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RESEARCH

Research and Practice Innovations

Advanced Glycation End Products in Foods and a Practical Guide to Their Reduction in the Diet

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ABSTRACT

Modern diets are largely heat-processed and as a result contain high levels of advanced glycation end products (AGEs). Dietary advanced glycation end products (dAGEs) are known to contribute to increased oxidant stress and inflammation, which are linked to the recent epidemics of diabetes and cardiovascular disease. This report significantly expands the available dAGE database, validates the dAGE testing methodology, compares cooking procedures and inhibitory agents on new dAGE formation, and introduces practical approaches for reducing dAGE consumption in daily life. Based on the findings, dry heat promotes new dAGE formation by >10- to 100-fold above the uncooked state across food categories. Animal-derived foods that are high in fat and protein are generally AGE-rich and prone to new AGE formation during cooking. In contrast, carbohydrate-rich foods such as vegetables, fruits, whole grains, and milk contain relatively few AGEs, even after cooking. The formation of new dAGEs during cooking was prevented by the AGE inhibitory compound aminoguanidine and significantly reduced by cooking with moist heat, using shorter cooking times, cooking at lower temperatures, and by use of acidic ingredients such as lemon juice or vinegar. The new dAGE database provides a valuable instrument for estimating dAGE intake and for guiding food choices to reduce dAGE intake.

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Advanced glycation end products (AGEs), also known as glycotoxins, are a diverse group of highly oxidant compounds with pathogenic significance in diabetes and in several other chronic diseases (1-6). AGEs are created through a nonenzymatic reaction between reducing sugars and free amino groups of proteins, lipids, or nucleic acids. This reaction is also known as the Maillard or browning reaction (7). The formation of AGEs is a part of normal metabolism, but if excessively high levels of AGEs are reached in tissues and the circulation they can become pathogenic (2). The pathologic effects of AGEs are related to their ability to promote oxidative stress and inflammation by binding with cell surface receptors or cross-linking with body proteins, altering their structure and function (8-10). Among the better-studied AGEs are the stable and relatively inert N^{ϵ}-carboxymethyl-lysine (CML) and the highly reactive derivatives of methylglyoxal (MG). Both these AGEs can be derived from protein and lipid glycoxidation (11,12).

In addition to AGEs that form within the body, AGEs also exist in foods. AGEs are naturally present in uncooked animal-derived foods, and cooking results in the formation of new AGEs within these foods. In particular, grilling, broiling, roasting, searing, and frying propagate and accelerate new AGE formation (7,13). A wide variety of foods in modern diets are exposed to cooking or thermal processing for reasons of safety and convenience as well as to enhance flavor, color, and appearance. The fact that the modern diet is a large source of AGEs is now well-documented (3,7,13). Because it had previously been assumed that dietary AGEs (dAGEs) are poorly absorbed, their potential role in human health and disease was largely ignored. However, recent studies with the oral administration of a single AGE-rich meal to human beings as well as labeled single protein-AGEs or diets enriched with specific AGEs such as MG to mice clearly show that dAGEs are absorbed and contribute significantly to the body's AGE pool (14-16).

Consumption of AGE-rich diets by mice is associated with elevated circulating and tissue AGEs and conditions such as atherosclerosis (17) and kidney disease (18). On the other hand, restriction of dAGEs prevents vascular and kidney dysfunction (18,19), diabetes type 1 or type 2 (20), improves insulin sensitivity (21,22), and accelerates wound healing (23). Low dAGE intake has also been shown to lengthen lifespan to the same extent as does energy restriction in mice (16). Studies in healthy human beings show that dAGEs directly correlate with circulating AGEs, such as CML and MG, as well as with markers of oxidative stress (24). Moreover, restriction of dAGEs in patients with diabetes (25) or kidney disease (26,27) as well as in healthy subjects (28) also reduces markers of oxidative stress and inflammation. Together, the findings from animal and human studies suggest that avoidance of dAGEs in food helps delay chronic diseases and aging in animals and possibly in human beings (3).

From a practical perspective, aside from a few reports, which include an initial dAGE database on 249 foods (13), this area is void of relevant information and guidance for professionals. The purpose of this report is to expand the existing dAGE database by more than twofold, validate the methods used to test AGEs in food, examine different procedures and reagents on new dAGE formed, and introduce practical methods to reduce the consumption of dAGEs in daily life.

METHODS

AGE Content of Foods

The AGE content of food samples was analyzed during the period 2003-2008. Foods were selected on the basis of their frequency on 3-day food records collected from healthy subjects in a catchment population in the Upper East Side and East Harlem in Manhattan, New York, NY. Therefore, these foods represent foods and culinary techniques typical of a Northeastern American multiethnic urban population. Foods were obtained from the cafeteria of The Mount Sinai Hospital, from local restaurants or supermarkets, or were prepared in the General Clinical Research Center at the Mount Sinai School of Medicine. Foods were subjected to standard cooking methods such as boiling (100°C), broiling (225°C), deep-frying (180°C), oven-frying (230°C), and roasting (177°C), unless otherwise stated in the database (see Table 1 available online at www.adajournal.org). The time of cooking varied as described in the database. Test procedures such as marinating, application of differing heating conditions, or cooking foods in differing fats or oils are also described in the database.

Preparation of food samples for AGE measurement was performed as previously described (13). Briefly, food samples were homogenized and dissolved in phosphate buffer saline and the supernatants tested for AGEs with enzyme-linked immunosorbent assay based on a monoclonal anti-CML antibody (4G9) (29,30). The AGE content of each food item was based on the mean value of at least three measurements per sample and expressed as AGE kilounits/100 g food.

Selected items from different food categories were tested by a second enzyme-linked immunosorbent assay for content of MG-derivatives using an anti-MG monoclonal antibody (3D11 mAb) (29) and the results were expressed as nmol/100 g or nmol/100 mL food. The test sensitivity for CML and MG was 0.1 U/mL and 0.004 nmol/mL, respectively; the intra-assay variation was ±2.6% (CML) and ±2.8% (MG) and the inter-assay variation was ±4.1% (CML) and ±5.2% (MG).

AGE Inhibitory Agents

Because a low or acidic pH arrests AGE development, new AGE formation in cooked meat was tested following exposure to acidic solutions (marinades) of lemon juice and vinegar. Samples from lean beef were marinated in acidic solutions of either lemon or vinegar for 1 hour before cooking (see the Figure). In addition, the effect of a prototypic AGE inhibitor (aminoguanidine, 200 μmol/L) was compared to that of a lipid antioxidant (butylated hydroxytoluene [BHT], 100 μmol/L) on new AGE formation during heating by assessing CML content in oil (extra virgin olive oil, Colavita, Linden, NJ) samples, heated at 100°C for 5 minutes.

Statistical Analysis

Data in the Table 1 (available online at www.adajournal.org), Table 2, and the Figure are presented as mean± standard error of the mean. Differences of mean values between groups were tested by unpaired Student *t* test or analysis of variance (followed by Bonferroni correction for multiple comparisons), depending on the number of groups. For nonparametric values, the Mann-Whitney U unpaired test or the Kruskal-Wallis analysis of ranks was used, depending on the number of groups. Correlation analyses were evaluated by Pearson's correlation coefficient. Significant differences were defined as a P value <0.05 and are based on two-sided tests. Data were analyzed using the SPSS statistical program (version 15.0 for Windows, 2005, SPSS Inc, Chicago, IL). For data presentation, food groups were based on the American Diabetes Association and the American Dietetic Association exchange lists for diabetes (31).

RESULTS AND DISCUSSION

AGE Content of Foods as Determined by CML Levels

The AGE content in 549 foods, based on CML, is presented in Table 1 (available online at www.adajournal.org).

The new database contains more than twice the number of food items than the previously reported database (13) and shows that, based on standard serving sizes, the meat group contained the highest levels of AGEs**.** Although fats tend to contain more dAGE per gram of weight, meats will likely contribute more to overall dAGE intake because meats are served in larger portions than are fats. When items in the meat category prepared by similar methods were compared, the highest dAGE levels were observed in beef and cheeses followed by poultry, pork, fish, and eggs. Lamb ranked relatively low in dAGEs compared to other meats (Table 1 available online at www.adajournal.org). It is noteworthy that even lean red meats and poultry contain high levels of dAGEs when cooked under dry heat. This is attributable to the fact that among the intracellular components of lean muscle there exist highly reactive amino-lipids, as well as reducing sugars, such as fructose or glucose-6-phosphate, the combination of which in the presence of heat rapidly accelerates new dAGE formation (30,32).

Higher-fat and aged cheeses, such as full-fat American and Parmesan, contained more dAGEs than lower-fat cheeses, such as reduced-fat mozzarella, 2% milk ched-

Table 2. Database of combined methylyglyoxal (MG) and carboxymetyllysine (CML) content of selected foods

Food item	Advanced Glycation End Product Content	
	Total MG nmol/100 g	Total CML kU/100 g
Solid foods (per 100 g food)		
Bread, white	3,630	8.3
Bread, wheat	4,840	105
Cereal, Life (Quaker Oats, Chicago, IL)	9,000	1,452
Cheese, American	16,790	8,677
Cheese, Brie	5,670	5,598
Chicken, grilled	14,440	4,848
Chicken, microwaved (5 min)	8,350	1,524
Chicken, raw	4,170	769
Crackers, Pepperidge Farms Goldfish (Campbell Soup Co, Camden, NJ)	4,170	2,176
Egg, fried	13,670	2,749
French fries	13,130	843
Margarine, Smart Balance (CFA Brands, Heart Beat Foods, Paramus, NJ)	10,790	6,229
Salmon, broiled with olive oil	14,950	4,334
Salmon, broiled, plain	9,350	3,347
Salmon, pan fried in olive oil	9,090	3,083
Salmon, raw	6,820	527
Salmon, raw, previously frozen	6,190	517
Steak, broiled, plain	17,670	7,478
Steak, pan fried in olive oil	18,150	10,058
Steak, raw	5,860	800
Tuna, solid white packed in water	4,060	452
	Total MG nmol/100 mL	**Total CML kU/100 mL**
Liquids (per 100 mL food)		
Ice cream, vanilla	620	352
Milk, whole	620	4.9
Olive oil, fresh (Colavita, Linden, NJ)	7,700	5,852
Olive oil, heated at 100°C for 5 min (Colavita, Linden, NJ)	9,700	6,295
Olive oil, heated at 100°C for 5 min + butylated hydroxytoluene (Colavita, Linden, NJ)	8,200	6,682
Olive oil, heated at 100°C for 5 min + aminoguanidine (Colavita, Linden, NJ)	7,900	5,763
Pudding, chocolate	160	16
Pudding, vanilla	110	13
Yogurt, Dannon (White Plains, NY)	830	3
Coke, diet (Coca-Cola Co, Atlanta, GA)	334	4
Coke, Diet Plus (Coca-Cola Co, Atlanta, GA)	422	2
Coca Cola Classic (Coca-Cola Co, Atlanta, GA)	13	3
Pepsi, diet (PepsiCo, Purchase, NY)	33	3
Pepsi, regular (PepsiCo, Purchase, NY)	325	2
Pepsi, diet, caffeine free (PepsiCo, Purchase, NY)	201	2.6
Pepsi Max, diet (PepsiCo, Purchase, NY)	202	3.3
SoBe Adrenaline Rush (South Beach Beverage Co, Norwalk, CT)	821	0.4
SoBe NO FEAR Super Energy (South Beach Beverage Co, Norwalk, CT)	339	0.06

dar, and cottage cheese. Whereas cooking is known to drive the generation of new AGEs in foods, it is interesting to note that even uncooked, animal-derived foods such as cheeses can contain large amounts of dAGEs. This is likely due to pasteurization and/or holding times at ambient room temperatures (eg, as in curing or aging processes) (33). Glycation-oxidation reactions, although at a slower rate, continue to occur over time even at cool temperatures, resulting in large accumulation of dAGEs in the long term.

High-fat spreads, including butter, cream cheese, margarine, and mayonnaise, were also among the foods highest in dAGEs, followed by oils and nuts. As with certain cheeses, butter and different types of oils are AGE-rich, even in their uncooked forms. This may be due to various extraction and purification procedures involving heat, in combination with air and dry conditions, however mild they are.

Of note, with heat kept constant, the type of cooking fat used led to different amounts of dAGEs. For instance, scrambled eggs prepared with a cooking spray, margarine, or oil had ~50% to 75% less dAGEs than if cooked with butter (Table 1 available online at www.adajournal.org).

In comparison to the meat and fat groups, the carbohydrate group generally contained lower amounts of AGEs (Table 1 available online at www.adajournal.org). This may be due to the often higher water content or higher level of antioxidants and vitamins in these foods, which may diminish new AGE formation. Furthermore, in this food category, most polysaccharides consist of nonreducing sugars, less likely to give rise to AGEs. The highest dAGE level per gram of food in this category was found in dry-heat processed foods such as crackers, chips, and cookies. This is likely due to the addition of ingredients such as butter, oil, cheese, eggs, and nuts, which during dry-heat processing substantially accelerate dAGE generation. Although AGEs in these snack types of food remain far below those present in meats, they may represent an important health hazard for people who consume multiple snacks during the day or as fast meals (34).

Grains, legumes, breads, vegetables, fruits, and milk were among the lowest items in dAGE, unless prepared with added fats. For instance, biscuits had more than 10 times the amount of dAGEs found in low-fat breads, rolls, or bagels.

Nonfat milk had significantly lower dAGEs than whole milk. Whereas heating increased the dAGE content of milk, the values were modest and remained low relative to those of cheeses (Table 1 available online at www.adajournal.org). Likewise, milk-related products with a high moisture index such as yogurt, pudding, and ice cream were also relatively low in AGEs. However, hot cocoa made from a dehydrated concentrate contained significantly higher amounts of AGEs.

AGE Content of Foods as Determined by MG Levels

Selected common foods were simultaneously analyzed for MG derivatives to determine whether food AGEs other than CML followed the same pattern (Table 2). A highly significant linear correlation (r=0.8, P=0.0001) was observed between the CML and MG content of foods prepared by different cooking techniques. As with CML, foods high in protein and fat contained higher amounts of MG than did carbohydrate-rich foods. Noncooked butter and oil contained low amounts of MG, but in dry-heated fat, as in french fries, MG content was significantly higher (Table 2). The highly significant internal correlation between two chemically distinct AGEs (CML and MG) in a variety of foods prepared by different methods validates the methodology applied and supports the choice of CML levels as a useful marker of dAGE content.

Effect of Cooking Procedures on AGE Formation in Foods

Preparation of common foods under varying conditions of water and heat had a different effect on dAGE content. For example, scrambled eggs prepared in an open pan over medium-low heat had about one half the dAGEs of eggs prepared in the same way but over high heat. Poached or steamed chicken had less than one fourth the dAGEs of roasted or broiled chicken. In all food categories, exposure to higher temperatures and lower moisture levels coincided with higher dAGE levels for equal weight of food as compared to foods prepared at lower temperatures or with more moisture. Thus, frying, broiling, grilling, and roasting yielded more dAGEs compared to boiling, poaching, stewing, and steaming. Microwaving did not raise dAGE content to the same extent as other dry heat cooking methods for the relatively short cooking times (6 minutes or less) that were tested.

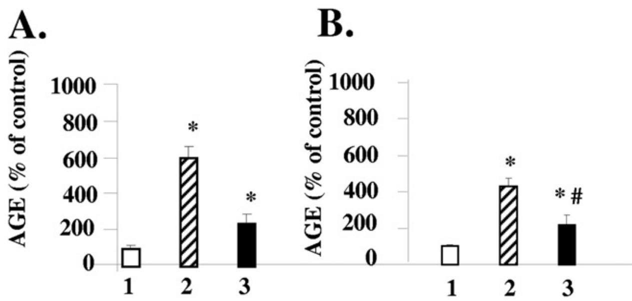

Figure. Effect of acidic environment on the advanced glycation end product (AGE) content of beef. Beef (25 g) was roasted for 15 minutes at 150°C with or without premarinating in 10 mL vinegar (A) or lemon juice (B) for 1 hour. Samples were homogenized and AGE (N^{ε}-carboxymethyl-lysine) content was assessed by enzyme-linked immunosorbent assay as described in the Methods section. Data are shown as % change from raw state. White bars represent raw state, hatched bars roasted without marinating and black bars marinated samples. *Significant changes compared to the raw state ($P<0.05$). #Significant changes compared to cooked without marinating samples. 1=raw beef. 2=roasted beef with no vinegar or lemon. 3=roasted beef after marinating with either vinegar or lemon for 1 hour.

Effect of AGE Inhibitors on New AGE Formation in Foods

The heat-induced new AGE formation in olive oil was completely prevented in the presence of the AGE inhibitor, aminoguanidine, but only partly blocked by the antioxidant BHT (Table 2). The amelioration of new AGE formation by the AGE inhibitor aminoguanidine compared to the anti-oxidant BHT suggests that the process seems to be driven by glycation rather than oxidation.

New AGE formation in cooked meat was also inhibited following exposure to acidic solutions (marinades) of lemon juice and vinegar. Beef that was marinated for 1 hour in these solutions formed less than half the amount of AGEs during cooking than the untreated samples (Figure).

Implications for Practice

Currently, there are limited data on dAGE intakes in the general population. The average dAGE intake in a cohort of healthy adults from the New York City area was recently found to be 14,700±680 AGE kU/day (24). These data could tentatively be used to define a high- or low-AGE diet, depending on whether the estimated daily AGE intake is significantly greater or less than 15,000 kU AGE. From the data presented in Table 1 (available online at www.adajournal.org), it is easy to see how people who consume a diet rich in grilled or roasted meats, fats, and highly processed foods could achieve a dAGE intake in excess of 20,000 kU/day. Conversely, people who regularly consume lower-meat meals prepared with moist heat (such as soups and stews) as part of a diet rich in plant foods could realistically consume half the daily intake seen in this cohort. A safe and optimal dAGE intake for the purposes of disease prevention has yet to be established. However, in animal studies, a reduction of dAGE by 50% of usual intake is associated with reduced levels of oxidative stress, less deterioration of insulin sensitivity and kidney function with age, and longer life span (16).

Reducing dAGE may be especially important for people with diabetes, who generate more endogenous AGEs than those without diabetes (5) and for those with renal disease, who have impaired AGE clearance from the body (14). Recently there has been heightened interest in therapeutic diets that are higher in protein and fat and lower in carbohydrate for weight loss, diabetes, and cardiovascular disease (35-41). This type of dietary pattern may substantially raise dAGE intake and thus contribute to health problems over the long term.

CONCLUSIONS

AGEs in the diet represent pathogenic compounds that have been linked to the induction and progression of many chronic diseases. This report reinforces previous observations that high temperature and low moisture consistently and strongly drive AGE formation in foods, whereas comparatively brief heating time, low temperatures, high moisture, and/or pre-exposure to an acidified environment are effective strategies to limit new AGE formation in food (13). The potentially negative effects of traditional forms of cooking and food processing have typically remained outside the realm of health considerations. However, accumulation of AGEs due to the systematic heating and processing of foods offers a new explanation for the adverse health effects associated with the Western diet, reaching beyond the question of overnutrition.

The current dAGE database demonstrates that a significantly reduced intake of dAGEs can be achieved by increasing the consumption of fish, legumes, low-fat milk products, vegetables, fruits, and whole grains and by reducing intake of solid fats, fatty meats, full-fat dairy products, and highly processed foods. These guidelines are consistent with recommendations by organizations such as the American Heart Association (42), the American Institute for Cancer Research (43), and the American Diabetes Association (44). It should, therefore, be possible to integrate this new evidence into established guidelines for disease prevention as well as medical nutrition therapy for a wide variety of conditions.

Equally important, consumers can be educated about low-AGE–generating cooking methods such as poaching, steaming, stewing, and boiling. For example, the high AGE content of broiled chicken (5,828 kU/100 g) and broiled beef (5,963 kU/100 g) can be significantly reduced (1,124 kU/100 g and 2,230 kU/100 g, respectively) when the same piece of meat is either boiled or stewed. The use of acidic marinades, such as lemon juice and vinegar, before cooking can also be encouraged to limit dAGE generation. These culinary techniques have long been featured in Mediterranean, Asian, and other cuisines throughout the world to create palatable, easily prepared dishes.

The new database may have limitations, including the fact that foods were selected from diets common in a northeastern metropolitan US area, and may thus not represent the national average. Another limitation is that only two of many AGEs have been measured. However, the fact that both are associated with markers of disease in healthy subjects and are elevated in patients with diabetes and kidney disease lends credibility to their role as pathogens in foods consumed by the general public and persons with certain chronic diseases.

Ongoing studies are needed to further expand the dAGE database and investigate additional methods for reducing AGE generation during home cooking and food processing. Future studies should continue to investigate the health effects of AGEs and refine recommendations for safe dietary intakes. However, current data support the need for a paradigm shift that acknowledges that how we prepare and process food may be equally important as nutrient composition.

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Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content

Food item	AGE Content		
	AGE[a] kU/100g	Serving size (g)	AGE kU/serving
Fats			
Almonds, blanched slivered (Bazzini's Nut Club, Bronx, NY)	5,473	30	1,642
Almonds, roasted	6,650	30	1,995
Avocado	1,577	30	473
Butter, whipped[b]	26,480	5	1,324
Butter, sweet cream, unsalted, whipped (Land O'Lakes, St Paul, MN)	23,340	5	1,167
Cashews, raw (Bazzini's Nut Club)	6,730	30	2,019
Cashews, roasted	9,807	30	2,942
Chestnut, raw	2,723	30	817
Chestnut, roasted, in toaster oven 350°F for 27 min	5,353	30	1,606
Cream cheese, Philadelphia soft, (Kraft, Northfield, IL)	10,883	30	3,265
Cream cheese, Philadelphia original (Kraft)	8,720	30	2,616
Margarine, tub	17,520	5	876
Margarine, tub, I Can't Believe it's Not Butter (Unilever, Rotterdam, The Netherlands)	9,920	5	496
Margarine, tub, Smart Balance (CFA Brands, Heart Beat Foods, Paramus, NJ)	6,220	5	311
Margarine, tub, Take Control (Unilever Best Foods)	4,000	5	200
Mayonnaise	9,400	5	470
Mayonnaise, imitation (Diet Source, Novartis Nutriton Group, East Hanover, NJ)	200	5	10
Mayonnaise, low fat (Hellman's, Unilever Best Foods)	2,200	5	110
Olive, ripe, large (5 g)	1,670	30	501
Peanut butter, smooth, Skippy (Unilever)	7,517	30	2,255
Peanuts, cocktail (Planters, Kraft)	8,333	30	2,500
Peanuts, dry roasted, unsalted (Planters, Kraft)	6,447	30	1,934
Peanuts, roasted in shell, salted (Frito-Lay, Plano, TX)	3,440	30	1,032
Pine nuts (pignolias), raw (Bazzini's Nut Club)	11,210	30	3,363
Pistachios, salted (Frito Lay)	380	30	114
Pumpkin seeds, raw, hulled (House of Bazzini, Bronx, NY)	1,853	30	556
Soybeans, roasted and salted (House of Bazzini)	1,670	30	501
Sunflower seeds, raw, hulled (House of Bazzini)	2,510	30	753
Sunflower seeds, roasted and salted (House of Bazzini)	4,693	30	1,408
Tartar Sauce, creamy (Kraft)	247	15	37
Walnuts, roasted	7,887	30	2,366
	AGE kU/100 mL	**Serving size (mL)**	**AGE kU/serving**
Fat, liquid			
Cream, heavy, ultra-pasteurized (Farmland Dairies, Fairlawn, NJ)	2,167	15	325
Oil, canola	9,020	5	451
Oil, corn	2,400	5	120
Oil, cottonseed (The B Manischewitz Company, Cincinnati, OH)	8,520	5	426
Oil, diaglycerol, Enova (ADM Kao LLC, Decatur, IL)	10,420	5	521
Oil, olive	11,900	5	595
Oil, olive, extra virgin, first cold pressed (Colavita, Linden, NJ)	10,040	5	502
Oil, peanut (Planters)	11,440	5	572
Oil, safflower (The Hain Celestial Group, Inc, Melville, NY)	3,020	5	151
Oil, sesame (Asian Gourmet)	21,680	5	1084
Oil, sunflower (The Hain Celestial Group, Inc)	3,940	5	197
Salad dressing, blue cheese (Kraft)	273	15	41
Salad dressing, caesar (Kraft)	740	15	111
Salad dressing, French (H. J. Heinz Co, Pittsburgh, PA)	113	15	17
Salad dressing, French, lite, (Diet Source, Novartis Nutr Corp)	0	15	0
Salad dressing, Italian (Heinz)	273	15	41
Salad dressing, Italian, lite (Diet Source, Novartis Nutr Corp)	0	15	0
Salad dressing, thousand island (Kraft)	187	15	28

(*continued*)

Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content (continued)

Meats and meat substitutes	AGE Content		
	AGE kU/100 g	Serving size (g)	AGE kU/serving
Beef			
Beef, bologna	1,631	90	1,468
Beef, corned brisket, deli meat (Boar's Head, Sarasota, FL)	199	90	179
Beef, frankfurter, boiled in water, 212° F, 7 min	7,484	90	6,736
Beef, frankfurter, broiled 450°F, 5 min	11,270	90	10,143
Beef, ground, boiled, marinated 10 min w/lemon juice	1,538	90	1,384
Beef, ground, pan browned, marinated 10 min w/lemon juice	3,833	90	3,450
Beef, ground, 20% fat, pan browned	4,928	90	4,435
Beef, ground, 20% fat, pan/cover	5,527	90	4,974
Beef, hamburger (McDonald's Corp[d], Oak Brook, IL)	5,418	90	4,876
Beef, hamburger patty, olive oil 180°F, 6 min	2,639	90	2,375
Beef, meatball, potted (cooked in liquid), 1 h[c]	4,300	90	3,870
Beef, meatball, w/sauce[c]	2,852	90	2,567
Beef, meatloaf, crust off, 45 min	1,862	90	1,676
Beef, raw	707	90	636
Beef, roast[b]	6,071	90	5,464
Beef, salami, kosher (Hebrew National, ConAgra Foods, Omaha, NE)	628	90	565
Beef, steak, broiled[c]	7,479	90	6,731
Beef, steak, grilled 4 min, George Foreman grill (Salton Inc, Lake Forest, IL)	7,416	90	6,674
Beef, steak, microwaved, 6 min	2,687	90	2,418
Beef, steak, pan fried w/olive oil	10,058	90	9,052
Beef, steak, raw	800	90	720
Beef, steak, strips, 450°F, 15 min[c]	6,851	90	6,166
Beef, steak, strips, stir fried with 1 T canola oil, 15 min	9,522	90	8,570
Beef, steak, strips, stir fried without oil, 7 min	6,973	90	6,276
Beef, stewed, shoulder cut[c]	2,230	90	2,007
Beef, stewed[b]	2,657	90	2,391
Beef, stewed, (mean)	2,443	90	2,199
Poultry			
Chicken, back or thigh, roasted then BBQ[b]	8,802	90	7,922
Chicken, boiled in water, 1 h	1,123	90	1,011
Chicken, boiled with lemon	957	90	861
Chicken, breast, skinless, roasted with BBQ sauce[c]	4,768	90	4,291
Chicken, breast, skinless, breaded[b]	4,558	90	4,102
Chicken, breast, skinless, breaded, reheated 1 min[b]	5,730	90	5,157
Chicken, breast, boiled in water[c]	1,210	90	1,089
Chicken, breast, breaded, deep fried, 20 min	9,722	90	8,750
Chicken, breast, breaded, oven fried, 25 min, with skin[c]	9,961	90	8,965
Chicken, breast, breaded/pan fried[c]	7,430	90	6,687
Chicken, breast, grilled/George Foreman grill (Salton Inc)	4,849	90	4,364
Chicken, breast, pan fried, 13 min, high[c]	4,938	90	4,444
Chicken, breast, pan fried, 13 min high/microwave 12.5 sec[c]	5,417	90	4,875
Chicken, breast, poached, 7 min, medium heat[c]	1,101	90	991
Chicken, breast, potted (cooked in liquid), 10 min medium heat[c]	2,480	90	2,232
Chicken, breast, roasted, 45 min with skin[c]	6,639	90	5,975
Chicken, breast, skinless, microwave, 5 min	1,524	90	1,372
Chicken, breast, skinless, poached, 15 min	1,076	90	968
Chicken, breast, skinless, raw	769	90	692
Chicken, breast, steamed in foil, 15 min, medium heat[c]	1,058	90	952
Chicken, breast, strips, stir fried with canola oil, 7 min	4,140	90	3,726
Chicken, breast, strips, stir fried without oil, 7 min	3,554	90	3,199
Chicken, breast, with skin, 450°F, 45 min[c]	8,244	90	7,420
Chicken, breast, skinless, broiled, 450°F, 15 min	5,828	90	5,245
Chicken, crispy (McDonald's[d])	7,722	90	6,950
Chicken, curry, cube skinless breast, panfry10 min, broiled 12 min[c]	6,340	90	5,706

(*continued*)

Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content (continued)

Meats and meat substitutes	AGE Content		
	AGE kU/100 g	Serving size (g)	AGE kU/serving
Chicken, curry, cube skinless breast, steam 10 min, broiled 12 min[c]	5,634	90	5,071
Chicken, dark meat, broiled, inside, 450°F, 15 min	8,299	90	7,469
Chicken, fried, in olive oil, 8 min	7,390	90	6,651
Chicken, ground, dark meat with skin, raw[c]	1,223	90	1,101
Chicken, ground, dark w/skin, pan fried, w/canola oil, 2.5 min, high heat[c]	3,001	90	2,701
Chicken, ground, white meat, pan fried, no added fat, 5 min, high heat[c]	1,808	90	1,627
Chicken, ground, white meat, pan fried, with oil	1,647	90	1,482
Chicken, ground, white meat, raw	877	90	789
Chicken, kebab, cubed skinless breast, pan fried, 15 min[c]	6,122	90	5,510
Chicken, leg, roasted[b]	4,650	90	4,185
Chicken, loaf, roasted[c]	3,946	90	3,551
Chicken, loaf, roasted, crust off[c]	1,420	90	1,278
Chicken, meat ball, potted (cooked in liquid), 1 h	1,501	90	1,351
Chicken, nuggets, fast food (McDonald's[d])	8,627	90	7,764
Chicken, potted (cooked in liquid) with onion and water	3,329	90	2,996
Chicken, roasted[c]	6,020	90	5,418
Chicken, selects (McDonald's)	9,257	90	8,331
Chicken, skin, back or thigh, roasted then BBQ[b]	18,520	90	16,668
Chicken, skin, leg, roasted[b]	10,997	90	9,897
Chicken, skin, thigh, roasted[b]	11,149	90	10,034
Chicken, thigh, roasted[b]	5,146	90	4,631
Turkey, burger, pan fried with cooking spray, 5 min, high heat[c]	7,968	90	7,171
Turkey, burger, pan fried with cooking spray, 5 min, high heat, microwaved 13.5 sec, high heat[c]	8,938	90	8,044
Turkey, burger, pan fried with 5 mL canola oil, 3.5 min, high heat[c]	8,251	90	7,426
Turkey, ground, grilled, crust	6,351	90	5,716
Turkey, ground, grilled, interior	5,977	90	5,379
Turkey, ground, raw	4,957	90	4,461
Turkey, burger, broiled	5,366	90	4,829
Turkey, breast, roasted	4,669	90	4,202
Turkey, breast, smoked, seared[c]	6,013	90	5,412
Turkey, breast, steak, skinless, marinated w/orange juice, broiled[c]	4,388	90	3,949
Pork			
Bacon, fried 5 min no added oil	91,577	13	11,905
Bacon, microwaved, 2 slices, 3 min	9,023	13	1,173
Ham, deli, smoked	2,349	90	2,114
Liverwurst (Boar's Head)	633	90	570
Pork, chop, marinated w/balsamic vinegar, BBQ[b]	3,334	90	3,001
Pork, chop, raw, marinated w/balsamic vinegar[b]	1,188	90	1,069
Pork, chop, pan fried, 7 min	4,752	90	4,277
Pork, ribs, roasted, Chinese take out	4,430	90	3,987
Pork, roast, Chinese take out	3,544	90	3,190
Sausage, beef and pork links, pan fried	5,426	90	4,883
Sausage, Italian, raw[b]	1,861	90	1,675
Sausage, Italian, BBQ[b]	4,839	90	4,355
Sausage, pork links, microwaved, 1 min	5,943	90	5,349
Lamb			
Lamb, leg, boiled, 30 min	1,218	90	1,096
Lamb, leg, broiled, 450°F, 30 min	2,431	90	2,188
Lamb, leg, microwave, 5 min	1,029	90	926
Lamb, leg, raw	826	90	743

(*continued*)

Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content (continued)

Meats and meat substitutes	AGE Content		
	AGE kU/100 g	Serving size (g)	AGE kU/serving
Veal			
Veal, stewed	2,858	90	2,572
Fish/seafood			
Crabmeat, fried, breaded (take out)	3,364	90	3,028
Fish, loaf (gefilte), boiled 90 min	761	90	685
Salmon, Atlantic, farmed, prev. frozen, microwaved, 1 min, high heat[c]	954	90	859
Salmon, Atlantic, farmed, prev. frozen, poached, 7 min, medium heat[c]	1,801	90	1,621
Salmon, Atlantic, farmed, prev. frozen, steamed, 10 min, medium heat[c]	1,212	90	1,091
Salmon, Atlantic, farmed, prev. frozen, steamed in foil, 8 min, medium heat[c]	1,000	90	900
Salmon, breaded, broiled 10 min	1,498	90	1,348
Salmon, broiled with olive oil	4,334	90	3,901
Salmon, canned pink (Rubenstein, Trident Seafoods, Seattle, WA)	917	90	825
Salmon, fillet, boiled, submerged, 18 min	1,082	90	974
Salmon, fillet, broiled	3,347	90	3,012
Salmon, fillet, microwaved	912	90	821
Salmon, fillet, poached	2,292	90	2,063
Salmon, pan fried in olive oil	3,083	90	2,775
Salmon, raw, previously frozen	517	90	465
Salmon, raw	528	90	475
Salmon, smoked	572	90	515
Scrod, broiled 450°F, 30 min	471	90	424
Shrimp frozen dinner, microwaved 4.5 min	4,399	90	3,959
Shrimp, fried, breaded (take out)	4,328	90	3,895
Shrimp, marinated raw[b]	1,003	90	903
Shrimp, marinated, grilled on BBQ[b]	2,089	90	1,880
Trout, baked, 25 min	2,138	90	1,924
Trout, raw	783	90	705
Tuna, patty, chunk light, broiled, 450°F, 30 min	747	90	672
Tuna, broiled, with soy, 10 min	5,113	90	4,602
Tuna, broiled, with vinegar dressing	5,150	90	4,635
Tuna, fresh, baked, 25 min	919	90	827
Tuna, loaf (chunk light in recipe), baked 40 min	590	90	531
Tuna, canned, chunk light, w/water	452	90	407
Tuna, canned, white, albacore, w/oil	1,740	90	1,566
Whiting, breaded, oven fried, 25 min[c]	8,774	90	7,897
Cheese			
Cheese, American, low fat (Kraft)	4,040	30	1,212
Cheese, American, white, processed	8,677	30	2,603
Cheese, brie	5,597	30	1,679
Cheese, cheddar	5,523	30	1,657
Cheese, cheddar, extra sharp, made with 2% milk (Cracker Barrel, Kraft)	2,457	30	737
Cheese, cottage, 1% fat (Light & Lively, Kraft)	1,453	30	436
Cheese, feta, Greek, soft	8,423	30	2,527
Cheese, mozzarella, reduced fat	1,677	30	503
Cheese, parmesan, grated (Kraft)	16,900	15	2,535
Cheese, Swiss, processed[b]	4,470	30	1,341
Cheese, Swiss, reduced fat (Alpine Lace, Alpine Lace Brands, Inc, Maplewood, NJ)	4,743	30	1,423
Soy			
Bacon bits, imitation, Bacos (Betty Crocker, General Mills, Minneapolis, MN)	1,247	15	187
Meatless jerky, Primal Strips (Primal Spirit Inc, Moundsville, WV)	1,398	90	1,258

(*continued*)

Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content (continued)

Meats and meat substitutes	AGE Content: AGE kU/100 g	Serving size (g)	AGE kU/serving
Soy burger, Boca Burger, 400°F, 8 min-4 each side[c] (BOCA Foods Co, Mandison, WI)	130	30	39
Soy burger, Boca Burger, microwaved, 1.5 min[c] (BOCA Foods Co)	67	30	20
Soy burger, Boca Burger, skillet, cook spray, 5 min[c] (BOCA Foods Co)	100	30	30
Soy burger, Boca Burger, skillet, w/1 tsp olive oil, 5 min[c] (BOCA Foods Co)	437	30	131
Soy burger, Boca Burger (BOCA Foods Co) (mean)	183	30	55
Tofu, broiled	4,107	90	3,696
Tofu, raw	788	90	709
Tofu, soft, raw	488	90	439
Tofu, sautéed, inside	3,569	90	3,212
Tofu, sautéed, outside	5,877	90	5,289
Tofu, sautéed (mean)	4,723	90	4,251
Tofu, soft, boiled 5 min, +2 min to return to boil[c]	628	90	565
Tofu, soft, boiled 5 min, +2 min,+ soy sauce, sesame oil[c]	796	90	716
Eggs			
Egg, fried, one large	2,749	45	1,237
Egg white powder (Deb-El Products, Elizabeth, NJ)	1,040	10	104
Egg white, large, 10 min	43	30	13
Egg white, large, 12 min	63	30	19
Egg yolk, large, 10 min	1,193	15	179
Egg yolk, large, 12 min	1,680	15	252
Egg, omelet, pan, low heat, cooking spray, 11 min[c]	90	30	27
Egg, omelet, pan, low heat, corn oil, 12 min[c]	223	30	67
Egg, omelet, pan, low heat, margarine, 8 min[c]	163	30	49
Egg, omelet, pan, low, butter, 13 min[c]	507	30	152
Egg, omelet, pan, low, olive oil, 12 min[c]	337	30	101
Egg, poached, below simmer, 5 min[c]	90	30	27
Egg, scrambled, pan, high, butter, 45 sec[c]	337	30	101
Egg, scrambled, pan, high, cooking spray, 1 min[c]	117	30	35
Egg, scrambled, pan, high, corn oil, 1 min[c]	173	30	52
Egg, scrambled, pan, high, margarine, 1 min[c]	123	30	37
Egg, scrambled, pan, high, olive oil, 1min[c]	243	30	73
Egg, scrambled, pan, med-low, butter, 2 min[c]	167	30	50
Egg, scrambled, pan, med-low, cooking spray, 2 min[c]	67	30	20
Egg, scrambled, pan, med-low, corn oil, 1.5 min[c]	123	30	37
Egg, scrambled pan, med-low, margarine, 2 min[c]	63	30	19
Egg, scrambled, pan, med-low, olive oil, 2 min[c]	97	30	29

Carbohydrates	AGE Content: AGE kU/100 g	Serving size (g)	AGE kU/serving
Bread			
Bagel, small, Lender's[b]	133	30	40
Bagel, large[b]	107	30	32
Bagel, toasted[b]	167	30	50
Biscuit (Mc Donald's[d])	1,470	30	441
Biscuit, refrigerator, baked-oven, 350°F, 17 min (Pillsbury Grands, General Mills)	1,343	30	403
Biscuit, refrigerator, uncooked (Pillsbury Grands, General Mills)	823	30	247
Bread, 100% whole wheat, center, toasted (Wonder, Interstate Bakeries, Inc, Irving, TX)	83	30	25
Bread, 100% whole wheat, center (Wonder)	53	30	16
Bread, 100% whole wheat, top crust (Wonder)	73	30	22
Bread, 100% whole wheat, top crust, toasted (Wonder)	120	30	36
Bread, Greek, hard	150	30	45

(*continued*)

Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content (continued)			
	AGE Content		
Carbohydrates	**AGE kU/100 g**	**Serving size (g)**	**AGE kU/serving**
Bread, Greek, hard, toasted	607	30	182
Bread, Greek, soft	110	30	33
Bread, pita	53	30	16
Bread, white, Italian, center (Freihoffer's, Bimbo Bakeries, Horsham, PA)	23	30	7
Bread, white, Italian, center, toasted (Freihoffer's)	83	30	25
Bread, white, Italian, crust (Freihoffer's)	37	30	11
Bread, white, Italian, top crust, toasted (Freihoffer's)	120	30	36
Bread, white, slice (Rockland Bakery, Nanuet, NY)	83	30	25
Bread, white, slice, toasted (Rockland Bakery)	107	30	32
Bread, whole wheat, slice (Rockland Bakery)	103	30	31
Bread, whole wheat, slice, toasted, slice, (Rockland Bakery)	137	30	41
Croissant, butter (Starbucks, Seattle, WA)	1,113	30	334
Roll, dinner, inside	23	30	7
Roll, dinner, outside	77	30	23
Breakfast cereals			
Bran flakes, from raisin bran (Post, Kellogg Co, Battle Creak, MI)	33	30	10
Cinnamon Toast Crunch (General Mills)	1,100	30	330
Corn Flakes (Kellogg's)	233	30	70
Corn Flakes, Honey Nut (Kellogg Co)	320	30	96
Corn Flakes, Sugar Frosted (Kellogg Co)	427	30	128
Corn Pops (Kellogg's)	1,243	30	373
Cream of Wheat, instant, prepared (Nabisco, East Hanover, NJ)	108	175	189
Cream of Wheat, instant, prepared with honey (Nabisco)	189	175	331
Fiber One (General Mills)	1,403	30	421
Froot Loops (Kellogg Co)	67	30	20
Frosted Mini Wheats (Kellogg Co)	210	30	63
Granola, Organic Oats & Honey (Cascadian Farms, Small Planet Foods, Minneapolis, MN)	427	30	128
Life, mean (Quaker Oats, Chicago, IL)	1,313	30	394
Puffed Corn Cereal (Arrowhead Mills, The Hain Celestial Group, Inc)	100	30	30
Puffed Wheat	17	30	5
Rice Krispies (Kellogg Co)	2,000	30	600
Total, Wheat and Brown Rice (General Mills)	233	30	70
Oatmeal, instant, dry (Quaker Oats)	13	30	4
Oatmeal, instant, prepared (Quaker Oats)	14	175	25
Oatmeal, instant, prepared with honey (Quaker Oats)	18	175	31
Breakfast foods			
French toast, Aunt Jemima, frozen, microwaved 1 min (Pinnacle Foods)	603	30	181
French toast, Aunt Jemima, frozen,10 min @ 400°F (Pinnacle Foods Corp)	850	30	255
French toast, Aunt Jemima, frozen, not heated (Pinnacle Foods Corp, Cherry Hill, NJ)	263	30	79
French toast, Aunt Jemima frozen, toaster medium-1 cycle (Pinnacle Foods)	613	30	184
Hot Cakes (McDonald's[d])	243	30	73
Pancake, from mix	823	30	247
Pancake, frozen, toasted (General Mills)	2,263	30	679
Pancake, homemade	973	30	292
Waffle, frozen, toasted (Kellogg Co)	2,870	30	861
Grains/legumes			
Beans, red kidney, raw	116	100	116

(*continued*)

Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content (continued)			
	AGE Content		
Carbohydrates	**AGE kU/100 g**	**Serving size (g)**	**AGE kU/serving**
Beans, red kidney, canned	191	100	191
Beans, red kidney, cooked 1 h	298	100	298
Pasta, cooked 8 min	112	100	112
Pasta, cooked 12 min	242	100	242
Pasta, spiral[b]	245	100	245
Rice, white, quick cooking, 10 min	9	100	9
Rice, Uncle Ben's white, cooked, 35 min (Mars, Inc, Houston, TX)	9	100	9
Rice, white, pan toasted 10 min, cooked 30 min	32	100	32
Starchy vegetables			
Corn, canned	20	100	20
Potato, sweet, roasted 1 h	72	100	72
Potato, white, boiled 25 min	17	100	17
Potato, white, roasted 45 min, with 5 mL oil/serving[c]	218	100	218
Potato, white, french fries (McDonald's[d])	1,522	100	1,522
Potato, white, french fries, homemade	694	100	694
Potato, white, french fries, in corn oil, held under heat lamp[b]	843	100	843
Potato, white, hash browns (McDonald's[d])	129	100	129
Crackers/snacks			
Breadsticks, Stella D'oro hard (Brynwood Partners, Greenwich, CT)	127	30	38
Cheez Doodles, crunchy (Wise Foods Inc, Berwick, PA)	3,217	30	965
Chex mix, traditonal (General Mills, Inc)	1,173	30	352
Chips, corn, Doritos (Frito Lay)	503	30	151
Chips, corn, Harvest Cheddar Sun Chips (Frito-Lay)	1,270	30	381
Chips, Platanitos, plantain (Plantain Products Co, Tampa, FL)	370	30	111
Chips, potato (Frito Lay)	2,883	30	865
Chips, potato, baked original potato crisps (Frito Lay)	450	30	135
Combos, nacho cheese pretzel (M & M Mars, McLean, VA)	1,680	30	504
Cracker, chocolate Teddy graham (Nabisco)	1,647	30	494
Cracker, Pepperidge Farms Goldfish, cheddar (Campbell Soup Co, Camden, NJ)	2,177	30	653
Cracker, Keebler honey graham (Kellogg Co)	1,220	30	366
Cracker, Old London melba toast (Nonni's Food Co, Tulsa, OK)	903	30	271
Cracker, oyster	1,710	30	513
Cracker, rice cake, corn (Taanug)	137	30	41
Cracker, saltine, hospital (Alliant)	937	30	281
Cracker, Keebler sandwich, club+cheddar, (Kellogg Co)	1,830	30	549
Cracker, toasted wheat	917	30	275
Cracker, wheat, round	857	30	257
Cracker, KA-ME rice crunch, plain (Liberty Richter, Bloomfield, NJ)	917	30	275
Popcorn, air popped, with butter	133	30	40
Popcorn, Pop Secret microwaved, fat free, no added fat (General Mills)	33	30	10
Pretzel, minis (Snyder's of Hanover, Hanover, NJ)	1,790	30	537
Pretzel, Q rolled	1,883	30	565
Pretzel, stick	1,600	30	480
Pretzel (mean)	1,757	30	527
Veggie Booty (Robert's American Gourmet, Seacliff, NY)	983	30	295
Cookies, cakes, pies, pastries			
Bar, granola, chocolate chunk, soft (Quaker)	507	30	152
Bar, Nutrigrain, apple cinnamon (Kellogg's)	2,143	30	643
Bar, Rice Krispies Treat (Kelloggs)	1,920	30	576
Bar,Granola, peanut butter & choc chunk, hard (Quaker)	3,177	30	953
Cake, angel food, Danish Kitchen (Sam's Club, Bentonville, AR)	27	30	8
Cookie, biscotti, vanilla almond (Starbucks)	3,220	30	966

(*continued*)

Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content (continued)			
	AGE Content		
Carbohydrates	**AGE kU/100 g**	**Serving size (g)**	**AGE kU/serving**
Cookie, chocolate chip, Chips Ahoy (Nabisco)	1,683	30	505
Cookie, Golden Bowl fortune (Wonton Food, Inc, Brooklyn, NY)	90	30	27
Cookie, Greek wedding, nut cookie	960	30	288
Cookie, meringue, homemade	797	30	239
Cookie, Keebler oatmeal raisin (Kellogg Co)	1,370	30	411
Cookie, Oreo (Nabisco)	1,770	30	531
Cookie, Nilla vanilla wafer (Nabisco)	493	30	148
Croissant, chocolate (Au Bon Pain, Boston, MA)	493	30	148
Danish, cheese (Au Bon Pain)	857	30	257
Donut, glazed devil's food cake (Krispy Kreme, Winston-Salem, NC)	1,407	30	422
Donut, chocolate iced, crème filled (Krispy Kreme)	1,803	30	541
Fruit pop, frozen (Dole, Westlake Village, CA)	18	60	11
Fruit roll up, sizzlin' red (General Mills)	980	30	294
Gelatin, Dole strawberry (Nestle, Minneapolis, MN)	2	125	2
Gelatin, Dole strawberry, sugar free (Nestle)	1	125	1
Ice cream cone, cake (Haagen Dazs, Oakland, CA)	147	30	44
Ice cream cone, sugar (Haagen Dazs)	153	30	46
Muffin, bran (Au Bon Pain)	340	30	102
Pie, apple, individual, baked (McDonald's[d])	637	30	191
Pie, crust, frozen, baked per pkg, mean Mrs. Smith's Dutch Apple Crumb and Pumpkin Custard (Kellogg Co)	1,390	30	417
Pie, Mrs. Smith's Dutch apple crumb, deep dish , apple filling (Kellogg Co)	340	30	102
Pie, Mrs. Smith's Dutch apple crumb, deep dish, crumbs (Kellogg Co)	1,030	30	309
Pie, Mrs. Smith's Dutch apple crumb, deep dish, crust (Kellogg Co)	1,410	30	423
Pie, Mrs. Smith's Dutch apple crumb, deep dish, pie (Kellogg Co)	893	30	268
Pie, Mrs. Smith's pumpkin custard, bake it fresh, original recipe, crust (Kellogg Co)	1,373	30	412
Pie, Mrs. Smith's pumpkin custard, bake it fresh, original recipe, custard (Kellogg Co)	617	30	185
Pie, Mrs. Smith's pumpkin custard, bake it fresh, original recipe, pie (Kellogg Co)	880	30	264
Pop tart, microwave-3 sec high power (Kellogg Co)	243	30	73
Pop tart, microwave-6 se medium high power (Kellogg's)	210	30	63
Pop tart, not heated (Kellogg Co)	133	30	40
Pop tart, toaster-low, 1 cycle (Kellogg Co)	260	30	78
Scone, cinnamon (Starbucks)	790	30	237
Sorbet, Edy's strawberry (Dryer's, Oakland, CA)	2	125	3
Sweet roll, cinnamon swirl roll (Starbucks)	907	30	272
Fruits			
Apple, baked	45	100	45
Apple, Macintosh	13	100	13
Banana	9	100	9
Cantaloupe	20	100	20
Coconut cream, Coco Goya cream of coconut (Goya, Secaucus, NJ)	933	15	140
Coconut milk, leche de coco, (Goya)	307	15	46
Coconut, Baker's Angel Flake, sweetened (Kraft)	590	30	177
Dates, Sun-Maid California chopped (Sun-Maid, Kingsburg, CA)	60	30	18
Fig, dried	2,663	30	799
Plums, Sun-Maid dried pitted prunes (Sun-Maid)	167	30	50
Raisin, from Post Raisin Bran (Kellogg Co)	120	30	36

(*continued*)

Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content (continued)

Carbohydrates	AGE Content AGE kU/100 g	Serving size (g)	AGE kU/serving
Vegetables (raw unless specified otherwise)			
Carrots, canned	10	100	10
Celery	43	100	43
Cucumber	31	100	31
Eggplant, grilled, marinated with balsamic vinegar[b]	256	100	256
Eggplant, raw, marinated with balsamic vinegar[b]	116	100	116
Green beans, canned	18	100	18
Portabella mushroom, raw, marinated with balsamic vinegar[b]	129	100	129
Onion	36	100	36
Tomato	23	100	23
Tomato sauce (Del Monte Foods, San Francisco, CA)	11	100	11
Vegetables, grilled (broccoli, carrots, celery)	226	100	226
Vegetables, grilled (pepper, mushrooms)	261	100	261
Other carbohydrates			
Sugar, white	0	5	0
Sugar substitute, aspartame as Canderel (Merisant, Chicago, IL)	0	5	0

Liquids	AGE Content AGE kU/100 mL	Serving size (mL)	AGE kU/serving
Milk and milk products			
Cocoa packet, Swiss Miss, prepared (ConAgra Foods)	262	250	656
Cocoa packet, Swiss Miss sugar-free, prepared (ConAgra Foods)	204	250	511
Ice cream, America's Choice vanilla (The Great Atlantic and Pacific Tea Co, Montvale, NJ)	34	250	84
Milk, fat-free (hospital)	1	250	2
Milk, Lactaid fat free (McNeil Nutritionals, Fort Washington, PA)	10	250	26
Milk, fat free (Tuscan Dairy Farms, Burlington, NJ)	2	250	4
Milk, fat free, with A and D	0	250	1
Milk, fat free, with A and D (microwaved,1 min)	2	250	5
Milk, fat free, with A and D (microwaved, 2 min)	8	250	19
Milk, fat free, with A and D (microwaved, 3 min)	34	250	86
Milk, soy (Imagine Foods, The Hain Celestial Group)	31	250	77
Milk, whole (4% fat)	5	250	12
Pudding, instant chocolate, fat-free, sugar-free, prepared	1	120	1
Pudding, instant chocolate, skim milk	1	120	1
Pudding, Hunt Wesson snack pack, chocolate (ConAgra Foods)	17	120	20
Pudding, Hunt Wesson snack pack, vanilla (ConAgra Foods)	13	120	16
Yogurt, cherry, (Dannon, White Plains, NY)	4	250	10
Yogurt, vanilla, (Dannon)	3	250	8
Fruit juice			
Juice, apple	2	250	5
Juice, cranberry	3	250	8
Juice, orange	6	250	14
Juice, orange, from fresh fruit	0	250	1
Juice, orange, with calcium	3	250	8
Vegetable juice			
Vegetable juice, V8 (Campbell Soup Co)	2	250	5
Other carbohydrate liquids			
Fruit pop, frozen (Dole)	18	60	11
Honey	7	15	1

(*continued*)

Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content (continued)

	AGE Content		
Liquids	**AGE kU/100 mL**	**Serving size (mL)**	**AGE kU/serving**
Sorbet, strawberry (Edy's)	2	125	3
Syrup, caramel, sugar free	0	15	0
Syrup, dark corn	0	15	0
Syrup, pancake, lite	0	15	0

	AGE Content		
Combination foods and solid condiments	**AGE kU/100 g**	**Serving size (g)**	**AGE kU/serving**
Combination foods			
Bacon Egg Cheese Biscuit (McDonald's[d])	2,289	100	2,289
Bacon, Egg and Cheese McGriddles (McDonald's[d])	858	100	858
Big Mac (McDonald's[d])	7,801	100	7,801
Casserole, tuna	233	100	233
Cheeseburger (McDonald's[d])	3,402	100	3,402
Chicken McGrill (McDonald's[d])	5,171	100	5,171
Corned beef hash, canned, microwaved 2 min, high power (Broadcast)	1,691	100	1,691
Corned beef hash, canned, stove top, medium heat, 12 min (Broadcast)	2,175	100	2,175
Corned beef hash, canned, unheated (Broadcast)	1,063	100	1,063
Double Quarter Pounder With Cheese (McDonald's[d])	6,283	100	6,283
Filet-O-Fish (McDonald's[d])	6,027	100	6,027
Gnocchi, potato/flour/Parmesan cheese, 3 min	535	100	535
Gnocchi, potato/flour/Parmesan cheese, 4.5 min	2,074	100	2,074
Hot Pocket, bacon, egg, cheese, oven, 350°F, 20 min (Nestle)	1,695	100	1,695
Hot Pocket-bacon, egg, cheese, microwaved 1 min (Nestle)	846	100	846
Hot Pocket-bacon, egg, cheese, frozen-not heated (Nestle)	558	100	558
Hummus, commercial	733	100	733
Hummus, with garlic and scallions	884	100	884
Hummus, with vegetables	487	100	487
Hummus (mean)	701	100	701
Macaroni and cheese[b]	2,728	100	2,728
Macaroni and cheese, baked[c]	4,070	100	4,070
Pasta primavera	959	100	959
Pesto, with basil (Buitoni, Nestle)	150	100	150
Pizza, thin crust	6,825	100	6,825
Salad, Italian pasta[c]	935	100	935
Salad, lentil potato[c]	123	100	123
Salad, tuna pasta[c]	218	100	218
Sandwich, cheese melt, open faced[c]	5,679	100	5,679
Sandwich, toasted cheese	4,333	100	4,333
Soufflé, spinach[c]	598	100	598
Timbale, broccoli[c]	122	100	122
Taramosalata (Greek style caviar spread)	678	100	678
Veggie burger, California burger, 400°F, 8 min-4 each side (Amy's Kitchen, Petaluma, CA)	198	100	198
Veggie burger, California burger, skillet, with spray, 5 min (Amy's)	149	100	149
Veggie burger, California burger, skillet, with 1 tsp olive oil, 5 min (Amy's)	374	100	374
Veggie burger, California burger, microwave, 1 min (Amy's)	68	100	68
Won ton, pork, fried (take out)	2,109	100	2,109
Ziti, baked	2,795	100	2,795
Condiments			
Ginger, crystallized	490	10	49
Candy, Hershey Special Dark Chocolate (The Hershey Co, Hershey, PA)	1,777	30	533

(*continued*)

Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content (continued)

Combination foods and solid condiments	AGE Content		
	AGE kU/100 g	Serving size (g)	AGE kU/serving
Candy, M & M's, milk chocolate (Mars)	1,500	30	450
Candy, Reese's Peanut Butter Cup (The Hershey Co)	3,440	30	1,032
Candy, Raisinets (Nestle)	197	30	59
Candy, Snickers (Nestle)	263	30	79
Pickle, bread and butter	10	30	3

Soups, liquid condiments, and miscellaneous liquids	AGE Content		
	AGE kU/100 mL	Serving size (mL)	AGE kU/serving
Soups			
Soup, beef bouillon	0.40	250	1
Soup, chicken bouillon	1.20	250	3
Soup, College Inn chicken broth, (Del Monte)	0.80	250	2
Soup, chicken noodle, (Campbell Soup Company)	1.60	250	4
Soup, couscous and lentil (Fantastic World Foods, Edison, NJ)	3.60	250	9
Soup, Knorr vegetable broth, (Unilever)	1.60	250	4
Soup, summer vegetable[c]	1.20	250	3
Condiments			
Ketchup	13.33	15	2
Mustard	0.00	15	0
Pectin	80.00	15	12
Soy sauce	60.00	15	9
Vinegar, balsamic	33.33	15	5
Vinegar, white	40.00	15	6
Miscellaneous			
SoBe Adrenaline Rush (South Beach Beverage Co, Norwalk, CT)	0.40	250	1
Budwiser Beer (Anheuser-Busch, St Louis, MO)	1.20	250	3
Breast milk, fresh	6.67	30	2
Breast milk, frozen	10.00	30	3
Coca Cola, classic (The Coca-Cola Co, Atlanta, GA)	2.80	250	7
Coffee, with milk and sugar	2.40	250	6
Coffee, drip method	1.60	250	4
Coffee, heating plate >1 h	13.60	250	34
Coffee, Taster's Choice instant (Nestle)	4.80	250	12
Coffee, instant, decaf (mean Sanka [Kraft] and Taster's Choice)	5.20	250	13
Coffee, Spanish	4.80	250	12
Coffee, with milk	6.80	250	17
Coffee, with sugar	7.60	250	19
Coke	6.40	250	16
Coke, Diet (The Coca-Cola Company)	1.20	250	3
Coke, Diet 2008 (The Coca-Cola Company)	4.00	250	10
Coke, Diet plus (The Coca-Cola Company)	1.60	250	4
Enfamil, old (Mead Johnson Nutritonal, Glenview, IL)	486.67	30	146
Ensure plus	12.80	250	32
Gelatin, Dole strawberry (Nestle)	1.60	125	2
Gelatin, Dole strawberry, sugar free (Nestle)	0.80	125	1
Glucerna (Abbott Nutrition, Columbus, OH)	70.00	250	175
Malta (Goya)	1.20	250	3
NOFEAR Super Energy Supplement (Pepsico, Purchase, NY)	0.40	250	1
Pepsi, diet (Pepsico)	2.80	250	7
Pepsi, diet MAX (Pepsico)	3.20	250	8
Pepsi, diet, caffeine free (Pepsico)	2.40	250	6
Pepsi, regular (Pepsico)	2.40	250	6
Resource (Nestle)	72.00	250	180
Rum, Bacardi Superior, 80 proof (Miami, FL)	0.00	250	0

(*continued*)

Table 1. The advanced glycation end product (AGE) content of 549 foods, based on carboxymethyllysine content (continued)

Soups, liquid condiments, and miscellaneous liquids	AGE Content		
	AGE kU/100 mL	Serving size (mL)	AGE kU/serving
Sprite (The Coca-Cola Company)	1.60	250	4
Sprite, diet (The Coca-Cola Company)	0.40	250	1
Tea, apple (RC Bigelow, Inc, Fairfield, CT)	0.40	250	1
Tea, Lipton Tea bag (Unilever)	2.00	250	5
Tea, Lipton Tea bag, decaf (Unilever)	1.20	250	3
Vodka, Smirnoff, 80 proof (Diageo, London, UK)	0.00	250	0
Whiskey, Dewar's White Label (Dewar's, Perthsire, UK)	0.40	250	1
Wine, pinot grigio (Cavit Collection, Port Washington, NY)	32.80	250	82
Wine, pinot noir (Cavit Collection)	11.20	250	28

[a]AGEs were assessed as carboxymethyllysine by enzyme-linked immunosorbent assay.
[b]MSC=Mount Sinai Hospital cafeteria.
[c]CRC=Mount Sinai Hospital Clinical Research Center.
[d]All McDonald's products were purchased in New York, NY, before July 2008.