
Stability of bovine allergens during food processing

Angelika Paschke, PhD* and Matthias Besler, PhD†

Objective: The primary objective of this review was to summarize reported findings about the influence of various food manufacturing processes on the potential alteration of bovine allergens in cow's milk, beef, and related food products.

Data Sources: This review was based on literature research in two German databases.

Study Selection: The expert opinion of the authors was used to select the relevant data for the review.

Results: Changes in allergenic activity during food processing are attributable to inactivation or destruction of epitope structures, formation of new epitopes, or improved access of previously hidden epitopes. The allergenic potency of food could be altered by several food manufacturing procedures—such as mechanical, purification, thermal, biochemical, and chemical processes. The main processing steps studied by investigators were heating (dry heating, boiling, or cooking) and enzymatic digestion. A review of the available literature on the alteration of bovine allergens in cow's milk, meat, and related food products revealed reduction (but not elimination) of allergenicity by heating of cow's milk for 10 minutes. Although homogenization did not change the allergenic potency of cow's milk, it decreased the allergenicity of beef, as did freeze-drying. Digestion studies showed varied results.

Conclusions: The allergenicity of some food products decreased during certain processing steps, but the results of other investigations differed. Therefore, more systematic research on the influence of food processing on allergenicity should be undertaken.

Ann Allergy Asthma Immunol 2002;89(Suppl):16–20.

INTRODUCTION

During the manufacturing of food, the allergenicity of a product may be altered by various processes. The allergenic activity may actually be unchanged, decreased, or even increased by food processing. The molecular basis of changes in the allergenic activity is the inactivation or destruction of epitope structures, the formation of new epitopes, or the enhanced access of hidden epitopes by denaturation of the native allergen. An overview of common manufacturing procedures that could potentially affect the allergenicity of food products is presented.

In the following material, published studies of cow's milk and meat and of their available products will be described. Of note, only some studies of the allergenicity of food products included evaluation by double-blind, placebo-controlled food challenge. Most investigations were performed by determination of the relative immunoglobulin (Ig)E-binding potencies of food allergens with application of radioallergosorbent tests (RAST) or enzyme-allergosorbent tests (EAST) and RAST or EAST inhibition studies, respectively.

FOOD MANUFACTURING PROCESSES

Important manufacturing processes that might influence the allergenicity of foods are outlined in Table 1.

The first manufacturing step is the preparation process. As an initial preparation step, washing should have no influence on the protein fraction. In some cases, preparation involves peeling or removal of a husk and storage of the food, and a change in allergenicity of the protein fraction is possible. For some fruits, the allergenicity of the peel is higher than that of the edible portion. This variation has been demonstrated for fruits of the Rosaceae family (the peach, for example).¹ The relative amount of the major allergen in apple (Mal d 1) has been shown to increase during ripening² and storage at 4° C for 3 weeks.³

By the breaking up and other mechanical procedures (such as cutting, grinding, mixing, suspending, homogenization, or extrusion) involved in the processing of food, surface denaturation of protein aggregations might occur (for example, during homogenization of milk). During the breaking up of food, oxidation of protein is also possible.

The various manufacturing procedures for isolation and purification of food (melting, pressing, extraction, distillation, refining, filtration, decanting, centrifugation, sieving, or polishing) might lead to a separation of the protein fraction and thus of the allergens from the basic food. The separation of starch from cereals and the separation of cream from milk are examples.

The list of thermal procedures in food manufacturing ranges from drying, evaporation, and heating (such as blanching, baking, cooking, grilling, roasting, steaming, pasteurization, sterilization, and ultrahigh heating) to cooling and freezing. Some model studies have duplicated these technologic heating processes to investigate the potential alteration of

University of Hamburg, Department of Chemistry, Section of Food Chemistry, Grindelallee 117, 20146 Hamburg, Germany.

† LEFO Institut für Lebensmittel und Umweltforschung, Untersuchung und Bewertung, Dr. Gerhard Wichmann GmbH, Ahrensburg, Germany.

Received for publication April 11, 2002.

Accepted for publication in revised form May 22, 2002.

Table 1. Manufacturing Processes Potentially Affecting the Allergenicity of Foods

Type of process	Examples
Preparation	Washing, peeling or removing the husk, storage
Breaking up and other mechanical procedures	Cutting, grinding, mixing, suspension, homogenization, extrusion
Isolation and purification	Melting, pressing, extraction, distillation, refining, filtration, decanting, centrifugation, sieving, polishing
Thermal procedures	Drying, evaporation, heating techniques (such as blanching, baking, cooking, grilling, roasting, steaming, pasteurization, sterilization, or ultrahigh heating), cooling, freezing
Biochemical procedures	Enzyme addition, fermentation
Genetic technology	...
Chemical or physical preservation	Use of salt, sugar, pH adjustment, alcohol, food additives such as benzoic acid, irradiation
Other procedures	Emulsifying, stabilization, texturization, coloring, bleaching, deodorizing

allergenicity during such procedures. Possible changes of proteins during heating are denaturation, side-chain amino acid alterations, and reactions with other molecules—such as in the Maillard reaction of proteins and amino acids with sugars that occurs in nonenzymatic browning reaction in food. The occurrence of such a reaction depends on various circumstances: the intensity and the duration of the thermal procedure, water activity, pH, salt concentration, and type and concentration of other molecules in the specific foodstuff.

Biochemical procedures involved in food manufacturing (such as fermentation or addition of an enzyme) can create compounds (for example, lactic or acetic acid) that are responsible for tenderizing meat or contribute to the production of bread or juice. These reactions have an influence on the structure of proteins. In addition, biochemical processes facilitate the production of hypoallergenic food. For example, the hydrolysis of milk-, soy-, wheat-, or rice-derived protein could reduce allergenicity. During these manufacturing processes, allergenicity could be altered in two ways. Technologically unavoidable traces of the enzyme itself could be a potential allergen, or the remaining protein after hydrolysis could still act as an allergen. However, as described, allergenicity could be reduced during these biochemical procedures.

In genetic technology, the genes of food raw material have been altered. Different enzymes or proteins synthesized by genetically modified microorganisms—or these genetically modified organisms themselves—applied to food production (milk, meat, fruits, vegetables, or beer) may induce new protein structures, as happens with transgenic plants and animals. These structures may involve new allergens. The possibility of modifying for less allergenicity (for example, in

genetically modified rice⁴) exists but higher allergenicity (for example, the Brazil nut allergen in transgenic soybeans⁵).

Chemical and physical methods for the preservation of food—such as the use of salt, sugar, alcohol, pH adjustment, or food additives (for example, benzoic acid)—could also potentially affect the protein structure of that food. Irradiation could also be classified as a thermal procedure, but it is not as effective as other heating processes.

Other procedures used in food processing, such as emulsifying, stabilization, texturization, coloring, bleaching, and deodorizing, might likewise influence protein structure.

MILK AND MILK PRODUCTS

The major allergens in milk from cows (*Bos domesticus*) consist of caseins (Bos d 8) and the whey proteins α -lactalbumin (approximately 14 kDa, Bos d 4) and β -lactoglobulin (approximately 18 kDa, Bos d 5). Other allergens in cow's milk are immunoglobulins (<150 kDa, Bos d 7) and serum albumin (approximately 66 kDa, Bos d 6; Table 2).⁶

In a study of allergic children and adults, raw milk, pasteurized milk (75° C, 15 seconds), and pasteurized and homogenized milk (60° C, 175 kg/cm²) caused allergic symptoms, with a trend toward higher allergenicity in the pasteurized milk samples.⁷ Homogenization as a mechanical procedure and brief (a few seconds) heating and pasteurization at 60° to 70° C do not change allergenic potency.

During heating of cow's milk, allergenicity has been shown to be decreased but not completely eliminated.^{8,9} The caseins and α -lactalbumin have a higher heat stability than do the whey proteins β -lactoglobulin and serum albumin.¹⁰ After milk was heated for 10 minutes at 100° C, a substantial reduction of allergenicity was noted. After only 2 or 5 minutes of such heating, however, no significant change in allergenicity was induced. In addition, in experiments with heating of skim milk, β -lactoglobulin and serum albumin were found to be inactivated, but α -lactalbumin and casein retained approximately 40 to 50% of their allergenic activity:

Table 2. Composition of Protein Fraction of Cow's Milk

Protein component	Molecular weight (kDa)	Medium content (%)
Caseins	—	80
α_{s1} -Caseins	23.6	34
α_{s2} -Caseins	25.2	8
β -Caseins	24	25
κ -Caseins	19	9
γ -Caseins	—	4
γ_1 -Caseins	20.5	
γ_2 -Caseins	11.8	
γ_3 -Caseins	11.6	
Whey proteins	—	20
β -Lactoglobulin	18.3	9
α -Lactalbumin	14.2	4
Serum albumin	66.3	1
Immunoglobulins	<150	2
Protease peptone	4–41	4

Allergic reactions to cow's milk products such as cheese, have been reported.^{11,12} Allergic reactions to cheese made from the milks of goats and sheep have been described as well.^{13,14} To our knowledge, studies on the manufacturing process of cheese relative to allergenic potency at the various steps have not been undertaken to date. Cheesemaking usually involves common procedures, such as pasteurization of milk, acidification by added starter cultures, and production of curd by adding rennet (mainly chymosin). Hereby the casein structure is changed to form a solid curd. The whey fraction, including α -lactalbumin and β -lactoglobulin, is separated from the curd. The ripening process is facilitated by enzymes produced by bacteria that have grown in the curd.

In one study,¹⁵ fermentation of sterilized cow's milk with use of a mixture of mesophilic and thermophilic lactic acid bacteria resulted in a 99% decrease in the antigenicity of α -lactalbumin and β -lactoglobulin (determined by enzyme-linked immunoadsorbent assay with use of rabbit antibodies). Nonetheless, allergenicity in skin tests was minimally affected.

In vitro experiments showed that purified milk proteins were more likely to be hydrolyzed by digestion with duodenal fluid and human trypsin and elastase than were proteins in milk. Caseins were degraded first, followed by β -lactoglobulin and α -lactalbumin, which were hydrolyzed at 100 and 500 times lower rates, respectively.^{16,17}

Digestion studies of whey proteins with pepsin (90 minutes) and pancreatic enzymes (pH 7.5 for 150 minutes) showed an 86 to 100% decrease of the proteins at pH 2 and 3, whereas at pH 4, only a 9 to 52% decrease of allergenicity was found for α -lactalbumin, serum albumin, and bovine immunoglobulins. β -Lactoglobulin was minimally affected by pepsin hydrolysis but almost completely digested by pancreatic enzymes.¹⁸

Astwood et al¹⁹ confirmed the high stability (>60 minutes) of β -lactoglobulin against peptic hydrolysis in vitro (pH 1.2). In contrast, caseins and serum albumin were completely hydrolyzed after 2 minutes and 30 seconds, respectively.

Hypoallergenic infant formulas are produced from caseins or whey proteins by means of heat denaturation and enzymatic hydrolysis, sometimes in combination with ultrafiltration. These formulas have decreased allergenic potency and are used as milk substitutes in infant nutrition. Although partially and extensively hydrolyzed formulas are available, only the extensively hydrolyzed formulas should be used in infants with cow's milk allergy.²⁰

Despite the fact that extensively hydrolyzed whey protein formulas^{21,22} as well as extensively hydrolyzed casein formulas^{7,23} are tolerated without allergic reaction by most children with cow's milk allergy, severe adverse reactions have also been reported in a few patients.²⁴⁻²⁸ The allergenic potency of hydrolyzed casein formulas has been shown to be lower than that of whey formulas.^{29,30}

Severe allergic reactions after ingestion of bakery products, pastry, chocolate, and sausages that contained milk proteins have been reported.³¹⁻³³ Although all these products

had been subjected to different processing steps, allergenicity was retained.

In addition to alteration of allergenic potency, the potential problem of allergen cross-contamination in processed foods remains. No reliable data have been published on the frequency of cross-contamination of processed foods with undeclared allergens. According to the report on the control of foodstuffs of the Standing Committee for Foodstuffs of the European Union, 2.3% of 838 "milk-free" samples from 6 European Union member states contained undeclared milk proteins.³⁴ Similarly, another study detected caseins that were not declared as an ingredient in tofu, hot dogs containing beef, bologna, frozen rice dessert, and tuna in aqueous solution.³⁵ Malmheden et al³⁶ measured undeclared casein in meatballs, recombined ham, sausages, lollipops, and meringue. Likewise, Jones et al³⁷ and Laoprasert et al³⁸ measured whey proteins in sorbets labeled "dairy-free products."

MEAT AND MEAT PRODUCTS

Major allergens that have been identified in meat are bovine serum albumins (66 kDa, Bos d 6), bovine γ -immunoglobulins (160 kDa, Bos d 7), actins, myoglobin, and tropomyosin. Other proteins (molecular weights 14, 18, 20, 45, and >60 kDa)³⁹ are also known as allergens in meat or meat products. Cross-reactivity to whey proteins from milk has been attributed to serum albumins and γ -globulins⁴⁰ (Table 3).

Denatured type I bovine collagen was identified as the major allergenic component of gelatin. Allergens with a molecular weight range of 40 to 120 kDa were detected by sodium dodecyl sulfate-polyacrylamide gel electrophoresis and immunoblot analysis.⁴¹ The cross-reactivity between gelatins from different mammals has been described.⁴²⁻⁴⁴

Allergic reactions to meat cooked rare or barely heated and well-cooked meat are possible.^{9,40,45} In general, a stronger IgE binding to proteins of raw meat extracts is found whereas the binding to extracts of cooked meat is weaker. Some patients have had anaphylactic reactions to rare beef but have tolerated well-cooked beef; other patients have shown adverse reactions after ingestion of both rare- and well-cooked beef. The water solubility of proteins has been demonstrated to decrease with length of heat treatment. After heating minced beef at 85° C up to 2 hours, additional protein bands appear in the immunoblot (at 17.8, 19, 14, 20, 45, and >60 kDa). The strongest IgE binding was detected for a 17.8-kDa allergen in patients with two positive double-blind, placebo-

Table 3. Characterization of Major Allergens in Meat

Allergen	Molecular weight (kDa)	Medium content
Serum albumin	66	From blood
γ -Immunoglobulins	160	From blood
Myoglobin	17	0.5%
Tropomyosin	68	1.7%
Collagen I (denatured)—major allergen in gelatin		

controlled food challenge to cooked beef. Bovine serum albumin and γ -globulin were not detectable by sodium dodecyl sulfate-polyacrylamide gel electrophoresis after heating minced beef at 85° C (for 10 and 3 minutes, respectively). In contrast, isolated serum albumin was stable in response to heating at 95° C for 15 minutes and isolated γ -globulin was denatured after 15 minutes of heating (at 65° C).

The allergenic potency of freeze-dried beef seems to be reduced or eliminated. In addition, reduction of allergenicity has been noted after homogenization of meat.^{46,47}

The allergenicity of serum albumin from beef after enzymatic digestion with pepsin has been investigated. For most patients, allergenicity was almost eliminated after digestion with pepsin for an interval which ranged from a few minutes to 2 to 4 hours.⁴⁷

CONCLUSION

Various processing techniques in the manufacture of foods, such as preparation steps (for example, peeling), mechanical procedures, isolation and purification, thermal intervention, biochemical processes, chemical or physical preservation, and texturization, bleaching, or deodorizing, can alter the allergenic potential, as shown in the literature. Further, investigators have found that bovine allergens in cow's milk, meat, and related products may be decreased, increased, or unchanged by exposure to processing techniques such as heating, pasteurization, homogenization, drying, and fermentation. Accordingly, more extensive research is needed to determine the precise effects of food processing on allergenicity.

REFERENCES

1. Brenna O, Pompei C, Ortolani C, et al. Technological processes to decrease the allergenicity of peach juice and nectar. *J Agric Food Chem* 2000;48:493–497.
2. Vieths S, Schöning B, Jankiewicz A. Occurrence of IgE binding allergens during ripening of apple fruits. *Food Agric Immunol* 1993;5:93–105.
3. Hsieh LS, Moos M Jr, Lin Y. Characterization of apple 18 and 31 kd allergens by microsequencing and evaluation of their content during storage and ripening. *J Allergy Clin Immunol* 1995;96:960–970.
4. Nakamura R, Matsuda T. Rice allergenic protein and molecular-genetic approach for hypoallergenic rice. *Biosci Biotechnol Biochem* 1996;60:1215–1221.
5. Nordlee JA, Taylor SL, Townsend JA, et al. Identification of a Brazil-nut allergen in transgenic soybeans. *N Engl J Med* 1996;334:688–692.
6. Besler M, Eigenmann P, Schwartz RH. Allergen data collection: cow's milk (*Bos domesticus*). Internet Symposium on Food Allergens 2000;2:9–74. Available at: <http://www.food-allergens.de/symposium-2-1/cows-milk/cows-milk-allergens.htm>.
7. Host A, Samuelsson EG. Allergic reactions to raw, pasteurized, and homogenized/pasteurized cow milk: a comparison; a double-blind placebo-controlled study in milk allergic children. *Allergy* 1988;43:113–118.
8. Norgaard A, Bernard H, Wal JM, et al. Allergenicity of individual cow milk proteins in DBPCFC-positive milk allergic adults. *J Allergy Clin Immunol* 1996;97:237.
9. Werfel SJ, Cooke SK, Sampson HA. Clinical reactivity to beef in children allergic to cow's milk. *J Allergy Clin Immunol* 1997;99:293–300.
10. Gjesing B, Osterballe O, Schwartz B, et al. Allergen-specific IgE antibodies against antigenic components in cow milk and milk substitutes. *Allergy* 1986;41:51–56.
11. Wüthrich B, Hofer T. Food allergies. III. Therapy: elimination diet, symptomatic drug prophylaxis and specific hyposensitization [in German]. *Schweiz Med Wochenschr* 1986;116:1401–1410.
12. Fiocchi A, Restani P, Decet E, et al. Evolution from ewe's milk to cow's milk allergy. *Allergy* 1999;54:401–402.
13. Wüthrich B, Johansson SG. Allergy to cheese produced from sheep's and goat's milk but not to cheese produced from cow's milk. *J Allergy Clin Immunol* 1995;96:270–273.
14. Umpierrez A, Quirce S, Maranon F, et al. Allergy to goat and sheep cheese with good tolerance to cow cheese. *Clin Exp Allergy* 1999;29:1064–1068.
15. Jedrychowski L, Wroblewska B. Reduction of the antigenicity of whey proteins by lactic acid fermentation. *Food Agric Immunol* 1999;11:91–99.
16. Jakobsson I, Lindberg T, Benediktsson B. In vitro digestion of cow's milk proteins by duodenal juice from infants with various gastrointestinal disorders. *J Pediatr Gastroenterol Nutr* 1982;1:183–191.
17. Jakobsson I, Borulf S, Lindberg T, Benediktsson B. Partial hydrolysis of cow's milk proteins by human trypsin and elastases in vitro. *J Pediatr Gastroenterol Nutr* 1983;2:613–616.
18. Schmidt DG, Meijer RJ, Slangen CJ, van Beresteijn EC. Raising the pH of the pepsin-catalysed hydrolysis of bovine whey proteins increases the antigenicity of the hydrolysates. *Clin Exp Allergy* 1995;25:1007–1017.
19. Astwood JD, Leach JN, Fuchs RL. Stability of food allergens to digestion in vitro. *Nat Biotechnol* 1996;14:1269–1273.
20. Bousquet J, Björkstén B, Brujnzeel-Koomen CA, et al. Scientific criteria and the selection of allergenic foods for product labelling. *Allergy* 1998;53(Suppl):3–21.
21. Schwartz RH, Peers LB, Amonette MS, Witherly SA. Usefulness of a cow's milk whey infant formula (Good Start) in the management of children with group 1A (topical reactors) IgE-mediated cow's milk allergy. *Pediatr Asthma Allergy Immunol* 1991;5:305–312.
22. Halcken S, Host A, Hansen LG, Osterballe O. Safety of a new, ultrafiltered whey hydrolysate formula in children with cow milk allergy: a clinical investigation. *Pediatr Allergy Immunol* 1993;4:53–59.
23. Sampson HA, Bernhisel-Broadbent J, Yang E, Scanlon SM. Safety of casein hydrolysate formula in children with cow milk allergy. *J Pediatr* 1991;118:520–525.
24. Lifschitz CH, Hawkins HK, Guerra C, Byrd N. Anaphylactic shock due to cow's milk protein hypersensitivity in a breast-fed infant. *J Pediatr Gastroenterol Nutr* 1988;7:141–144.
25. Amonette MS, Schwartz RH, Mattson L. Double-blind, placebo-controlled food challenges (DBPCFC) demonstrating acute IgE-mediated allergic reactions to Good Start, ultrafiltered Good Start, Alfa-Ré, Nutramigen, and Alimentum in seven-year-old. *Pediatr Asthma Allergy Immunol* 1991;5:245–251.
26. Saylor JD, Bahna SL. Anaphylaxis to casein hydrolysate formula. *J Pediatr* 1991;118:71–74.
27. Businco L, Cantani A, Longhi MA, Giampietro PG. Anaphylactic reactions to a cow's milk whey protein hydrolysate (Alfa-

- Re, Nestle) in infants with cow's milk allergy. *Ann Allergy* 1989;62:333–335.
28. Ragno V, Giampietro PG, Bruno G, Businco L. Allergenicity of milk protein hydrolysate formulae in children with cow's milk allergy. *Eur J Pediatr* 1993;152:760–762.
 29. Oldaeus G, Björkstén B, Einarsson R, Kjellman NI. Antigenicity and allergenicity of cow milk hydrolysates intended for infant feeding. *Pediatr Allergy Immunol* 1991;2:156–164.
 30. Wahn U, Wahl R, Rugo E. Comparison of the residual allergenic activity of six different hydrolyzed protein formulas. *J Pediatr* 1992;121:S80–S84.
 31. Sampson HA, Mendelson L, Rosen JP. Fatal and near-fatal anaphylactic reactions to food in children and adolescents. *N Engl J Med* 1992;327:380–384.
 32. Bernaola G, Echechipia S, Urrutia I, et al. Occupational asthma and rhinoconjunctivitis from inhalation of dried cow's milk caused by sensitization to α -lactalbumin. *Allergy* 1994;49:189–191.
 33. Foucard T, Edberg U, Malmheden YI. Fatal and severe food hypersensitivity: peanut and soya underestimated allergens. *Lakartidningen* 1997;94:2635–2638.
 34. Standing Committee for Foodstuffs of the European Union. Report on the coordinated programme for the official control of foodstuffs for 1997. Brussels: European Commission, 1997.
 35. Gern JE, Yang E, Evrard HM, Sampson HA. Allergic reactions to milk-contaminated "nondairy" products. *N Engl J Med* 1991;324:976–979.
 36. Malmheden YI, Eriksson A, Everitt G, et al. Analysis of food proteins for verification of contamination of mislabelling. *Food Agric Immunol* 1994;6:167–172.
 37. Jones RT, Squillace DL, Yunginger JW. Anaphylaxis in a milk-allergic child after ingestion of milk-contaminated kosher-pareve-labeled "dairy-free" dessert. *Ann Allergy* 1992;68:223–227.
 38. Laoprasert N, Wallen ND, Jones RT, et al. Anaphylaxis in a milk-allergic child following ingestion of lemon sorbet containing trace quantities of milk. *J Food Prot* 1998;61:1522–1524.
 39. Restani P, Fiocchi A, Beretta B, et al. Meat allergy, III: proteins involved and cross-reactivity between different animal species. *J Am Coll Nutr* 1997;16:383–389.
 40. Ayuso R, Lehrer SB, Tanaka L, et al. IgE antibody response to vertebrate meat proteins including tropomyosin. *Ann Allergy Asthma Immunol* 1999;83:399–405.
 41. Wahl R, Kleinhans D. IgE-mediated allergic reactions to fruit gums and investigation of cross-reactivity between gelatine and modified gelatine-containing products. *Clin Exp Allergy* 1989;19:77–80.
 42. Sakaguchi M, Nakayama T, Inouye S. Food allergy to gelatin in children with systemic immediate-type reactions, including anaphylaxis, to vaccines. *J Allergy Clin Immunol* 1996;98:1058–1061.
 43. Sakaguchi M, Hori H, Ebihara T, et al. Reactivity of the immunoglobulin E in bovine gelatin-sensitive children to gelatins from various animals. *Immunology* 1999;96:286–290.
 44. Sakaguchi M, Hori H, Hattori S, et al. IgE reactivity to α 1 and α 2 chains of bovine type I collagen in children with bovine gelatin allergy. *J Allergy Clin Immunol* 1999;104:695–699.
 45. Fisher AA. Allergic contact urticaria to raw beef: histopathology of the specific wheal reaction at the scratch test site. *Contact Dermatitis* 1982;8:425.
 46. Fiocchi A, Restani P, Riva E, et al. Heat treatment modifies the allergenicity of beef and bovine serum albumin. *Allergy* 1998;53:798–802.
 47. Fiocchi A, Restani P, Riva E, et al. Meat allergy, II: effects of food processing and enzymatic digestion on the allergenicity of bovine and ovine meats. *J Am Coll Nutr* 1995;14:245–250.

Requests for reprints should be addressed to:
Dr. Angelika Paschke
University of Hamburg
Department of Chemistry
Section of Food Chemistry
Grindelallee 117
20146 Hamburg, Germany
E-mail: angelika.paschke@uni-hamburg.de