Ann Allergy Asthma Immunol xxx (2020) 1–9

Contents lists available at ScienceDirect

Risk of shared equipment in restaurants for consumers with peanut allergy: a simulation for preparing Asian foods

A simulation for preparing Asian foods

Benjamin C. Remington, PhD [*,†]; W. Marty Blom, PhD [*]; Boris Bassa [‡]; Stef J. Koppelman, PhD [†]

[*] Netherlands Organisation for Applied Scientific Research (TNO), Utrecht, The Netherlands
[†] Food Allergy Research and Resource Program, University of Nebraska-Lincoln, Lincoln, Nebraska
[‡] Bassa Culinair, Utrecht, The Netherlands

ARTICLE INFO

Article history:
Received for publication May 30, 2020.
Received in revised form July 22, 2020.
Accepted for publication July 27, 2020.

ABSTRACT

Background: Allergic reactions to meals consumed outside the home are common and can be severe and sometimes fatal.

Objective: To quantify the risk reduction potentially achieved by increasing an individual's threshold sensitivity to peanut (such as by means of immunotherapy) in scenarios of peanut exposure through shared kitchen materials in a restaurant setting.

Methods: Three versions of popular peanut-containing sauces were selected to represent common ingredients used in Asian cooking. Different combinations of utensils, equipment, sauces, and test conditions were prepared by a professional chef, with or without common cleaning procedures, to represent normal daily practice. Residue amounts of peanut-containing material on kitchen equipment and utensils were measured and used for quantitative risk assessment to model the risk reduction associated with increasing an individual's threshold.

Results: Shared utensils had mean residue amounts of 23 to 1519 mg peanut protein (no cleaning) and 3 to 82 mg peanut protein (after water rinse). Shared woks and pans had up to 20 mg peanut protein after rinsing. Individuals who reach a threshold of 300 mg peanut protein have a predicted relative risk reduction of 94.9% to greater than 99.99% with brief cleaning. With no cleaning, relative risk reductions were 63.5% to 91.1% for individuals with a baseline threshold of less than or equal to 100 mg peanut protein who reach a threshold of 300 mg peanut protein, increasing to 91% to 99.7% when reaching a threshold value of 1000 mg peanut protein.

Conclusion: In all shared kitchen material scenarios that we studied, achieving an eliciting dose of 300 or 1000 mg peanut protein seems clinically relevant for the peanut-allergic population.

© 2020 American College of Allergy, Asthma & Immunology. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

The prevalence of peanut allergy among children and adolescents in the United States or Europe has recently been estimated to be approximately 2%.[1,2] Allergen avoidance and use of self-injectable epinephrine are the cornerstones of peanut allergy management in the United States[3,4] and Europe[5] and form a large burden for patients with peanut allergy and their families.[6] Complete food allergen avoidance is difficult and not often achieved, as evidenced by a recent study, which reported half of all patients with food allergy experienced a severe allergic reaction that required visiting the emergency department in the past, and approximately 1 in 5 have had such a reaction in the past year.[1]

Patients with peanut allergy can be exposed to peanut in a multitude of ways, including at home, in restaurants, or at schools and daycare centers,[7-11] with reactions typically attributed to packaged foods and meals outside the home.[12,13] For packaged foods, some studies estimate the risk of reaction to peanut contamination by performing quantitative risk assessment

Reprints: Stef J Koppelman, PhD, University of Nebraska-Lincoln, Lincoln, Nebraska; E-mail: farrp@unl.edu.

Disclosures: Dr Remington reports receiving grants from The Dutch Ministry of Economic Affairs; grants, travel support, and personal fees from DBV Technologies; and travel support from International Life Sciences Institute Europe. Dr Koppelman reports receiving grants from the University of Nebraska and DBV Technologies; personal fees from DBV Technologies; and owns stock and stock options from DBV Technologies. The remaining authors have no conflicts of interest to report.

Funding Sources: This study was, in part, funded by DBV Technologies.

https://doi.org/10.1016/j.anai.2020.07.030

1081-1206/© 2020 American College of Allergy, Asthma & Immunology. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

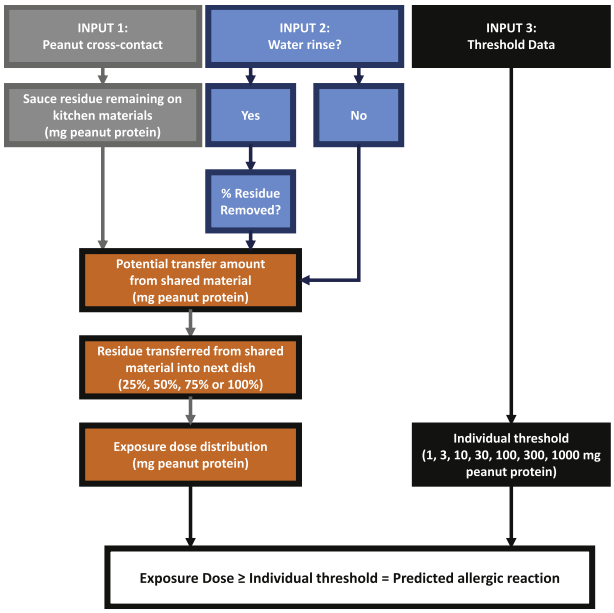


Figure 1. A general overview of the quantitative risk assessment setup. Random selection (n = 100,000) from input 1 (peanut cross-contact) and, depending on the scenario, input 2 (water rinse, yes/no) resulted in the exposure dose. The exposure was then compared with input 3 (a constant threshold dose of peanut protein) to determine if there was a risk of an allergic reaction. This was repeated 50 times for a total of 5,000,000 simulated eating occasions for each individual threshold value.

modeling with known contamination levels and consumption amounts.[14-20] A few of these previous studies modeled the estimated clinical benefits of increasing a hypothetical individual's threshold through immunotherapy[14,15] and in a specific population undergoing treatment with epicutaneous immunotherapy.[16] Absolute risks and relative risk reductions were presented for an unexpected reaction to peanut when consuming packaged foods on a per-eating-occasion basis[14-16] and on a yearly basis.[16] The baseline frequency of reaction on a yearly basis obtained with this model was similar to what has been reported by others for the US population, with a decrease in reaction rate modeled after immunotherapy.[1,16]

Different forms of immunotherapy for peanut allergy are under development at various stages,[21-23] with a single form currently approved for restricted use by the United States Food and Drug Administration,[24,25] and additional options are being used outside of a regulatory pathway.[26] Regardless of the approach, these aim to increase the threshold for reaction rather than enable eating peanuts ad libitum. Increasing a threshold by immunotherapy may provide a buffer against reactions to unintentionally ingested peanut, such as in the case of peanut-contaminated foods. A recent study investigated the goals of caregivers of children with peanut allergy in the United States and found that obtaining such buffer against reactions is a strongly desired attribute of peanut immunotherapy, irrespective of treatment modality.[27] Previous quantitative risk assessments of risk of allergic reactions from peanut contamination in packaged foods have shown that increasing an individual's threshold from less than or equal to 100 mg peanut protein of 300 mg peanut protein resulted in a relative risk reduction of greater than 95% for both the US population[14] and European population.[15]

Reactions to meals outside the home are a common cause of allergic reactions,[12,13] and these reactions can be severe, potentially even fatal.[28-30] Restaurant best practices indicate that any food equipment (ie, utensils, pots, pans, cooking surfaces) intended for allergen-free food use must be cleaned and sanitized before use. However, restaurants do not always adhere to best practice allergen protocols, as illustrated by a number of documented restaurant cases of peanut-related allergic reactions.[31-33] Even in cases in which a food allergy is declared to restaurant staff, accidental or unexpected allergic reactions still occur.[12] In these cases in which the informing waitstaff did not prevent a reaction, a mistaken ingredient, shared cooking equipment or utensils, or a number of other factors could have played a role in an unexpected reaction. To date, no such data were available to estimate the risk of an allergic reaction to such exposures.

The aim of this study was to quantify the risk reduction that may be achieved by increasing an individual's threshold sensitivity to peanut (such as by means of immunotherapy) in the scenario of exposure by peanut-contaminated restaurant meals prepared with shared cooking utensils or equipment. We chose to work with 3 sauces that are widely used in Asian recipes and often prepared in kitchens in which peanut ingredients/sauces containing peanut are

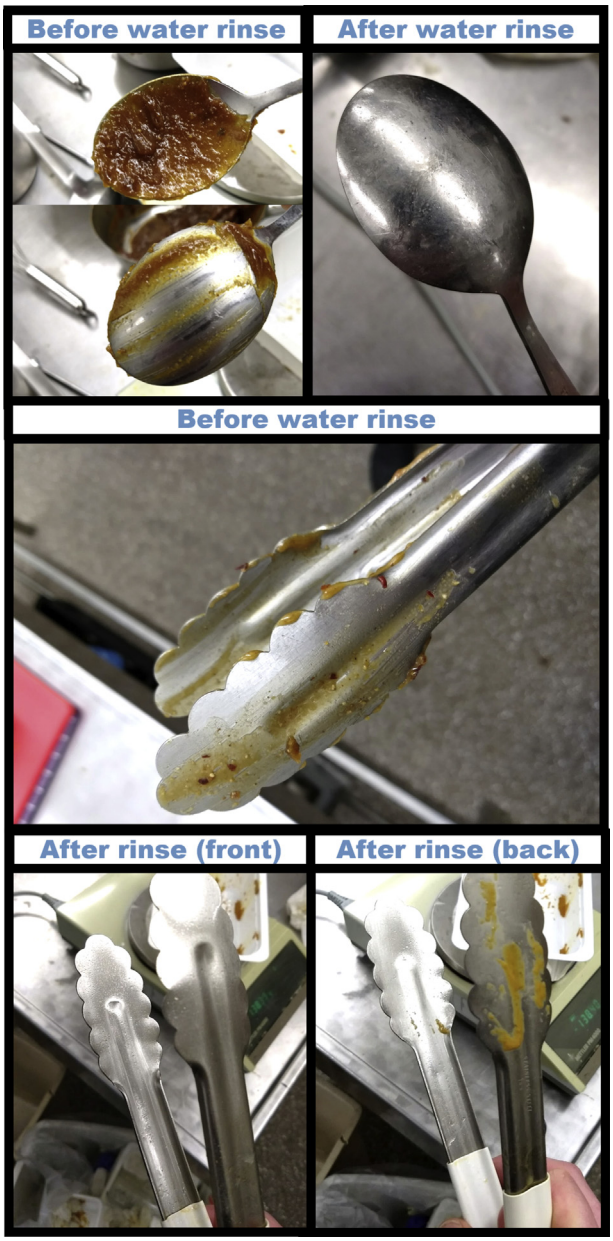


Figure 2. Examples of different utensils, under different test conditions, before and after a warm water rinse. Data on the peanut protein measured on equipment are presented in Table 2.

also used. For these types of recipes, it is assumed that the risk of cross-contact by means of shared cooking utensils and cooking pans is high. Several dishes were prepared in a professional kitchen by a chef, with or without applying common cleaning procedures to represent the daily practice. The amounts of the residue of peanut-containing material on kitchen equipment and utensils were measured and used as input for quantitative risk assessment.

Methods

Three versions of popular peanut-containing sauces were selected to represent common ingredients used in Asian cooking, including the sugar-based Pad Thai and General Tso's sauces, and a thicker, oil-based Indian coconut curry, thus representing 3 different textures with potentially different stickiness characteristics (recipes in eTable 1). A chef with experience and expertise in different types of Asian kitchens prepared the sauces and performed the experiments. At the time of the experiments, the chef was blinded to the purpose and funding source of the study. The sauces used creamy peanut butter as the peanut ingredient (18.6%-39.5% peanut, 4.6%-9.9% peanut protein by the recipe). The viscosity of sauces was determined as detailed in the eSupplement.

Cooking Experiments

The amount of peanut-containing sauce residue (in mg) sticking to professional kitchen equipment (wok, saucepan) and utensils (whisks, tongs, spatulas, soup ladles, spoons) was measured by weighing (digital laboratory scales with mg read-out) after preparation of sauces or single-serve meals, before and after possible cleaning steps. The amount of sauce residue remaining on a utensil was measured before and after brief warm water rinses in a shared pot of warm water for a couple of seconds, and sauce residue on the cooking equipment was measured before and after a brief scrub with a brush and warm water (no soap or detergent used). Replications of each combination ($n = 5$) were completed to measure the range of results. Milligram amounts of peanut protein were derived from the weighed amount of sauce using the recipes in eTable 1.

Pad Thai

Single-serve meals of peanut-containing Pad Thai were prepared using 150 g of vegetables (30 g onions, 40 g green/yellow/red pepper, 80 g white cabbage), 150 g of rice noodles (5 mm), 12 g of wok oil, and 50 g of Pad Thai sauce. After the removal of the cooked vegetables and rice noodles from the wok, the amount of the remaining sauce residue was measured before and after cleaning.

Indian Coconut Milk Curry

One hundred fifty grams of the thicker, oil-based Indian coconut milk curry sauce was heated in a wok or saucepan for single-serve meal preparation. The sauce was poured or scraped out of the preparation equipment, and the amount of sauce remaining for potential transfer into the next dish was measured before and after cleaning.

General Tso's

Similar to preparation in a restaurant kitchen, 150 g of breaded and freshly deep-fried boneless chicken was added to a mixing bowl with an average of 35 g of sauce (range of 30-50 g) and tossed until the chicken was coated with sauce. After removing the chicken for the plating of the meal, the amount of sauce remaining in the mixing bowl was measured before and after cleaning.

Quantitative Risk Assessments and Relative Risk Reduction Calculation

The quantitative risk assessments performed in this study incorporated the data acquired during the cooking experiments as inputs to predict the milligram exposure amount to residual peanut protein from shared kitchen utensils and equipment. The risk model calculated a milligram exposure amount of peanut protein through a random selection of the following: (1) the amount of sauce residue remaining on the shared kitchen material; (2) the percentage of residue removed if a brief rinse/scrub with water occurred; and (3) the amount of residue transferred from the shared kitchen material into the next dish (4 scenarios for transfer: 25%, 50%, 75%, or 100%). It should be noted that for conservatism, all measured percentages of residue removed after a brief rinse/scrub with water were available for combination with all utensils within the quantitative risk assessment, which leads to potentially higher simulated exposure amounts than those measured during the cooking experiments. The overall approach of this study is outlined in Figure 1. The reduction in risk of a predicted allergic reaction owing to an increased threshold of reaction can be expressed as a percentage decrease in risk to further evaluate the benefits of an increased threshold. The percentage decrease in risk was calculated using the percentage of predicted reactions and using the following formula:

$$\left(1 - \frac{\textit{Risk at achieved mg peanut protein threshold}}{\textit{Risk at baseline mg peanut protein threshold}}\right) \times 100\% = \textbf{\textit{Percentage decrease in risk}}\ (\%)$$

The model assumed that patients did not react with allergic symptoms to exposure doses below their threshold dose. Further details regarding the quantitative risk assessment are provided in the eSupplement.

Results

Cooking Utensils (Spoons, Whisks, Tongs)

Residual peanut and potential peanut transfers were collected for 26 different combinations of utensils, sauces, and test conditions (not yet heated, cooked—still hot, cooked, then cooled) (Fig 2). The mean sauce transfer amounts of 268 to 32,696 mg sauce (23-1519 mg peanut protein) were measured on shared restaurant kitchen utensils, depending on the sauce and utensil (Table 1). The common practice of rinsing of kitchen utensils in a shared pot of warm water removed a mean of 90.6% (range of 77.6%-97.6%) of sauce residue for all sauces. This resulted in a mean measured amount of 64 to 1754 mg of sauce (3-82 mg peanut protein) from utensils, which can potentially be transferred if the utensil were to be used (in this rinsed form) for the preparation of another sauce. Using the conservative inputs within the quantitative risk assessment, a worst-case maximum predicted exposure amount after water rinsing of shared utensils was approximately 365 mg peanut protein when combining all available percentages of residue removed after a brief rinse/scrub with water with all the sauces and utensils within the study.

As could be expected, the stickier, sugar-based Pad Thai and General Tso's sauces left more residual sauce on the utensils than the oil-based Indian coconut milk curry in most cases in which the sauces were tested with similar utensils, with the exception of the soup ladles. In addition, the sugar-based Pad Thai and General Tso's sauces became highly viscous when heated and left more sauce residue on the utensils than if the sauce had not yet been heated. Conversely, the oil-based Indian coconut milk curry was more viscous at a lower temperature, and generally, more residue was measured on the utensils with the cooled sauce than with the heated sauce. These general trends of the oil-based Indian coconut milk curry being more viscous at a lower temperature and the sugar-based Pad Thai and General Tso's being more viscous after heating was confirmed when the 3 sauces were tested for viscosity

Table 1
Sauce Transfer Results (Milligram Peanut Protein) for the Tested Sauce and Utensil Combinations (Grouped by Utensil)

Sauce	Test condition	Utensil	Peanut residue remaining on utensil (mg peanut protein), mean (minimum-maximum), n = 5
Coconut curry	Cooked, then cooled	Whisk S	56 (40-70)
	Cooked, then cooled	Whisk S postwater	7 (5-8)
	Cooked, still hot	Whisk S	59 (38-80)
	Cooked, still hot	Whisk S postwater	5 (3-7)
General Tso's	Not yet heated	Whisk S	193 (167-236)
	Not yet heated	Whisk S postwater	23 (16-34)
Pad Thai	Not yet heated	Whisk S	244 (173-316)
Coconut curry	Cooked, then cooled	Whisk M	143 (128-161)
	Cooked, then cooled	Whisk M postwater	4 (1-7)
	Cooked, still hot	Whisk M	86 (41-115)
	Cooked, still hot	Whisk M postwater	3 (0-7)[a]
General Tso's	Not yet heated	Whisk M	384 (318-431)
	Not yet heated	Whisk M postwater	25 (19-35)
	Cooked, then cooled	Whisk M	468 (443-485)
	Cooked, then cooled	Whisk M postwater	22 (14-34)
Pad Thai	Not yet heated	Whisk M	338 (248-449)
	Not yet heated	Whisk M postwater	40 (35-50)
Coconut curry	Cooked, then cooled	Whisk L	321 (290-350)
	Cooked, then cooled	Whisk L postwater	12 (5-21)
	Cooked, still hot	Whisk L	225 (204-245)
	Cooked, still hot	Whisk L postwater	15 (3-52)
General Tso's	Not yet heated	Whisk L	709 (543-915)
	Not yet heated	Whisk L postwater	54 (22-85)
Pad Thai	Not yet heated	Whisk L	689 (611-885)
Coconut curry	Cooked, still hot	Tongs	123 (80-178)
	Cooked, still hot	Tongs postwater	25 (14-46)
Pad Thai	Cooked, then cooled	Tongs	215 (147-267)
	Cooked, then cooled	Tongs postwater	42 (22-65)
General Tso's	Not yet heated	Tablespoon	320 (246-495)
	Not yet heated	Tablespoon postwater	11 (7-24)
	Cooked, then cooled	Tablespoon	338 (286-414)
	Cooked, then cooled	Tablespoon postwater	25 (10-54)
Pad Thai	Not yet heated	Tablespoon	350 (274-441)
Coconut curry	Cooked, still hot	Soup ladle S	522 (408-703)
	Cooked, still hot	Soup ladle S postwater	13 (9-16)
Pad Thai	Cooked, then cooled	Soup ladle S	131 (107-154)
	Cooked, then cooled	Soup ladle S postwater	29 (16-47)
Coconut curry	Cooked, still hot	Soup ladle M	909 (663-1319)
	Cooked, still hot	Soup ladle M postwater	50 (33-77)
Coconut curry	Cooked, still hot	Soup ladle L	1519 (1380-1629)
	Cooked, still hot	Soup ladle L postwater	82 (65-124)
Pad Thai	Cooked, then cooled	Small pinchers	23 (19-26)
	Cooked, then cooled	Small pinchers, heavy smear	86 (71-103)
General Tso's	Not yet heated	Silicone spatula M	214 (191-244)
	Not yet heated	Silicone spatula M postwater	17 (10-24)
	Cooked, then cooled	Silicone spatula M	145 (94-199)
	Cooked, then cooled	Silicone spatula M postwater	30 (21-43)

Abbreviations: L, large; M, medium; S, small.
NOTE. Sauce transfer results are presented pre- and post–water rinse (mean [minimum-maximum, n = 5]).
[a]The range of 0 mg to 7 mg peanut protein for coconut curry (Cooked, still hot; Whisk M postwater) includes 1 of 5 replicates in which no residual sauce was detected.

at room temperature (18°C) and when heated (60°C, 100°C) using a rheometer (eFigs 1 and 2).

Equipment (Woks, Pans, Bowls)

Single-serve meals were prepared for 7 different combinations of sauce, cooking equipment, and test conditions (Fig 3). Shared cooking equipment had potential transfer amounts of 270 to 21,800 mg sauce (23-2151 mg peanut protein), depending on equipment and recipe (Table 2). Heating and cooking single-serve meals in a steel wok or pan resulted in less potential sauce transfer than a mixing bowl used to toss and coat food with a sauce before plating, even though the mixing bowl had the least amount of sauce present (35 g in mixing bowl vs 50 g or 150 g in pans). The scraping of a meal out of the preparation wok/pan led to greater than 95% of the sauce being removed, whereas the breaded and fried chicken took up just under 50% of the sauce during tossing and coating, and left an average of 15.7 g of sauce (1.5 g of peanut protein) in the mixing bowl. However, despite the large amounts of sauce residues after cooking, there was no measurable sauce residue found in most cases (32 of 35) after common cleaning practice (brief scrub with a brush and warm water, no dishwasher sanitation assistance). In a few cases (3 of 35), up to 0.2 g sauce residue (up to 20 mg peanut protein) remained after this brief cleaning.

Similar to the utensil experiments, the stickier, sugar-based Pad Thai sauce (postscraping, before cleaning) left more residual sauce on the cooking equipment than the oil-based Indian coconut milk curry (postscraping, before cleaning) when the sauces were tested under analogous conditions. Interestingly though, the Indian coconut milk curry had 3 positive samples after a brief scrub with a brush and warm water, whereas Pad Thai had no detectable residue after a brief scrub. The mixing bowls used to prepare General Tso's chicken had the most sauce residue present after meal preparation, but the sauce was not heated while in the mixing bowl; thus, the

Figure 3. Examples of different shared cooking equipment, under different test conditions, before and after a brief scrub with a brush and warm water (no soap, no dishwasher sanitation assistance).

sauce was quickly removed during a brief scrub with a brush and warm water, leaving no detectable material.

Quantitative Risk Assessments

Absolute Risks

To quantify the potential relative risk reduction owing to an increased threshold of reaction after immunotherapy in the population with peanut allergy consuming foods prepared with shared kitchen utensils, we first assessed the risk of shared kitchen materials transferring a peanut-containing sauce into another dish. The percentage of eating occasions predicted to result in an allergic reaction (exposure $\geq$ threshold) (Fig 1) for each of the shared material scenarios (shared utensils—not cleaned, shared utensils—warm water rinse, shared wok/pan—not cleaned, shared wok/pan—brief scrub with brush and water) is presented in Table 3.

As expected from the sauce residue results, the worst-case scenario of uncleaned kitchen materials being used to prepare a "peanut-free" dish resulted in very high risk of exposure, with 100% of the predicted exposure amounts being greater than 3 mg peanut protein, and the overwhelming majority of predicted exposure amounts being greater than 30 mg peanut protein (for both utensils and wok/pans). In the case of uncleaned, shared utensils, allergic reactions were predicted in 61.8%% of eating occasions in individuals with a 100 mg peanut protein threshold, in 22.6% of eating occasions in individuals with a 300 mg peanut protein threshold, and in 2.0% of eating occasions in individuals with a 1000 mg peanut protein threshold. Similarly, high absolute risks were predicted if uncleaned woks/pans were used to make a "peanut-free" dish for individuals with a 100 mg peanut protein threshold or less. Lower risks were predicted for individuals with a 300 or 1000 mg peanut protein threshold when comparing the risks of a shared wok/pan to shared utensils. These results indicate that an uncleaned, shared utensil potentially presents a higher risk to the population with peanut allergy than an unwashed wok/pan. Mixing bowls were not included in the quantitative risk assessment scenarios because there were no detectable materials remaining during experimental meal preparation after a brief scrub with a brush and warm water, and the adamant opinion from the chef that a dirty mixing bowl would not be reused but instead quickly brushed

Table 2
Sauce Transfer Results (Milligram Peanut Protein) for the Shared Cooking Equipment Pre- and Postbrief Scrub With Brush and Warm Water, No Dishwasher Sanitation Assistance (Minimum-Maximum, N = 5)

Sauce	Equipment	Test condition	Peanut residue remaining on equipment (mg peanut protein)
Coconut Curry	Carbon steel wok	Preclean (pour only)	149-502
	Carbon steel wok	Preclean (scraping)	37-65
	Carbon steel wok	Postwater	Not detected
	Stainless steel wok	Preclean (scraping)	98-181
	Stainless steel wok	Postwater	0-9[a]
	Stainless steel saucepan	Preclean (scraping)	121-232
	Stainless steel saucepan	Postwater	0-5[a]
General Tso's	Plastic mixing bowl	Preclean (pour only)	1490-1668
	Plastic mixing bowl	Postwater	Not detected
	Stainless steel mixing bowl	Preclean (pour only)	1234-2151
	Stainless steel mixing bowl	Postwater	Not detected
Pad Thai	Carbon steel wok	Preclean (scraping)	23-116
	Carbon steel wok	Postwater	Not detected
	Stainless steel wok	Preclean (scraping)	42-296
	Stainless steel wok	Postwater	Not detected

[a]The range of 0 mg to 9 mg peanut protein for coconut curry (stainless steel wok, postwater) includes 4 of 5 replicates in which no residual sauce was detected. Similarly, the range of 0 mg to 5 mg peanut protein for coconut curry (stainless steel saucepan, postwater) includes 3 of 5 replicates in which no residual sauce was detected.

and rinsed with water owing to potential flavor or color changes in the next product.

When assessing the risks of utensils that have been quickly rinsed in warm water, 50.2% of the eating occasions were predicted to cause an allergic reaction in individuals with a 10-mg peanut protein threshold. However, individuals with a 300-mg peanut protein threshold were predicted to be at risk in only 0.1% of eating occasions in which a shared utensil was used in the cooking process. Owing to the fact that a brief scrub with a brush and warm water effectively removed sauce residues in most cases (32 of 35), there were predicted allergic reactions in only 1.3% of simulated eating occasions for individuals with a 10-mg peanut protein threshold, and no reactions were predicted in individuals with a reaction threshold greater than or equal to 30 mg peanut protein.

Relative Risk Reductions

To further evaluate the benefits of an increased threshold, the relative risk reduction for a predicted allergic reaction owing to an increase in reactivity threshold can be expressed as a relative percentage decreased.[14,15] The relative risk reduction was calculated using the percentage of predicted reactions in Table 3. For example, in the case of shared utensils after a water rinse, an individual with a baseline threshold of 30 mg peanut protein who increases their threshold to 300 mg, decreases their absolute risk of allergic reaction from 18.6% to 0.1% (Table 3), which corresponds to a relative risk reduction of 99.3%.

$$\left(1 - \frac{0.1}{18.6}\right) \times 100\% = 99.3\% \textit{ relative risk reduction}$$

Further relative risk reduction calculations are shown in Figure 4. Individuals who reach a threshold value of 300 mg peanut protein have a predicted relative risk reduction of 63.5% to 77.4% when consuming dishes prepared with uncleaned, shared cooking utensils, and a relative risk reduction of 80.4% to 91.1% when consuming dishes prepared with uncleaned, shared cooking woks/pans. Individuals who achieved a threshold value of 1000 mg peanut protein or more had modeled relative risk reductions of 91.0% to 98.0% (uncleaned utensils) and 97.0% to 99.7% (uncleaned woks/pans).

When focusing on utensils and woks/pans that had been briefly cleaned with warm water, individuals who reach a threshold value of 300 mg peanut protein had predicted relative risk reductions of 94.9% to 99.9% (utensils rinsed with warm water) and greater than 99.99% (woks/pans rinsed with warm water) when consuming dishes prepared with shared cooking materials. A brief scrub with a brush and warm water led to no predicted risk at baseline for individuals with a threshold value of greater than or equal to 30 mg peanut protein, and thus, no modeling of relative risk reduction was possible because of the lack of predicted risk at baseline. In the current simulation, individuals who achieved a threshold value of 1000 mg peanut protein or more were no longer predicted to be at a risk of an allergic reaction owing to dishes prepared with shared cooking utensils or shared woks/pans that had been rinsed with warm water (>99.99% risk reduction).

Additional "sauce dilution" studies were done by assuming the peanut sauce contamination on a shared utensil transferred into a 1- or 5-liter "peanut-free" sauce to be used later for servings of 35 g, 50 g, or 150 g of sauce for single-serve meal preparation. These sauce volumes and serving amounts were chosen from the recipes created by the chef for this study and normal sauce volumes for sauces in home and restaurant kitchens. In the sauce contamination simulations, "uncleaned utensil" refers to a sauce contaminated with an uncleaned utensil, whereas "postwater utensil"

Table 3
Risk Assessment Results (Absolute Risks) for Consumption of a Single-Serve Meal Contaminated With Peanut by Shared Cooking Materials

Scenario	Individual with peanut allergy's threshold value (mg peanut protein)						
	1 mg	3 mg	10 mg	30 mg	100 mg	300 mg	1000 mg
Utensils	100%	100%	98.7%	90.2%	61.8%	22.6%	2.0%
Utensils Postclean	95.9%	82.5%	50.2%	18.6%	2.4%	0.1%	NR
Wok/Pan	100%	100%	97.6%	83.6%	45.4%	8.9%	0.3%
Wok/Pan Postclean	12.0%	9.0%	1.3%	NR	NR	NR	NR

Abbreviation: NR, no reaction predicted.
NOTE. Presented as the percentage of eating occasions predicted to result in an allergic reaction. "Postclean" refers the use of utensil or wok/pan after the common cleaning procedure of a quick rinse in warm water (utensils) or a quick scrub with a brush and warm water (wok/pan).

Utensils - not cleaned	Achieved Threshold Dose (mg peanut protein)						
	1	3	10	30	100	300	1000
Baseline Threshold Dose (mg peanut protein) 1	0.0%	0.0%	1.3%	9.8%	38.2%	77.4%	98.0%
3		0.0%	1.3%	9.8%	38.2%	77.4%	98.0%
10			0.0%	8.6%	37.4%	77.1%	97.9%
30				0.0%	31.4%	75.0%	97.8%
100					0.0%	63.5%	96.7%
300						0.0%	91.0%
1000							0.0%

Utensils - Post-water Rinse	Achieved Threshold Dose (mg peanut protein)						
	1	3	10	30	100	300	1000
Baseline Threshold Dose (mg peanut protein) 1	0.0%	14.0%	47.7%	80.6%	97.5%	99.9%	>99.99%
3		0.0%	39.2%	77.4%	97.1%	99.8%	>99.99%
10			0.0%	62.9%	95.2%	99.8%	>99.99%
30				0.0%	87.0%	99.3%	>99.99%
100					0.0%	94.9%	>99.99%
300						0.0%	>99.99%
1000							NRB

Equipment - not cleaned	Achieved Threshold Dose (mg peanut protein)						
	1	3	10	30	100	300	1000
Baseline Threshold Dose (mg peanut protein) 1	0.0%	0.0%	2.4%	16.4%	54.6%	91.1%	99.7%
3		0.0%	2.4%	16.4%	54.6%	91.1%	99.7%
10			0.0%	14.3%	53.5%	90.9%	99.7%
30				0.0%	45.7%	89.4%	99.7%
100					0.0%	80.4%	99.4%
300						0.0%	97.0%
1000							0.0%

Equipment - Post-brief scrub with brush and warm water	Achieved Threshold Dose (mg peanut protein)						
	1	3	10	30	100	300	1000
Baseline Threshold Dose (mg peanut protein) 1	0.0%	25.1%	88.9%	>99.99%	>99.99%	>99.99%	>99.99%
3		0.0%	85.2%	>99.99%	>99.99%	>99.99%	>99.99%
10			0.0%	>99.99%	>99.99%	>99.99%	>99.99%
30				NRB	NRB	NRB	NRB
100					NRB	NRB	NRB
300						NRB	NRB
1000							NRB

Relative Risk Reduction Scale

Highest Risk						Lowest Risk

Figure 4. Relative risk reduction calculations owing to an increase in the threshold for individuals with peanut allergy consuming a single-serve restaurant/kitchen meal prepared with a utensil or cooking wok/pan previously used to prepare a dish peanut-containing sauce. NRB, no reaction predicted at baseline threshold dose.

refers to a sauce that was contaminated by a utensil that had previously been rinsed with warm water. Reactions were not predicted in any of the 4 sauce dilution scenarios for individuals with a 300- or 1000-mg peanut protein threshold (eTable 2 and eFig 3).

Discussion

The results of this study confirm the existence of risks to a consumer with peanut allergy when eating at restaurants that cook Asian-Indian style meals with shared equipment and utensils. In our experiments, rinsing with warm water significantly decreased the amount of peanut residue and, therefore, the risk of food contamination, but it did not completely remove all peanut protein. Based on previously published peanut-allergic threshold dose-distribution data,[34-37] the observed mean sauce transfer of 3 to 82 mg peanut protein from shared utensils after water rinsing is still predicted to cause reactions in roughly 10% to 50% of individuals with peanut allergy.

In comparison with previous studies, the predicted absolute risks of an allergic reaction per eating occasion of a single-serve meal contaminated by unwashed kitchen materials were higher than the risks predicted per eating occasion of a contaminated packaged food,[14,15] regardless of the individual threshold level observed. This is not surprising given the much higher contamination per eating occasion observed in this study. The larger predicted absolute risks could be expected for single-serve meals owing to the large amounts of sauce residue on uncleaned utensils or equipment potentially being used to directly prepare a "peanut-free" single-serve meal. However, if a brief wash with water was conducted, then the predicted absolute risks of an allergic reaction for single-serve meals were comparable with the absolute risks previously predicted in packaged foods.[14,15]

Avoidance of peanut is only an effective risk management strategy when peanut is clearly identifiable. However, avoidance is not always possible in either packaged foods or nonpackaged foods.[12,17,38,39] For nonpackaged foods, even in cases in which allergic individuals informed restaurant staff of an allergy, accidental or unexpected allergic reactions still occur.[12] In these cases in which informing the waitstaff did not prevent a reaction, a mistaken ingredient, shared cooking equipment or utensils, or a number of other factors could have played a role in an unexpected reaction. To date, no quantitative data were available for exposure scenarios in restaurant kitchens and for the potential risk reductions provided by therapy for peanut allergy. Individuals who achieve a threshold value of 300 mg peanut protein have predicted relative risk reductions of approximately 95% or higher for risk of an allergic reaction owing to dishes prepared with shared cooking utensils previously rinsed with warm water. In the worst-case scenarios of uncleaned, shared materials, individuals who achieve a threshold value of 300 mg peanut protein are predicted to have relative risk reductions of at least 63.5% and up to 91.1%. If a threshold of 1000 mg peanut protein is reached posttherapy, the predicted relative risk reduction increased to more than 91% in the worst-case scenarios with uncleaned, shared materials and these individuals were no longer predicted to be at a risk of an allergic reaction if shared cooking materials that had been rinsed with warm water. Although these modeled relative risk reductions are encouraging, it does not mean that individuals with peanut allergy undergoing immunotherapy or other potential treatments should disregard all cautions when eating out; rather, they should still avoid noticeably unclean kitchens and alert restaurant staff and individuals preparing the food that they have a peanut allergy.

Although not exactly the same, cooking at home does resemble cooking in restaurant kitchens to some extent. Whisks, spoons, and tongs are also common utensils for home cooking, and woks, pans, and mixing bowls are used at home for meal preparation as well. A quick cleaning, such as rinsing with warm water or a quick brush may be more practical than sanitation by dishwasher during the process meal preparation in a home cooking scenario. In the home kitchen, it is more likely that smaller size utensils and equipment are used, and these have been included in this study as well. In addition, our study covers the preparation of larger (5-L) and smaller (1-L) volumes of sauce, of which the smaller volume may better represent home cooking. Therefore, we believe that the current results on relative risk reduction are, to some extent, applicable for home cooking scenarios.

It is well known that reactions to meals outside the home are a common, potentially severe cause of allergic reactions,[12,13,28-30] but it is not clear how frequently exposures outside the home are actually occurring because many of these exposures will go unreported. Thus, 1 limitation of this study is that we were unable to incorporate the frequency of use of shared utensils and equipment in a home or restaurant kitchen because of data gaps surrounding this topic. The current data gap exists (for all food allergens) because it is difficult to conduct systematic, controlled, and comparable research across home and restaurant kitchens. Devising a cost-effective, controlled study to investigate the frequency of use of shared utensils and equipment at home or restaurant kitchens is an area of potential future research.

One additional potential limitation of this study is the use of defined threshold values at baseline and defined achieved threshold values. It is known that for an individual, threshold may vary slightly over time[40-42] because of external factors.[43,44] A recent study among 71 adults with peanut allergy revealed that repeating thresholds may vary up to 2-fold.[44] Yet, a double-blind, placebo-controlled food challenge is the definitive standard for food allergy diagnosis, and the change in threshold determined by a double-blind, placebo-controlled food challenge is used as the primary outcome of food allergen immunotherapy trials.[45,46] Therefore, we believe that investigating risk reduction by using a change in threshold is relevant.

Our study confirms and quantifies the existence of risks to a consumer with peanut allergy when eating at restaurants that cook Asian-Indian style meals with shared materials by quantification of risk from peanut protein potentially present on shared utensils and woks/pans. We conclude that achieving an eliciting dose of 300- or 1000 mg peanut protein is clinically relevant for the peanut-allergic population in all shared kitchen material scenarios studied.

Supplementary Data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.anai.2020.07.030.

References

1. Gupta RS, Warren CM, Smith BM, et al. The public health impact of parent-reported childhood food allergies in the United States. *Pediatrics*. 2018;142(6):e20181235.
2. Nwaru BI, Hickstein L, Panesar SS, et al. Prevalence of common food allergies in Europe: a systematic review and meta-analysis. *Allergy*. 2014;69(8):992–1007.
3. National Institute of Allergy and Infectious Diseases–Sponsored Expert Panel, Boyce JA, Assa'ad A, et al. Guidelines for the diagnosis and management of food allergy in the United States: report of the NIAID-sponsored expert panel. *J Allergy Clin Immunol*. 2010;126(6 Suppl):S1–S58.
4. Burks AW, Jones SM, Boyce JA, et al. NIAID-sponsored 2010 guidelines for managing food allergy: applications in the pediatric population. *Pediatrics*. 2011;128(5):955–965.
5. Muraro A, Werfel T, Hoffmann-Sommergruber K, et al. EAACI food allergy and anaphylaxis guidelines: diagnosis and management of food allergy. *Allergy*. 2014;69(8):1008–1025.
6. Shaker M, Greenhawt M. Peanut allergy: burden of illness. *Allergy Asthma Proc*. 2019;40(5):290–294.
7. Cherkaoui S, Ben-Shoshan M, Alizadehfar R, et al. Accidental exposures to peanut in a large cohort of Canadian children with peanut allergy. *Clin Transl Allergy*. 2015;5(1):16.
8. Yu JW, Kagan R, Verreault N, et al. Accidental ingestions in children with peanut allergy. *J Allergy Clin Immunol*. 2006;118(2):466–472.
9. Nguyen-Luu NU, Ben-Shoshan M, Alizadehfar R, et al. Inadvertent exposures in children with peanut allergy. *Pediatr Allergy Immunol*. 2012;23(2):133–139.

10. Clark AT, Ewan PW. Good prognosis, clinical features, and circumstances of peanut and tree nut reactions in children treated by a specialist allergy center. *J Allergy Clin Immunol*. 2008;122(2):286–289.
11. Sheikh A, Dhami S, Regent L, Austin M, Sheikh A. Anaphylaxis in the community: a questionnaire survey of members of the UK Anaphylaxis Campaign. *JRSM Open*. 2015;6(7):2054270415593443.
12. Michelsen-Huisman AD, van Os-Medendorp H, Blom WM, et al. Accidental allergic reactions in food allergy: causes related to products and patient's management. *Allergy*. 2018;73(12):2377–2381.
13. Clifford E. Victoria's Anaphylaxis Notification System. Available at: http://allergenbureau.net/wp-content/uploads/2019/05/CLIFFORD_2019-Presentation-Anaphylaxis-Notification-System-FAMS2019.pdf. Accessed December 2, 2019.
14. Baumert JL, Taylor SL, Koppelman SJ. Quantitative assessment of the safety benefits associated with increasing clinical peanut thresholds through immunotherapy. *J Allergy Clin Immunol Pract*. 2018;6(2):457–465.e4.
15. Remington BC, Krone T, Koppelman SJ. Quantitative risk reduction through peanut immunotherapy: safety benefits of an increased threshold in Europe. *Pediatr Allergy Immunol*. 2018;29(7):762–772.
16. Remington BC, Krone T, Kim EH, et al. Estimated risk reduction to packaged food reactions by epicutaneous immunotherapy (EPIT) for peanut allergy. *Ann Allergy, Asthma Immunol*. 2019;123(5):488–493.e2.
17. Remington BC, Baumert JL, Marx DB, Taylor SL. Quantitative risk assessment of foods containing peanut advisory labeling. *Food Chem Toxicol*. 2013;62:179–187.
18. Rimbaud L, Heraud F, La Vieille S, Leblanc J-C, Crepet A. Quantitative risk assessment relating to adventitious presence of allergens in food: a probabilistic model applied to peanut in chocolate. *Risk Anal*. 2010;30(1):7–19.
19. Rimbaud L, Heraud F, La Vieille S, Leblanc J, Crepet A. Quantitative risk assessment relating to the inadvertent presence of peanut allergens in various food products. *Int Food Risk Anal J*. 2013;3:4. https://doi.org/10.5772/56646, accessed August 17, 2020.
20. Robertson ON, Hourihane JO, Remington BC, Baumert JL, Taylor SL. Survey of peanut levels in selected Irish food products bearing peanut allergen advisory labels. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess*. 2013;30(9):1467–1472.
21. Fleischer DM, Greenhawt M, Sussman G, et al. Effect of epicutaneous immunotherapy vs placebo on reaction to peanut protein ingestion among children with peanut allergy: The PEPITES randomized clinical trial. *JAMA*. 2019;321(10):946–955.
22. Kim EH, Yang L, Ye P, et al. Long-term sublingual immunotherapy for peanut allergy in children: clinical and immunologic evidence of desensitization. *J Allergy Clin Immunol*. 2019;144(5):1320–1326.e1.
23. Tang MLK, Ponsonby AL, Orsini F, et al. Administration of a probiotic with peanut oral immunotherapy: a randomized trial. *J Allergy Clin Immunol*. 2015;135(3):737–744.e8.
24. PALISADE Group of Clinical Investigators, Vickery BP, Vereda A, et al. AR101 oral immunotherapy for peanut allergy. *N Engl J Med*. 2018;379(21):1991–2001.
25. U.S. Food and Drug Administration. FDA approves first drug for treatment of peanut allergy for children. Available at: https://www.fda.gov/news-events/press-announcements/fda-approves-first-drug-treatment-peanut-allergy-children. Accessed February 4, 2020.
26. Wasserman RL, Hague AR, Pence DM, et al. Real-world experience with peanut oral immunotherapy: lessons learned from 270 patients. *J Allergy Clin Immunol Pract*. 2019;7(2):418–426.e4.
27. Greenhawt M, Marsh R, Gilbert H, Sicherer S, DunnGalvin A, Matlock D. Understanding caregiver goals, benefits, and acceptable risks of peanut allergy therapies. *Ann Allergy Asthma Immunol*. 2018;121(5):575–579.
28. Xu YS, Kastner M, Harada L, Xu A, Salter J, Waserman S. Anaphylaxis-related deaths in Ontario: a retrospective review of cases from 1986 to 2011. *Allergy Asthma Clin Immunol*. 2014;10(1):38.
29. Bock SA, Muñoz-Furlong A, Sampson HA. Further fatalities caused by anaphylactic reactions to food, 2001-2006. *J Allergy Clin Immunol*. 2007;119(4):1016–1018.
30. Pumphrey RSH, Gowland MH. Further fatal allergic reactions to food in the United Kingdom, 1999-2006. *J Allergy Clin Immunol*. 2007;119(4):1018–1019.
31. Kwon J, Lee YM, Wen H. Knowledge, attitudes, and behaviors about dining out with food allergies: a cross-sectional survey of restaurant customers in the United States. *Food Control*. 2020;107:106776.
32. Furlong TJ, DeSimone J, Sicherer SH. Peanut and tree nut allergic reactions in restaurants and other food establishments. *J Allergy Clin Immunol*. 2001;108(5):867–870.
33. Versluis A, Knulst AC, Kruizinga AG, et al. Frequency, severity and causes of unexpected allergic reactions to food: a systematic literature review. *Clin Exp Allergy*. 2015;45(2):347–367.
34. Taylor SL, Baumert JL, Kruizinga AG, et al. Establishment of reference doses for residues of allergenic foods: report of the VITAL Expert Panel. *Food Chem Toxicol*. 2014;63:9–17.
35. Allen KJ, Remington BC, Baumert JL, et al. Allergen reference doses for precautionary labeling (VITAL 2.0): clinical implications. *J Allergy Clin Immunol*. 2014;133(1):156–164.
36. Ballmer-Weber BK, Fernandez-Rivas M, Beyer K, et al. How much is too much? Threshold dose distributions for 5 food allergens. *J Allergy Clin Immunol*. 2015;135(4):964–971.
37. Remington BC, Westerhout J, Meima MY, et al. Updated population minimal eliciting dose distributions for use in risk assessment of 14 priority food allergens. *Food Chem Toxicol*. 2020;139:111259.
38. Remington BC, Baumert JL, Blom WM, Houben GF, Taylor SL, Kruizinga AG. Unintended allergens in precautionary labelled and unlabelled products pose significant risks to UK allergic consumers. *Allergy*. 2015;70(7):813–819.
39. Blom WM, Michelsen-Huisman AD, van Os-Medendorp H, et al. Accidental food allergy reactions: products and undeclared ingredients. *J Allergy Clin Immunol*. 2018;142(3):865–875.
40. Crevel R, Moneret-Vautrin DA, Morisset M, Sheffield D, Taylor SL, Baumert JL. A preliminary analysis of the evolution of peanut thresholds over repeated challenges in a population of consecutive clinic patients. *J Allergy Clin Immunol*. 2010;125(2):AB84.
41. Nelson HS, Lahr J, Rule R, Bock A, Leung D. Treatment of anaphylactic sensitivity to peanuts by immunotherapy with injections of aqueous peanut extract. *J Allergy Clin Immunol*. 1997;99(6 Pt 1):744–751.
42. Glaumann S, Nopp A, Johansson SGO, Borres MP, Nilsson C. Oral peanut challenge identifies an allergy but the peanut allergen threshold sensitivity is not reproducible. *PLoS One*. 2013;8(1):e53465.
43. Turner PJ, Baumert JL, Beyer K, et al. Can we identify patients at risk of life-threatening allergic reactions to food? *Allergy*. 2016;71(9):1241–1255.
44. Dua S, Ruiz-Garcia M, Bond S, et al. Effect of sleep deprivation and exercise on reaction threshold in adults with peanut allergy: a randomized controlled study. *J Allergy Clin Immunol*. 2019;144(6):1584–1594.e2.
45. U.S. Food and Drug Administration. Allergenic Products Advisory Committee. FDA Briefing Document. Clinical development of allergen immunotherapies for the treatment of food allergy. Available at: https://www.fda.gov/media/95961/download. Accessed December 17, 2019.
46. Pajno GB, Fernandez-Rivas M, Arasi S, et al. EAACI guidelines on allergen immunotherapy: IgE-mediated food allergy. In: Muraro A, Roberts G, eds. *Allergen Immunotherapy Guidelines Part 2: Recommendations*. Zurich: European Academy of Allergy and Clinical Immunology; 2017:49–70.

Supplementary Data

Methods for Recipes

Detailed recipes of the 3 different sauces are provided in eTable 1.

Methods for Viscosity Measurement

The viscosity of the 3 sauces (sugar-based Pad Thai sauce, General Tso's sauce, and oil-based Indian coconut curry) was each measured in duplicate at 3 temperatures (18°C, 60°C, 100°C). A cup and big bob system with 25-mm bob probe recorded 600 measurements at intervals of 0.5 seconds over 5 minutes, whereas the shear rate increased from 0.1 to 100 per second (Anton Paar Physica MCR 301, Graz, Austria).

Results for Viscosity Measurement

The results for viscosity measurement are presented in eFigures 1 and 2.

Methods for Quantitative Risk Assessments

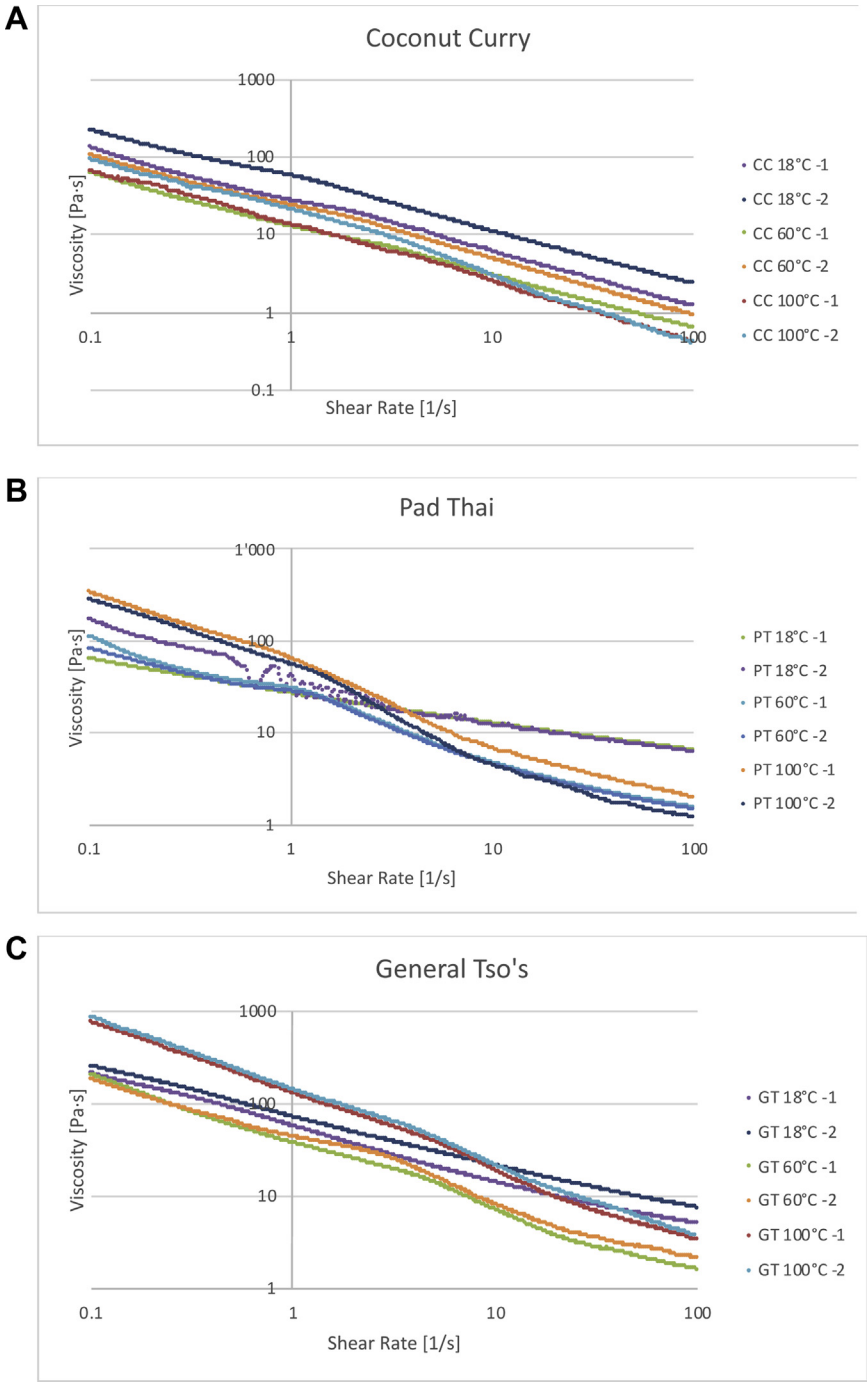
The quantitative risk assessments performed in this study incorporated the data acquired during the cooking experiments as inputs to predict the milligram exposure amount to residual peanut protein from shared kitchen utensils (whisks, tongs, spatulas, soup ladles, spoons) or equipment (wok, saucepan). Similar to previous methodologies,[1,2] the Monte-Carlo–based risk models used in this study simulated 100,000 randomly calculated exposure doses and compared them with a constant threshold dose of 1, 3, 10, 30, 100, 300, or 1000 mg of peanut protein to determine if there was a risk of an allergic reaction. These milligram peanut protein amounts for individual clinical thresholds were representative of milligram protein amounts in the Joint American and European guidelines for double-blind, placebo-controlled, food challenges[3] and are representative of the individual thresholds doses for individuals with peanut allergy in graded food challenges.[4] Conservatively, it was assumed that all the peanut protein transferred into the next restaurant/kitchen single-serve meal was consumed by the individual with peanut allergy. An allergic reaction was predicted to occur if the exposure dose (mg of peanut protein) was greater than the individual threshold dose (mg of peanut protein). This process of simulating 100,000 eating occasions was then repeated 50 times for a total of 5,000,000 simulated eating occasions for each individual threshold value, resulting in the percentage of risk for allergic reactions at the indicated peanut threshold.

eTable 1
Recipes for the 3 Sauces Containing Peanut by Recipe Used in Kitchen-Based Experiments

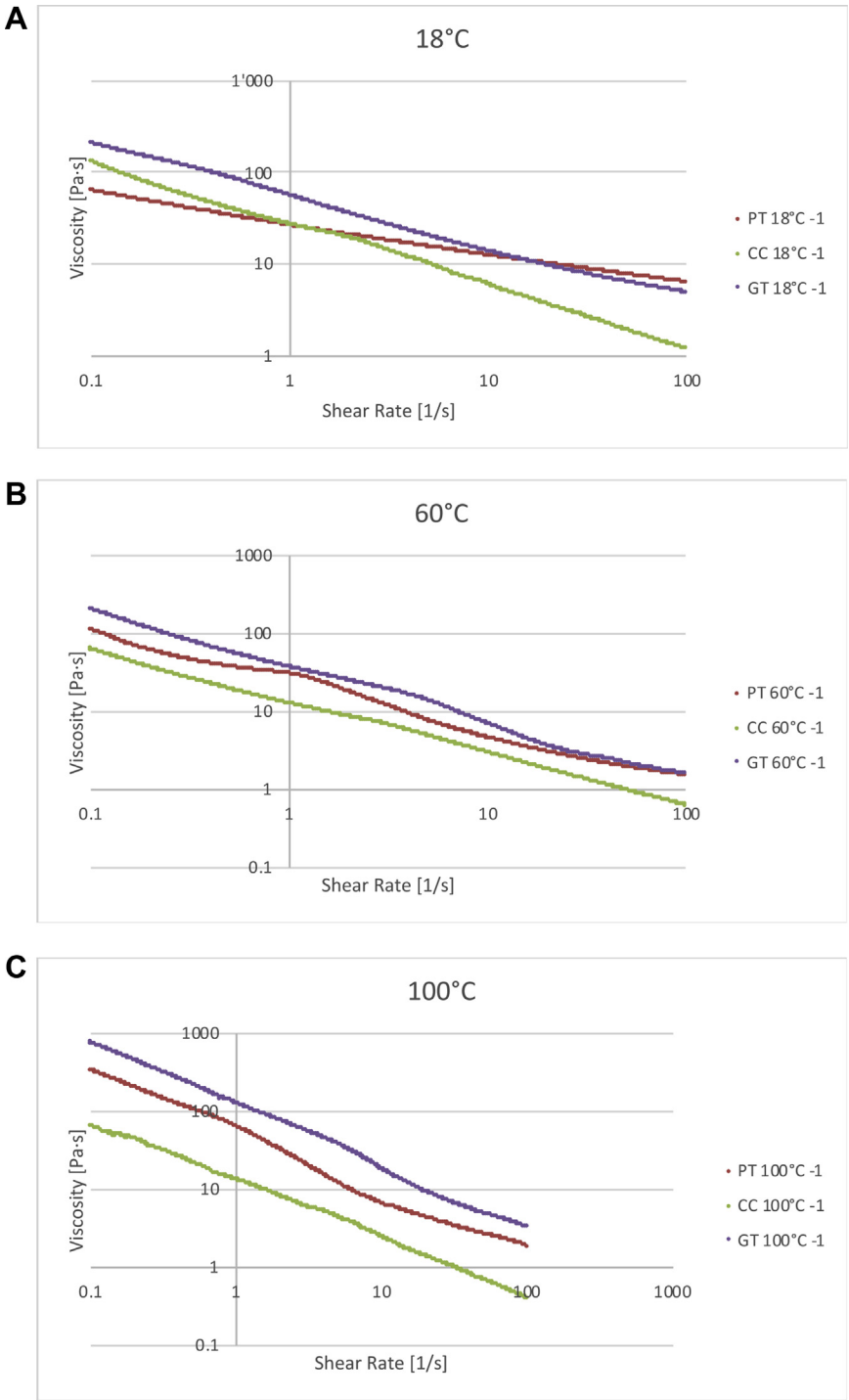
	Ingredient	% Weight of total recipe	% Peanut protein in total recipe
Sugar-based Pad Thai sauce			
125 g	Creamy peanut butter	34%	8.5%
120 g	Honey	32%	
45 g	Soy sauce	12%	
30 g	Rice vinegar	8%	
20 g	Extra virgin olive oil	5%	
10 g	Sesame oil	3%	
10 g	Minced fresh garlic	3%	
7.5 g	Minced fresh ginger root	2%	
2 g	Crushed red pepper flakes	1%	
Sugar-based General Tso's sauce			
600 g	Creamy peanut butter	39.5%	9.9%
400 g	Soy sauce	26%	
200 g	Honey	13%	
150 g	Molasses (goela djawa)	10%	
60 g	Vinegar	4%	
50 g	Sesame oil	3%	
30 g	Minced fresh garlic	2%	
30 g	Hot sauce (Siracha)	2%	
Oil-based Indian coconut milk curry sauce			
800 g	Chicken broth	30%	
800 g	Coconut milk	30%	
500 g	Creamy peanut butter	18.6%	4.6%
240 g	Ketchup	9%	
220 g	Red curry paste	8%	
40 g	Vegetable oil	1%	
30 g	Corn starch	1%	
30 g	Water	1%	
30 g	Molasses (goela djawa)	1%	

For easy comparison with previous studies,[1,2] the results of this study are presented as the individual with peanut allergy risk or the probability of a reaction occurring when it is conservatively assumed that all individuals have peanut allergy and all consume a product that contains unintended peanut residue during every eating occasion.

In addition, it is well known that individuals with peanut allergy are not likely to frequent Asian restaurants every day or cook at home every day with peanut-based sauces and shared cooking materials; thus, the risks in everyday life would be lower than those presented in this study. However, these conservative estimations do allow for the calculation of the predicted absolute risk when consuming a meal contaminated with peanut owing to shared cooking materials. Further calculation of the predicted relative risk reduction owing to an increased threshold of reaction after peanut immunotherapy is also possible.



eFigure 1. The viscosity of the 3 sauces. (A) oil-based Indian coconut curry, (B) sugar-based Pad Thai sauce, and (C) sugar-based General Tso's sauce. The sauces were measured in duplicate at 3 temperatures (18°C, 60°C, 100°C). CC, coconut curry; GT, General Tso's; PT, Pad Thai.



eFigure 2. The viscosity of the 3 sauces at temperatures (A) 18°C, (B) 60°C, and (C) 100°C. CC, coconut curry; GT, General Tso's; PT, Pad Thai.

Results for Quantitative Risk Assessment for the Consumption of Sauces

eTable 2

Risk Assessment Results (Absolute Risks) for Consumption of a Single-Serve Restaurant/Kitchen "Peanut-Free" Meal Prepared With Random Selections of 35-g, 50-g, or 150-g of a Sauce That Has Been Contaminated by a Shared Utensil Previously Been Used to Prepare a Peanut-Containing Sauce

Scenario	Individual with peanut allergy's threshold value (mg peanut protein)						
	1 mg	3 mg	10 mg	30 mg	100 mg	300 mg	1000 mg
1-L sauce: uncleaned utensil	98.3%	90.5%	60.5%	24.3%	2.8%	NR	NR
1-L sauce: postwater utensil	50.8%	20.3%	3.7%	0.3%	NR	NR	NR
5-L sauce: uncleaned utensil	81.2%	44.3%	12.1%	1.5%	NR	NR	NR
5-L sauce: postwater utensil	10.9%	1.6%	NR	NR	NR	NR	NR

Abbreviation: NR, no reaction predicted.

NOTE. Presented as the percentage of eating occasions predicted to result in an allergic reaction. Sauces of 1 L and 5 L were chosen in relation to home and restaurant kitchen volumes. "Uncleaned utensil" refers to a sauce contaminated with an uncleaned utensil, whereas "postwater utensil" refers to a sauce that was contaminated by a utensil previously been rinsed with warm water.

1-L Sauce: Uncleaned utensil		**Achieved Threshold Dose (mg peanut protein)**						
		1	**3**	**10**	**30**	**100**	**300**	**1000**
Baseline threshold dose (mg peanut protein)	**1**	0.0%	8.0%	38.5%	75.3%	97.1%	>99.99%	>99.99%
	3		0.0%	33.2%	73.1%	96.9%	>99.99%	>99.99%
	10			0.0%	59.8%	95.4%	>99.99%	>99.99%
	30				0.0%	88.5%	>99.99%	>99.99%
	100					0.0%	>99.99%	>99.99%
	300						NRB	NRB
	1000							NRB

1-L sauce: Postwater utensil		**Achieved threshold dose (mg peanut protein)**						
		1	**3**	**10**	**30**	**100**	**300**	**1000**
Baseline threshold dose (mg peanut protein)	**1**	0.0%	60.0%	92.7%	99.4%	>99.99%	>99.99%	>99.99%
	3		0.0%	81.7%	98.6%	>99.99%	>99.99%	>99.99%
	10			0.0%	92.2%	>99.99%	>99.99%	>99.99%
	30				0.0%	>99.99%	>99.99%	>99.99%
	100					0.0%	NRB	NRB
	300						0.0%	NRB
	1000							NRB

eFigure 3. Relative risk reduction calculations owing to an increase in the threshold for individuals with peanut allergy consuming a single-serve restaurant/kitchen "peanut-free" meal prepared with a sauce that has been contaminated by a shared utensil previously been used to prepare a peanut-containing sauce. "Uncleaned utensil" refers to a sauce contaminated with an uncleaned utensil, whereas "postwater utensil" refers to a sauce that was contaminated by a utensil previously been rinsed with warm water. NRB, no reaction predicted at baseline threshold dose.

5-L sauce: Uncleaned utensil		Achieved Threshold Dose (mg peanut protein)						
		1	3	10	30	100	300	1000
Baseline Threshold Dose (mg peanut protein)	1	0.0%	45.5%	85.1%	98.2%	>99.99%	>99.99%	>99.99%
	3		0.0%	72.7%	96.7%	>99.99%	>99.99%	>99.99%
	10			0.0%	87.7%	>99.99%	>99.99%	>99.99%
	30				0.0%	>99.99%	>99.99%	>99.99%
	100					0.0%	NRB	NRB
	300						0.0%	NRB
	1000							NRB

5-L sauce: Postwater utensil		Achieved threshold dose (mg peanut protein)						
		1	3	10	30	100	300	1000
Baseline threshold dose (mg peanut protein)	1	0.0%	85.5%	99.9%	>99.99%	>99.99%	>99.99%	>99.99%
	3		0.0%	99.2%	>99.99%	>99.99%	>99.99%	>99.99%
	10			0.0%	>99.99%	>99.99%	>99.99%	>99.99%
	30				0.0%	NRB	NRB	NRB
	100					0.0%	NRB	NRB
	300						0.0%	NRB
	1000							NRB

Relative risk reduction scale

Highest Risk						Lowest Risk

eFigure 3. (*continued*).

eReferences

1. Baumert JL, Taylor SL, Koppelman SJ. Quantitative assessment of the safety benefits associated with increasing clinical peanut thresholds through immunotherapy. *J Allergy Clin Immunol Pract*. 2018;6(2):457–465.e4.
2. Remington BC, Krone T, Koppelman SJ. Quantitative risk reduction through peanut immunotherapy: safety benefits of an increased threshold in Europe. *Pediatr Allergy Immunol*. 2018;29(7):762–772.
3. Sampson HA, Gerth van Wijk R, Bindslev-Jensen C, et al. Standardizing double-blind, placebo-controlled oral food challenges: American Academy of Allergy, Asthma & Immunology-European Academy of Allergy and Clinical Immunology PRACTALL consensus report. *J Allergy Clin Immunol*. 2012;130(6):1260–1274.
4. Taylor SL, Baumert JL, Kruizinga AG, et al. Establishment of reference doses for residues of allergenic foods: report of the VITAL Expert Panel. *Food Chem Toxicol*. 2014;63:9–17.