data were recorded on the type and amount of sample, thermal processing method, amount of water used for thermal processing, amount of oil used, amount of salt added, and total duration of thermal processing.

Sample Preparation

Vegetables. Velox potatoes harvested in 2012 and fresh Nantes carrots harvested in September 2012 were stored at 4°C until March 2013, when they were used in the present study. They were peeled, rinsed, and then prepared as follows. Potatoes were left uncut and cooked for 37 minutes, diced into 20 × 20 mm cubes, and steamed for 28 minutes or fried as sticks in 300 mL oil for 12 minutes. Carrots were left uncut and cooked for 49 minutes, diced