Economia agro-alimentare /
Food Economy
An International Journal on Agricultural and Food Systems
Vol. 28, Iss. 1, Art. 8, pp. 41-65 - ISSNe 1972-4802
DOI: 10.3280/ecag2026oa20287

Exploring Red Kidney Bean Flour as Partial Substitute to Rice Flour in Gluten-free Ramen Noodles: Consumers' WTP in Thailand

Chaowana Phetcharat[a], Jeffrey D. Vitale[*,b], Pavalee Chompoorat Tridtitanakiat[c], Wanlanai Saiprasert[d], Weirong Lu[b]

[a] Faculty of Economics, Chiang Mai University, Thailand
[b] Ferguson College of Agriculture, Oklahoma State University, United State of America
[c] Faculty of Agro-Industry, Chiang Mai University, Thailand
[d] Department of Management and Entrepreneurship, Chiang Mai University, Thailand

Abstract

This study aims to elicit consumers' willingness to pay (WTP) for gluten-free ramen noodles, exploring the alternative flour formulation of red kidney bean (RKB) to substitute for rice flour. Using the experimental method, first-price auction, with adult consumers as participants, truncated regression was applied to identify the WTP bids for three types of gluten-free ramen noodles. The findings reveal that the WTP bids for rice kernel and 30% RKB flour-based ramen noodles are not significantly different, whereas consumers would pay 12.56 baht/150 g less for the 40% RKB flour item compared to the rice kernel item. The results also suggest that participants in the experiments would pay 15.452 baht/150 g less for the 40% RKB flour item compared to the 30% RKB flour item. These results underscore the 30% RKB flour is the optimal formulation for producing gluten-free ramen noodles to substitute for rice flour. This study also highlights the distinct preferences across individual characteristics and nutritional concerns, which underscores the potential for developing ramen noodles to satisfy consumer preferences beyond celiac concerns – providing food nutrition and improving well-being of consumers through dietary choices.

Article info

Type:
Article
Submitted:
28/05/2025
Accepted:
19/03/2026
Available online:
17/04/2026

JEL codes:
D12, D44, D91, Q13

Keywords:
Experimental auction
Gluten-free
Nutrition
Ramen noodles
Red kidney bean
Willingness to pay

* *Corresponding author*: Jeffrey D. Vitale - Department of Agricultural Economics, Ferguson College of Agriculture, Oklahoma State University - 418 Ag Hall, Stillwater, OK, 74078, U.S.A. E-mail: jeffrey.vitale@okstate.edu.

1. Introduction

A notable recent global trend toward finding substitutes for basic food ingredients has been driven by several compelling factors (Wang & Jian, 2022). One significant catalyst for this shift is food security, which has garnered increasing concern among consumers, with gluten being a particularly crucial aspect. In recent years, there has been an increase in the number of people suffering from celiac disease due to gluten-related disorders, which may lead to inflammation and complications (Lebwohl *et al*., 2018). This results in patients with celiac disease having new needs, such as reducing the risk of noncommunicable diseases (NCDs) and improving their health and the economic aspects of nutrition. Gluten-free food products, which are in increasing demand, are becoming a prospective market segment. Based on the average growth rate of 12.3% from 2009 to 2014 across various countries in Europe, America, and Asia, the gluten-free food market was forecasted to increase annually by 11% by 2020 (Lobanov *et al*., 2018). And, the market of gluten-free products is estimated to grow from USD 6.3 billion to USD 12.4 billion by 2035, with baked goods, infant formula, ready meals, and pasta being important such products in the market (Future Market Insights, 2025). Corresponding shifts in number of diagnosed coeliac patients suggest that gluten-free products potentially appeal to the individuals owing to their perceived health benefits. However, Bathrellou *et al.* (2025), Gorgitano and Sodano (2019), Guennouni *et al.* (2019), Hassan *et al.* (2024), and Jamieson *et al.* (2018) identified consumption constraints limiting access to gluten-free products, with individuals with gluten sensitivity or celiac disease often facing challenges regarding the unavailability, quality, and affordability of gluten-free products. Gorgitano and Sodano (2019) found that only 44% of the 212 stores in their sample offered these specialized products. Gorgitano and Sodano's (2019) study in Italy revealed that the average price of gluten-free pasta is 2.5 times higher (USD 0.427/100 g) than that of regular pasta, with the price premium ranging from 7.92% ($0.018/100 g) to a significant 31.4% (USD 0.710/100 g).

Despite these price differentials, the demand for gluten-free products, accounting for 14% of pasta consumption, appeared to far surpass dietary safety needs, since less than 1% (0.34%) of the Italian population is genuinely gluten-intolerant. Globally, there is a growing emphasis on healthier and more secure lifestyles, which has resulted in an increasing demand for innovative functional foods, such as nutrient-rich and non-allergenic food products. Alsubhi *et al.* (2022) provided a comprehensive summary of the research findings from numerous studies investigating consumers' willingness to pay (WTP) for healthier products. Of the 26 experiments reviewed in their study, 88.5% revealed a price premium for healthier foods encompassing

attributes such as lower fat, sodium, sugar, and cholesterol, and their various combinations. The observed WTP premiums ranged from 5.6% to 91.5%, with an average of 30.7%. Nganje *et al.* (2008) found the highest WTP premium to be for reduced-fat bread (USD 2.27/100 g) in USA. Jurado and Gracia (2017) found the lowest WTP to be on reduced saturated fat breakfast cereal (USD 0.42/100 g)[1] in Spain. De-Magistris and Lopéz-Galán (2016) found that Spanish consumers were willing to pay an additional 7.2% (USD 0.175/100 g) for cheese labeled as having lower fat content than traditional cheese. Similarly, Di Vita *et al.* (2016) estimated a WTP premium of 21.36% (USD 0.052/100 g) for reduced-salt bread compared to conventional bread.

A promising alternative to wheat is red kidney bean (*Phaseolus vulgaris* L.) (RKB), a gluten-free pulse that enhanced nutritional benefits, including being an excellent source of fiber, protein, and other micronutrients (Chompoorat *et al.*, 2018a; Hangen and Bennink, 2002). The red kidney bean flour is a high potent pseudo-cereal for improving protein and fiber levels in gluten-free products. Food nutritionists emphasize the nutritional value of legumes, characterizing them as wholesome, nutrient-dense, and high-protein food choices, capable of reducing the risk of heart disease and stroke (Margier *et al.*, 2018; Tharanathan & Mahadevamma, 2003). The use of non-meat-based proteins, such as beans and pulses, is an affordable means of improving nutrition among households in developing countries. Simultaneously, there is a heightened awareness of sustainability issues throughout the entire supply chain, extending from farm to fork. An illustrative example of this is the multitude of benefits that legumes offer across diverse domains. Replacing meat and dairy products with legumes provides an opportunity to alleviate the strain on agricultural resources and mitigate greenhouse gas emissions associated with livestock management (Day, 2013; Davis *et al.*, 2010; Jones & Ejeta, 2016; Röös *et al.*, 2017). Legumes can serve as viable meat and gluten alternatives, addressing consumer preferences and health benefit of dietary allergenic proteins, in addition to their environmental benefits (Bellarby *et al.*, 2013; Gao *et al.*, 2018). This transition to functional foods, such as gluten-free products and non-meat based proteins, aligns with the broader push for sustainability in the food industry, promoting food security and more environmentally responsible food system. Embracing these changes proactively allows the industry to meet evolving demands and contribute to sustainable and resilient food systems on a global scale.

1. EUR 1 approximately equals to USD 1.133 in May 2025 (European Central Bank, 2025).

1.1. *Focus of the study*

Ramen noodles are popular food products, especially in Asia, because they are quick, convenient, and easy to cook, with a long shelf life. Based on recent statistics, 121.2 billion servings of ramen noodles were consumed worldwide, totaling USD 21 million in 2022 (Global Industry Analysts, 2023; World Instant Noodles Association, 2023). Ramen noodles are manufactured using wheat flour that contains gluten as their main ingredient. Although there is an increasing demand for food products using substitutes of traditional wheat flour, manufacturers' search for profitable substitute ratios has been difficult because of properties of wheat such as viscoelasticity, which provide baking benefits, including a desirable texture, taste, and other qualities not found in other grains and legumes (Capriles *et al*., 2014; Chompoorat *et al*., 2018b). Nonetheless, several studies have demonstrated the potential feasibility of substituting wheat with other processed flours. For example, Ouazib *et al*. (2016) observed that processed rather than raw chickpeas were an improved substitute for wheat in bread when mixed at a 10% substitution rate. Awolu (2017) suggested that the composite flour with 85% pearl millet flour in addition to kidney beans and tigernut flours could be used as an alternative flour to the 100% wheat flour in bread. In addition, Chompoorat *et al*. (2020) reported that the combination of RKB flour with rice flour forms a different dough structure owing to the higher protein content and presence of amylose and amylopectin. However, the pursuit of such attributes – flavor and texture profiles – may entail additional processing steps (Gao *et al*., 2018), resulting in elevated production costs.

On the consumer front, the purchase decision depends not only on the price of goods and income but also on sociodemographic factors such as age, gender, and education (Croson and Gneezy, 2009; Perrin *et al*., 2019; Sgroi *et al*., 2024). Sgroi *et al*. (2024) reported that the frequency of consumption of functional foods is influenced by sociodemographic factors such as age, gender, and income. Furthermore, extensive literature indicates that consumers' preferences and expectations regarding foods are often associated with their nutritional value and sensory aspects, particularly taste, texture, and smell (Alencar *et al*., 2021; Diep *et al*., 2014; Fu, 2008; Hatcher *et al*., 2014; Liu *et al*., 2019; Miskelly & Moss, 1985; Smewing, 2016). Hence, the use of substituting ingredients can address these challenges, meet consumer preferences, and offer potential benefits to the food industry.

In rice-producing countries, such as Thailand, rice flour is used as a substitute for wheat flour in ramen noodles, but only in small markets. To the best of our knowledge, no study has directly examined consumer WTP for gluten-free ramen noodles in Thailand and Asia. This study aims to (1) investigate associations between consumers' WTP values,

demographic factors, and consumers' nutritional concerns, and (2) verify WTP estimate differences between three flour-based formulations of gluten-free ramen noodles. An experimental method (auction) was employed to elicit consumers' WTP bids. This study presents initial evidence of Thai consumers' WTP for different types of ramen noodles. The experimental auctions provide non-hypothetical preference data, enabling insights into consumer acceptance of the flour formulations. The findings aim to inform businesses in designing and developing innovative products that support healthier diets and improve consumers' nutritional well-being.

To familiarize the reader with experimental auctions and WTP studies, the following subsection (Section 2) describes the development of such approaches based on a review of recent methodological developments and the experimental method. The experimental designs and regression model are presented and discussed in Section 3. Section 4 reports the results of the experimental auctions and discusses the findings and compares them with previous studies. Conclusions and suggestions for further research are presented in the final section.

2. Background on experimental auction

Experimental auctions have been applied in food valuation literature to determine consumers' willingness-to-pay value for market and non-market goods – which are a non-hypothetical and incentive-compatible choice experiments – in which individuals exchange real money for real goods. Unlike the state-preferences surveys which elicits consumers' WTP from hypothetical choices, the auction mechanism incentivize participants to place bids to reveal their true preferences (Canavari *et al*., 2018; Fox *et al*., 1998; Lusk *et al*., 2001). This experimental method can be applied to examine biding behavior of the consumers and understand the factors influencing consumers' WTP bid for a good (e.g., Alemu & Olsen, 2020; Bernard *et al*., 2006; Huffman *et al*., 2003; Lee *et al*., 2011; Lusk *et al*., 2001; Rousu *et al*., 2004).

Various auction mechanisms have been used to elicit valuations, including first-price, second-price, (random) *n*th-price auctions, and the Becker-DeGroot-Marschak (BDM) mechanism. Selecting an appropriate auction format is an important methodological consideration because each mechanism possesses distinct properties that needs to be considered (Canavari *et al*., 2018; Lusk *et al*., 2001; Lusk and Shogren, 2007). Canavari *et al*. (2018) found that the second-price auction is the most frequently used format, followed by the BDM and (random) *n*th-price auction mechanisms. A Vickrey second-price auction encourages participants to bid their

true maximum WTP; however, it may not fully capture the preferences of participants whose bids fall outside the market-clearing price range. In contrast, a randomness in the *n*th-price auction absorbs off-margin bids and motivates participants to reveal their private bids closer to market clearing price (Canavari *et al.*, 2018; Huffman *et al.*, 2003; Lusk *et al.*, 2001; Shogren *et al.*, 2001).

Despite this advantage, the *n*th-price format can be costly, as the number of units sold increases with the value of *n*. The BDM mechanism is often preferred by researchers who wish to avoid the logistical challenges of bringing participants together at the same time and place (Canavari *et al.*, 2018). However, concerns regarding potential biases persist, as valuation outcomes may depend on the underlying distribution of the randomly generated comparison prices (Vassilopoulos *et al.*, 2018, as cited in Canavari *et al.*, 2018).

When the objective is to elicit valuations for products that are new or not yet available in the market – and when only a single trial can be conducted – the first-price auction may provide a suitable approximation of consumers' WTP (Lusk *et al.*, 2001). In this mechanism, the winning bidder purchases the product at their bid price using real money, which motivates participants to bid cautiously and sincerely. Although first-price and second-price bids may converge under assumptions of risk neutrality and independent private valuations, the second-price auction often requires repeated trials, which may lead to confusion among participants unfamiliar with auction procedures (Lusk *et al.*, 2001).

In this research, ramen noodles made from red kidney bean (RKB) flour are a new product that is unfamiliar to consumers and not yet commercially available, while rice kernel–based products are found only in a limited number of health food stores. A single-trial auction was used to examine consumers' WTP for each type of gluten-free ramen noodles with participants who had little prior experience with auction mechanisms. Therefore, the first-price seal bid auction is an essential component of this study. In order to observe the effect of consumer demographics and concerns on nutritional profiles on participants' behavior in the experiment, demographic variables and scale-based measures of participants' nutritional concerns were incorporated as predictors of WTP. This indirect method provides a causal interpretation of the effects of individual characteristics on consumer preferences and enhances the precision of WTP estimates (Canavari *et al.*, 2018; Lusk *et al.*, 2001).

3. Material and methods

Primary data were collected using a laboratory experimental auctions. This approach allows researchers to elicit consumers' WTP for gluten-free ramen noodles by controlling for key constituents of the market. Auctions were conducted mainly at Chiang Mai University, Thailand, from June to July, 2019. Participants were recruited using several methods, including word-of-mouth, phone, social media posts, and flyers placed at the entrances of common areas in the office buildings of Chiang Mai University. The study questionnaire was piloted in March and April 2019, and the adjusted version was submitted to the Chiang Mai University Research Ethics Committee for ethical review and approval[2]. During the recruitment process, participants were told they would be paid 200 baht cash, of which 100 baht was given for their time as a gift, and another 100 baht was provided for them to use to make a purchase of a product[3]. Participants were also informed that they would learn about the auction mechanism through a practice round to ensure their understanding of the experimental procedure.

3.1. *Study's experimental design and sample size*

In the experiment, three types of gluten-free ramen noodles were conducted to access the mean difference in consumers' WTP for flour-based formulations. Six experimental sessions were conducted with two sessions for each ramen flour-based formulation. The sample size per flour treatment was calculated using the optimum sample arrangement – Sixteen S-squared over D-squared – proposed by previous studies (Canavari *et al*., 2018; Drichoutis *et al*., 2015; Lehr, 1992; List *et al*., 2011; Noordzij *et al*., 2010). This standard approach was applied to our study by using a Type I error level (alpha) of 0.01, a statistical power of (1 – *beta*) 0.90, and a 10-unit standard deviation change in the mean bids between flour-based items. The minimum sample size per treatment was therefore 30 (see Appendix, Table 1 for the sample size calculation). While the experiment was designed to have 30 participants in each flour-based treatment; some recruited participants might not show up in a given session. Hence, 15-18 individuals were recruited on average for each auction session to account for possible no-

2. This research was approved by the Chiang Mai University Research Ethics committee in CMUREC No. 62/049.

3. 1 THB (baht) approximately equals to 0.033 USD in November 2025 (Bank of Thailand, 2025).

shows. A total of 105 individuals aged 18-70 years participated in the study, with 35 participants per treatment. This recruited number was also aligned with the sample size calculated based on power and alpha values of 0.95 and 0.01, respectively.

The recruited participants were randomly assigned into experimental sessions without being given any information about the product details. Prior to the experiment, the participants were told that they could participate in only one experimental session. The experiment followed a between-subject design, in which participants evaluated only one type of product treatment (Charness *et al.*, 2012). This is similar to what would occur in a real market setting for new and/or healthy products, such as in bistros and restaurants, where not many gluten-free food options are available. The randomization procedure of the study is also supported by the Neyman-Rubin model of causal inference, which notes that a within-subject design does not provide a causal interpretation of the treatment effect due to confounding responses from the same individual under both control and treatment conditions. Conversely, the between-subject design with the proper randomization is considered an unbiased estimate of the causal effect that the research wants to isolate (Rubin, 1974, as cited in Briz *et al.*, 2017; Canavari *et al.*, 2018).

We acknowledge of the study's limitations related to the efficient estimation and inference of the results for the broader population based on a small group of samples. However, an equal number of participants per treatment and a larger sample size than the number of model predictors would provide sufficient power to estimate the treatment effect on the outcome of this pilot study. In addition, the observations collected for this study met the minimum requirements, ensuring an acceptable level of statistical power and detectable effect size (Drichoutis *et al.*, 2015, as cited in Briz *et al.*, 2017).

3.2. *Experimental trial and flour-based treatments*

In the auction, three types of gluten-free ramen noodles were prepared for the experimental trials: pure rice kernel flour and two blended alternatives with different proportions of RKB flour (30% and 40% RKB flour-based formulations). The cooked gluten-free ramen noodles were placed in disposable plastic bowls and served to the participants along with a manufactured non-gluten free item. The manufacturing of non-gluten-free ramen noodles primarily uses wheat flour; these noodles have long been available in the market and are commonly consumed in Asia. A conventional non-gluten-free item was used as a benchmark product to help consumers

compare the characteristic differences between gluten- and non-gluten-free products. The manufactured non-gluten-free item was presented to subjects with its label removed to avoid the effect of brand reputation on consumers' WTP, whereas the gluten-free item was labeled with its weight and product flour composition. Information about the average market price per package of 150 g of manufactured non-gluten-free ramen noodles (42 baht) was provided to the participants.

For each session, participants were informed that Ramen A was a non-gluten-free product made from wheat flour and contained gluten, whereas Ramen B/C/D did not contain gluten and was made from pure rice kernel, 30% RKB or 40% RKB flour-based formulations, respectively. The participants received information about gluten: that it is a protein found in wheat, barley, and rye (Lebwohl *et al*., 2017). Gluten can pose health risks to patients with celiac disease, who are sensitive to gluten. To verify WTP differences among three types of gluten-free ramen noodles, participants in the experimental trial were asked to submit only their bids for the gluten-free item (Ramen B/C/D) beginning at zero. The experimental auction involved several steps, which are explained in the next subsection.

3.3. *Participant activities in the auction session*

After the participants arrived and registered for the experiment, the auction was conducted in the following five steps:

Step 1: Each participant was given an ID number to maintain anonymity and assigned a seat. The seats were placed far apart to ensure that the participants were unable to communicate with one another.

Step 2: The study monitors welcomed the participants and provided details of the research project and experimental auction procedure. Once the participants signed a consent form, the study monitor asked them to complete the first part of the questionnaire, which consisted of questions on their demographics and concerns regarding food nutritional profiles.

Step 3: After the participants completed the pre-auction questionnaire, a warm-up round auction of a napkin was conducted. Participants were asked to examine the napkin and provide the WTP bid for the product that they would purchase using the given 100 baht. Once the participants provided a written WTP bid, the study monitors collected a sealed bid from all the participants and announced the highest bid. The bids were written on a whiteboard. The winner of the auction paid the highest bid, that is, their own bid, in exchange for the napkin. At this stage, the participants were encouraged to clarify the auction methods before proceeding to the real auction round.

Step 4: Following the warm-up round, the first-price auction for specific flour formulations of gluten-free ramen noodles was conducted: (1) rice kernel flour, (2) 30% RKB-blended flour, and (3) 40% RKB-blended flour. In this session, cooked ramen noodles were served along with the manufactured items. After experiencing the products, the participants were asked to submit their bids for the gluten-free item in that experimental trial.

Step 5: Session monitors collected and ordered the bids from highest to lowest. The highest and second highest bids in that session were announced. Those who gave the highest bid were the winners of the trial and paid their bid in exchange for a 150 g pack of gluten-free ramen noodles.

3.4. *Econometric model*

In the survey, demographic variables and scale-differential questions regarding participants' concerns regarding nutritional profiles were used to quantify the WTP values. Participants' concerns regarding protein content, saturated fat content, and gluten-related ingredients were elicited using a scale between 1 and 10. A value of 1 indicates the participant is not concerned about these nutritional values at all, whereas a score of 10 is given if the participant is extremely concerned. Initially, the study included other variables, such as participants' average years of schooling, income, concern regarding carbohydrate and sodium contents, and interaction variables between demographics and nutritional concern, as the components of an explanatory variable, but only the five variables stated above were included in the model. Model selection was based on the Schwarz criterion – Bayesian Information criterion (data available upon request from the authors). In accordance with the study's sample size, the Schwarz criterion penalizes the loss of degrees of freedom resulting from the addition of variables to the model (Greene, 2008; Schwarz, 1978). The study also used the Variance Inflation Factor and White's tests to detect multicollinearity problems and heteroskedasticity. The test results revealed no collinearity between the independent variables and failed to reject the null hypothesis of homoskedasticity.

In the regression model, participants' WTP bids were set as dependent variables, and two demographic variables (age and gender) and three questions on participants' concerns regarding food nutritional profiles (protein content, saturated fat content, and gluten-related ingredients) were included in the x vector. During the experiments, none of the participants placed negative or zero bids, and the bids for all flour treatments were consequently truncated above zero, in which the Ordinary Least Squares estimator was not an appropriate approach (Amore & Murtinu, 2019; Green,

2008; Wilson & Tisdell, 2002). Therefore, a truncated regression was applied to identify the WTP bids, which was formulated as:

$$WTP_{i,j} = \alpha_0 + \sum_{k=1} \beta_k X_{k,i} + \sum_{n=1} \delta_n Z_{n,i} + \sum_{j=1} \psi_j TR_j + e_{i,j} \quad (1)$$

where the existing variables $WTP_{i,j}$ represents the bidding price of participant i for ramen noodles that made from flour-based formulation j ϵ {rice kernel, 30% RKB blend, and 40% RKB blend}; $X_{k,i}$ is the kth explanatory variable for participant demographics (k = 1, 2 for age and male gender, respectively); $Z_{n,i}$ indicates participants' concern regarding nutritional profile n (n = 1, 2, 3 for protein content, saturated fat content, and gluten, respectively); TR_j is a dummy variable for flour-based treatments; α_0 denotes the intercept representing a reference category of the rice kernel flour item; β_k and δ_n are parameters to be estimated for the effects of participant demographics and concern, respectively; ψ_i is the parameter capturing how flour-based formulation influences WTP values; and $e_{i,j}$ is the corresponding error term for flour formulation j.

As stated earlier, the study objective was to investigate the associations between consumers' WTP values, demographics, and participants' nutritional concerns. The hypotheses regarding the demographics and concern factors – H_0: $\beta_1 = 0$, $\beta_2 = 0$ and H_0: $\delta_1 = 0$, $\delta_2 = 0$, $\delta_3 = 0$ – were tested. It was hypothesized that participants' age, and gender would affect the WTP bid, with male and younger participants placing higher bids for all the gluten-free flour items. It was hypothesized that participants who have a higher level of concern for protein and saturated fat content, as well as gluten-related ingredients, would have increased the participants' bidding amount. The dummy variable for flour-based formulations were tested (H_0: $\psi_1 = 0$, $\psi_2 = 0$), which was expected to be significantly different from zero. Additionally, the second objective of this research was to identify WTP differences among three types of gluten-free ramen noodles. The study conducted the tests for mean equality on consumers' WTP from different flour formulations. The WTPs from 30% RKB and 40% RKB flour-based formulations are expected to be equal to that for the rice kernel flour item (H_0: $\alpha_0 = \psi_1$, $\alpha_0 = \psi_2$). Moreover, the bidding values for 30% RKB flour and 40% RKB flour-based items were expected to be equal, that is the null hypothesis (H_0: $\psi_1 = \psi_2$) cannot be rejected.

4. Results and discussion

4.1. *Demographic characteristics of the sample*

The variable definitions and descriptive statistics for the 105 participants are presented in Table 1. Of the 105 participants, 77% were women. The average age of the participants was 36.71 years; there were 13 participants aged > 60 years. The mean number of years of schooling for all participants was 18.85 years (at a bachelor's degree), with only 3.8% not having completed high school. More than 22% had a college degree, and 60% were studying in college. The participants had an average monthly income of 26,930 baht. Nearly 80% of the participants had a monthly income of less than or equal to 30,000 baht, whereas only 2.85% had an income greater than 100,000 baht. Most participants had similar education levels and incomes, which may have led to similar opinions toward gluten-free products, given their demographic background.

For the scale-differential question, the participants indicated their high concern for protein and saturated fat content (mean score at 7.26 and 7.38, respectively), whereas the concern for gluten-related ingredients was moderate (mean score at 4.58).

Table 1 - Summary statistics of the sample

Variable	Definition	Mean	Std. Dev.	Min	Max
Age	Years	36.71	15.12	18	70
Male	1 = male; 0 = female	0.23	0.42	0	1
Edu	Highest education level (year of schooling)	18.85	2.51	9	26
Income	Baht per month	26,930	28,862	4,000	150,000
Protein content	1 = not at all concerned; 10 = extremely concerned	7.26	2.09	1	10
Saturated fat content	1 = not at all concerned; 10 = extremely concerned	7.38	2.09	1	10
Gluten-related ingredient	1 = not at all concerned; 10 = extremely concerned	4.58	2.93	1	10

Table 2 shows the mean bids for gluten-free ramen noodles by flour formulation. Among the three flour-based products, participants were willing to pay less for the product made from 40% RKB flour-based formulation than for those made from rice kernel- and 30% RKB flour-based. The bidding price for the 40% RKB flour item was only 31.06 baht/150 g, below the bids for the other two items by 11 baht/150 g.

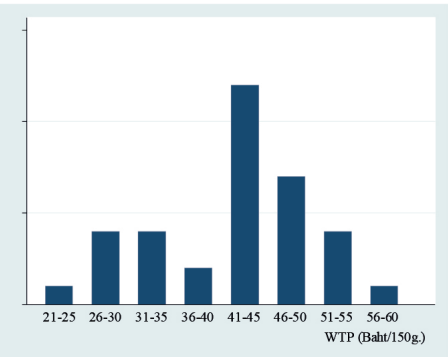
Meanwhile, the mean bid for the 30% RKB flour-based ramen noodles was only one baht lower than that for the item made from rice kernel flour. Additionally, none of the participants placed the bid below 10 baht for all the products; therefore, the consumers' WTP was left-truncated at 10.

Table 2 - Average consumer WTP for ramen noodles, by flour formulation

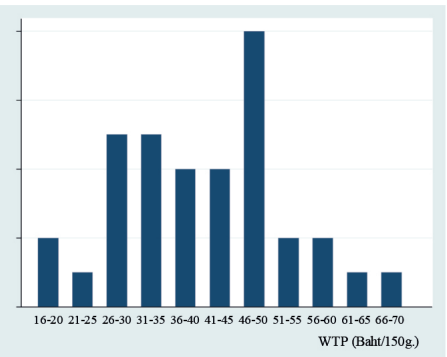
Flour formulation	**Mean (baht/150g)**	**Std. Dev.**	**Min**	**Max**
Rice kernel	43.17	8.55	25	60
30% RKB	42.26	12.12	20	69
40% RKB	31.06	14.71	10	60

The histograms presented in Figure 1 (a-c) shows the distribution of the bid prices for gluten-free ramen noodles by flour formulation. The majority of participants gave a higher bid of 41-50 baht for rice kernel- and 30% RKB flour-based formulations. The minimum bids for these two products were 25 and 20 baht, respectively. Conversely, most participants in the 40% RKB experimental trial gave lower bids that fell within a wider range below 41 baht (i.e., 10-40 baht). This result indicates a difference in consumers' WTP between the ramen noodles made from rice kernel- and 40% RKB flour formulations.

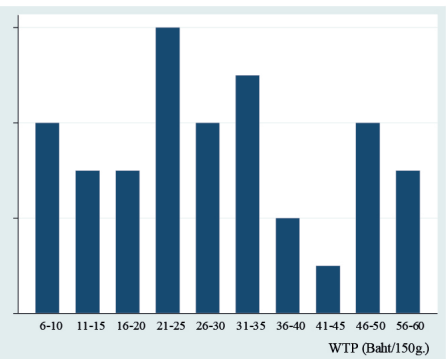
Figure 1(a-c) - The bid distribution for ramen noodles, by flour formulation



(a) Rice kernel flour



(b) 30% RKB flour



(c) 40% RKB flour

4.2. *Willingness to pay for gluten-free ramen noodles and influencing factors*

The truncated regression results from fitting Equation (1) with the effects of flour treatments are presented in Table 3. The models were estimated using the maximum-likelihood procedure in the TRUNCREG procedure in STATA, version 17. The Wald chi-squared test for all coefficients was zero and was rejected at the 1% level, indicating that the model was statistically significant. The results revealed significant correlations between consumer demographics and concerns on food nutritional profiles, flour formulations, and consumers' WTP values, with clear implications for determining the preferable flour formulation for producing gluten-free ramen noodles.

Table 3 - Truncated regression results

Variable	Coefficient	Standard Error
Constant	46.011***	5.319
Age	–0.239**	0.100
Gender (male)	–6.264**	3.107
Protein_Concern	2.013**	0.795
Saturated fat_Concern	–0.822	0.751
Gluten_Concern	–0.598	0.470
30% RKB flour	2.896	3.423
40% RKB flour	–12.556***	3.289
Sigma	11.563	0.890
Log likelihood	–400.667	

Note: (***) significant at 1% level, and (**) significant at 5% level.

The beta coefficients for age and (male) gender were significantly different from zero and negatively correlated with the WTP bid for gluten-free ramen noodles (–0.239 and –6.264 respectively, significant at 5% level). A one-year increase in participants' age leads to a 0.239 baht decrease in the bidding amount. Male participants give lower bids than female ones, as a great magnitude at –6.264 baht/150 g. These results align with prior research highlighting the role of sociodemographic factors (e.g., age, gender, and education) in consumers' decisions to purchase goods and services, including dietary choices (Bärebring *et al*., 2020; Christoph *et al*., 2018; Croson & Gneezy, 2009; Sgroi *et al*., 2024). The negative relationship between age, gender, and WTP bids indicates that older male consumers have limited perception of a healthy diet and less acceptance of a new food product, which is consistent with prior studies on food awareness, such as those by Bärebring *et al*. (2020) and Perrin *et al*. (2019), who reported differences in the perceptions of food nutrition and safety between male and female consumers.

Concern variables for food nutritional profiles further shaped consumers' WTP bid. The positive and significant coefficient of participants' concern for protein content is specifically observed (2.013, significant at 5%), suggesting that an individual who has one higher level of concern above the average for protein content is significantly willing to pay more for the gluten-free ramen noodles (2.013 baht/150 g). This result aligns with the findings of Di Vita *et al*. (2016) and Luga *et al*. (2020), who observed that the sensory score/ WTP value of food products tends to be higher when the foods incorporate

healthy nutrients, such as high protein and low sodium. Conversely, concerns regarding gluten had no significant effect on the bidding amount. These findings imply that consumers who have no food intolerance may be reluctant to consume gluten-free products, and that their dietary preference for healthy foods – providing a balance of protein, fat, and fiber – plays a critical role in their consumption choices. Regarding consumers' concerns about saturated fat content, the coefficient shows an unexpected insignificant result.

While the dummy coefficient for the 30% RKB flour-based formulation was not significantly different from zero, The 40% RKB flour formulation was negatively correlated with the WTP amount (–12.556, significant at 1%). This indicates that consumers would pay 12.56 baht/150 g less for the item that made with 40% RKB flour-based formulation compared to the rice kernel item. The insignificant coefficient for the 30% RKB flour-based formulation suggested that the amount consumers would pay for the 30% RKB flour ramen noodles did not differ from the WTP for the rice kernel item (ρ = 0.39). Furthermore, the mean equality test on WTP differences highlights the alternative flour formulation to substitute for rice kernel flour. The hypothesis that the average bids of 30% RKB- and 40% RKB flour items would be equal (H_0: $\psi_1 = \psi_2$) was rejected – i.e., ρ = 0.00. The result shows that consumers would pay less for the 40% RKB flour-based ramen noodles compared to the 30% RKB flour item (–15.452, significant at 5%). The results illuminate the 40% RKB flour-based formulation decreases the consumers' preferences for ramen noodles, whereas the 30% RKB flour is the optimal formulation for producing gluten-free ramen noodles in comparison to the rice kernel flour.

Based on the statistical significance and sign of the estimated parameters in Equation (1), the WTP amount for gluten-free ramen noodles across flour-based formulations can be predicted. For instance, if the consumer offers a positive bid, an increase in the substitution rate of rice flour to a 40% RKB formulation will reduce the bids for ramen noodles. The WTP bids for the 40% RKB flour item were only 29.05 baht/150 g when the bidder was male aged 36.71 years and indicating a concern of level 7 for protein content. The same consumer would pay up to 41.61 and 44.50 baht/150 g for rice kernel- and 30% RKB flour-based items, respectively (Table 4). This finding reveals that the extra attributes of gluten-free flour beyond using the 30% RKB flour composition appeared to significantly decrease consumer WTP bids. This is consistent with the findings of Chompoorat *et al.* (2020), who reported that the overall quality score of the flavor – taste, texture, and smell – of RKB cupcakes increased when a higher percentage of rice kernel flour was added to the RKB flour.

Overall, two flour formulations – (1) rice kernel and (2) 30% RKB flour composition – demonstrate higher consumer preferences than a 40% RKB

flour formulation. The older male consumers have limited perception of a healthy diet and less acceptance of a new food item than female. An individual concern for protein content increased the bidders' amount for the ramen noodles. These findings highlight the distinct preferences across individual characteristics, which may guide policy intervention to support food industries in developing innovative products to meet consumer demand, bolster food security, and improve well-being for all people.

Table 4 - Expected mean of WTP for gluten-free ramen noodles, by flour formulation

Flour formulation	Mean WTP* (baht/150g)	Standard Error	*p*-value
Rice kernel	41.61	2.269	0
30% RKB flour	44.50	2.200	0
40% RKB flour	29.05	2.284	0

Note: The mean of WTP bids were calculated from 105 observations.

Conclusions

A first-price auction was conducted to quantify consumers' WTP values for ramen noodles with three alternative flour formulations. We found that all participants offered positive bids for all types of gluten-free ramen noodles. The WTP bids did not differ between rice kernel- and 30% RKB flour-based items. Only the average bid level for ramen noodles made from 40% RKB flour was significantly lower than those for the rice kernel and 30% RKB flour items. The scale-differential questions on the participants' concerns about nutritional profiles showed that the individual concern for protein content increased the bidders' amount for the ramen noodles. However, concerns about gluten and saturated fat content did not affect the WTP bid for all types of ramen noodles.

The findings underscore the potential of developing gluten-free ramen noodles to satisfy consumer preferences beyond celiac concerns, driven by health-conscious consumers seeking to improve their well-being through dietary choices. In situations where wheat (non-gluten-free) ramen noodles are available in the market, rice kernel and 30% RKB-flour ramen noodles could become an alternative product for consumers who are gluten-intolerant and/or seeking a healthier diet. Our study reports the results of experimental auctions in which consumers bid on ramen noodles. The method provides non-

hypothetical data on consumer preference for the flour formulation of gluten-free ramen noodles, which is the first step in identifying consumer perceptions in the development of commercial products. Although our experiment was conducted only in Thailand, this is the first experimental study to determine the effects of RKB flour, consumer demographics, and concerns regarding food nutritional profiles on the WTP amount for ramen noodles, which is a popular food in Asia. A larger sample size from a wider geographical region and recent year should be considered in future studies. The experimental analysis should be further extended to include more auction formats to improve the accuracy of the current findings. Potential failures in randomization across treatments, due to unobserved heterogeneity arising from the auction practice round, may lead to biased estimates and should therefore be carefully addressed in future experimental auctions[4]. Furthermore, the manufacturing cost for alternative products that made from RKB flour is an essential factor that should be considered to obtain a better estimate of whether this change actually benefits consumers as well as the food processing industry.

Data availability statement

The data supporting the findings of this study are available from the first author on reasonable request.

Conflict of interest disclosure

There is no conflict of interest.

Ethics approval statement

Authors confirmed that this research was approved by the Chiang Mai University Research Ethics Committee in CMUREC No. 62/049.

Funding information

- Agricultural Research Development Agency (Public Organization), Thailand, Grant Year 2018, Grant No. CRP6105021460 (Subproject#3).
- Chiang Mai University, Thailand.

4. For further discussion of the failure of randomization to treatment, see Briz *et al.* (2017).

Authors' contributions

Chaowana Phetcharat: conceptualization, data collection, perform the statistical analysis, and writing original draft for methodology, result, and conclusion; Jeffrey D. Vitale: conceptualization, writing final draft, and supervision; Pavalee Chompoorat Tridtitanakiat and Wanlanai Saiprasert: conceptualization and data collection, as well as writing original draft for the introduction; Weirong Lu: prepared data and writing second draft for introduction and literature review.

Acknowledgement

The data used in this research was collected under the project of "Economic and market analysis of healthy food products with red kidney bean flour". The project was supported through a grant from the Agricultural Research Development Agency (Public Organization), Thailand. The authors are grateful to acknowledge our funding provider and also thank Chiang Mai University for financial assistance in completing this research. The views expressed are those of the authors, and not necessarily represent the views of the funders.

Competing interest

Authors have no relevant financial and non-financial competing interests that could affect the work reported in this paper.

References

Alencar, N. M. M., de Araújo, V. A., Faggian, L., da Silveira Araújo, M. B., & Capriles, V. D. (2021). What about gluten-free products? An insight on celiac consumers' opinions and expectations. *Journal of Sensory Studies*, *36*(4), e12664. Doi: 10.1111/joss.12664.

Alemu, M. H., & Olsen, S. B. (2020). An analysis of the impacts of tasting experience and peer effects on consumers' willingness to pay for novel foods. *Agribusiness*, *36*(4), 653-674. Doi: 10.1002/agr.21644.

Alsubhi, M., Blake, M., Nguyen, T., Majmudar, I., Moodie, M., & Ananthapavan, J. (2022). Consumer willingness to pay for healthier food products: A systematic review. *Obesity Reviews*, *24*(1), e13525. Doi: 10.1111/obr.13525.

Althubaiti A. (2022). Sample size determination: A practical guide for health researchers. *Journal of General and Family Medicine*, *24*(2), 72-78. Doi: 10.1002/jgf2.600.

Amore, M. D., & Murtinu, S. (2019). Tobit models in strategy research: Critical issues and applications. *Global Strategy Journal*, *11*(3), 331-355. Doi: 10.1002/ gsj.1363.

Awolu, O. O. (2017). Optimization of the functional characteristics, pasting and rheological properties of pearl millet-based composite flour. *Heliyon*, *3*(2), e00240. Doi: 10.1016/j.heliyon.2017.e00240.

Bank of Thailand (2025, November 11). *Statistics and Dissemination (Daily Foreign Exchange Rates.* -- https://www.bot.or.th/en/statistics/exchange-rate.html.

Bathrellou, E., Bountziouka, V., Lamprou, D., Fragedaki, E., Papachristou, E., Vriesekoop, F., & Kontogianni, M. D. (2025). Higher cost of gluten-free products compared to gluten-containing equivalents is mainly attributed to staple foods. *Nutrition bulletin*, *50*(1), 44-51. Doi: 10.1111/nbu.12716.

Bärebring, L., Palmqvist, M., Winkvist, A., & Augustin, H. (2020). Gender differences in perceived food healthiness and food avoidance in a Swedish population-based survey: a cross sectional study. *Nutrition Journal*, *19*(1), 140. Doi: 10.1186/s12937-020-00659-0.

Bellarby, J., Tirado, R., Leip, A., Weiss, F., Lesschen, J. P., & Smith, P. (2013). Livestock greenhouse gas emissions and mitigation potential in europe. *Global Change Biology*, *19*(1), 3-18. Doi: 10.1111/j.1365-2486.2012.02786.x.

Hangen, L., & Bennink, M. R. (2002). Consumption of black beans and navy beans (Phaseolus vulgaris) reduced azoxymethane-induced colon cancer in rats. *Nutrition and cancer*, *44*(1), 60-65. Doi: 10.1207/S15327914NC441_8.

Bernard, J. C., Zhang, C., & Gifford, K. (2006). An experimental investigation of consumer willingness to pay for non-GM foods when an organic option is present. *Agricultural and Resource Economics Review*, *35*(2), 374-385. Doi: 10.1017/ s1068280500006808.

Briz, T., Drichoutis, A. C., & Nayga, R.M. (2017). Randomization to treatment failure in experimental auctions: The value of data from training rounds. *Journal of Behavioral and Experimental Economics*, *71*, 56-66. Doi: 10.1016/j. socec.2017.09.004.

Canavari, M., Drichoutis, A.C., Lusk, J. L., & Nayga, R.M. (2018). How to run an experimental auction: A review of recent advances. *Munich Personal RePEc Archive*. Paper No. 89715. -- https://mpra.ub.uni-muenchen.de/89715/.

Capriles, V. D., & Arêas, J. A. G. (2014). Novel approaches in gluten-free breadmaking: interface between food science, nutrition, and health. *Comprehensive Reviews in Food Science and Food Safety*, *13*(5), 871-890. Doi: 10.1111/1541-4337.12091.

Charness, G., Gneezy, U., & Kuhn, M. A. (2012). Experimental methods: Between subject and within-subject design. *Journal of Economic Behavior & Organization*, *81*(1), 1-8. Doi: 10.1016/j.jebo.2011.08.009.

Christoph, M. J., Larson, N., Hootman, K. C., Miller, J. M., & Neumark-Sztainer, D. (2018). Who Values Gluten-Free? Dietary Intake, Behaviors, and Sociodemographic Characteristics of Young Adults Who Value Gluten-Free Food. *Journal of the Academy of Nutrition and Dietetics*, *118*(8), 1389-1398. Doi: 10.1016/j.jand.2018.04.007.

Croson, R., & Gneezy, U. (2009). Gender differences in preferences. *Journal of Economic Literature*, *47*(2), 448-74. Doi: 10.1257/jel.47.2.448.

Chompoorat, P., Kantanet, N., Hernández Estrada, Z. J., & Rayas-Duarte, P. (2020). Physical and dynamic oscillatory shear properties of gluten-free red kidney bean batter and cupcakes affected by rice flour addition. *Foods*, *9*(5), 616. Doi: 10.3390/ foods9050616.

Chompoorat, P., Rayas-Duarte, P., Hernández Estrada, Z. J., Phetcharat, P., & Khamsee, Y. (2018a). Effect of heat treatment on rheological properties of red kidney bean gluten free cake batter and its relationship with cupcake quality. *Journal of Food Science and Technology*, *55*, 493-4944. Doi: 10.1007/s13197-018-3428-z.

Chompoorat, P., Hernández-Estrada, Z. J., Mulvaney, S. J., Payton, M. E., Lavine, B. K., Fasasi, A., & Rayas-Duarte, P. (2018b). Comparison of rheological properties of wet gluten: Creep-recovery and biaxial compression. *LWT*, *98*, 197-203.

Croson, R., & Gneezy, U. (2009). Gender differences in preferences. *Journal of Economic Literature*, *47*(2), 448-74. Doi: 10.1257/jel.47.2.448.

Davis, J., Sonesson, U., Baumgartner, D. U., & Nemecek, T. (2010). Environmental impact of four meals with different protein sources: case studies in Spain and Sweden. *Food Research International*, *43*(7), 1874-1884. Doi: 10.1016/j. foodres.2009.08.017.

Day, L. (2013). Proteins from land plants-potential resources for human nutrition and food security. *Trends in Food Science & Technology*, *32*(1), 25-42. Doi: 10.1016/j. tifs.2013.05.005.

De-Magistris, T., López-Galán, B., & Caputo, V. (2016). The impact of body image on the WTP values for reduced-fat and low-salt content potato chips among obese and non-obese consumers. *Nutrients*, *8*(12), 830. Doi: 10.3390/ nu8120830.

Di Vita, G., D'amico, M., Lombardi, A., & Pecorino, B. (2016). Evaluating trends of low sodium content in food: The willingness to pay for salt-reduced bread, a case study. *Agricultural Economics Review*, *17*(875-2017-1562), 82-99. Doi: 10.22004/ ag.econ.262442.

Diep, S., Daugelaite, D., Strybulevych, A., Scanlon, M., Page, J., & Hatcher, D. (2014). Use of ultrasound to discern differences in Asian noodles prepared across wheat classes and between varieties. *Canadian Journal of Plant Science*, *94*(3), 525-534. Doi: 10.4141/cjps2013-043.

Drichoutis, A. C., Lusk, J. L., & Nayga, R. M. (2015). The veil of experimental currency units in second price auctions. *J. Econ. Sci. Assoc*, *1*(2), 182-196. Doi: 10. 1007/s40881-015-0014-2.

European Central Bank (2025, May 6). *Statistics.* -- https://www.ecb.europa.eu/stats/ policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html.

Fox, J., Shogren, J. F., Hayes, D. J., & Kliebenstein, J. B. (1998). CVM-X: Calibrating contingent values with experimental auction markets. *American Journal of Agricultural Economics*, *80*(3), 455-465. Doi: 10.2307/1244548.

Fu, B. X. (2008). Asian noodles: History, classification, raw materials, and processing. *Food Research International*, *41*(9), 888-902. Doi: 10.1016/j. foodres.2007.11.007.

Future Market Insights (2025, November 6). Gluten-free Food Market. -- https:// www. futuremarketinsights.com/reports/gluten-free-food-market.

Gao, Y., Janes, M. E., Chaiya, B., Brennan, M. A., Brennan, C. S., & Prinyawiwatkul, W. (2018). Gluten-free bakery and pasta products: prevalence and quality improvement. *International Journal of Food Science and Technology*, *53*(1), 19-32, Doi: 10.1111/ijfs.13505.

Global Industry Analysts (2023, August 5). Global Instant Noodles Industry. -- https://www.reportlinker.com/p05443576/Global-Instant-Noodles Industry.html?utm_source=GNW.

Gorgitano, M. T., & Sodano, V. (2019). Gluten-free products: From dietary necessity to premium price extraction tool. *Nutrients*, *11*(9), 1997. Doi: 10.3390/nu11091997.

Greene, W. H. (2008). *Econometric analysis*, *5*th Edition. Pearson International, New Jersey: Pearson Education.

Guennouni, M., Khoudri, N.E., Bourrouhouate, A., Hilali, A. (2019). Availability and cost of gluten-free products in Moroccan supermarkets and e-commerce platforms. *British Food Journal*, *124*(1), 1-13. Doi: 10.1108/BFJ-06-2019-0411.

Hassan, H. F., Mourad, L., Khatib, N., Assi, R., Akil, S., Khatib, S. E., Hteit, R. (2024). Perceptions towards gluten free products among consumers: A narrative review. *Applied Food Research*, *4*(2), 1-5. Doi: 10.1016/j.afres.2024.100441.

Hatcher, D. W., Salimi, A., Daugelaite, D., Strybulevych, A., Scanlon, M. G., & Page, J. H. (2014). Application of ultrasound to the evaluation of rheological properties of raw Asian noodles fortified with barley β-glucan. *Journal of Texture Studies*, *45*(3), 220-225.

Huffman, W. E., Shogren, J. F., Rouso, M., & Tegene, A. (2003). Consumer willingness to pay for genetically modified food labels in a market with diverse information: Evidence from experimental auction. *Journal of Agricultural and Resource Economics*, *28*(3), 48 1-502. Doi: 10.22004/ag.econ.31071.

Iuga, M., Boestean, O., Ghendov-Mosanu, A., & Mironeasa, S. (2020). Impact of Dairy Ingredients on Wheat Flour Dough Rheology and Bread Properties. *Foods*, *9*(6), 828. Doi: 10.3390/foods9060828.

Jamieson, J. A., Weir, M., & Gougeon, L. (2018). Canadian packaged gluten-free foods are less nutritious than their regular gluten-containing counterparts. *PeerJ*, *6*, e5875. Doi: 10.7717/peerj.5875.

Jones, A. D., & Ejeta, G. (2016). A new global agenda for nutrition and health: the importance of agriculture and food systems. *Bulletin of the World Health Organization*, *94*(3), 228. Doi: 10.2471/BLT.15.164509.

Jurado, F., & Gracia, A. (2017). Does the valuation of nutritional claims differ among consumers? *Insights from Spain*. *Nutrients*, *9*(2), 132. Doi: 10.3390/nu9020132.

Kunselman A. R. (2024). A brief overview of pilot studies and their sample size justification. *Fertility and Sterility*, *121*(6), 899-901. Doi: 10.1016/j.fertnstert.2024.01.040.

Lee, J. Y., Han, D. B. H., Nayga, R. M., & Lim, S. S. (2011). Valuing traceability of imported beef in Korea: An experimental auction approach. *The Australian Journal of Agricultural and Resource Economics*, *55*(3), 360-373. Doi: /10.1111/j.1467-8489.2011.00553.x.

Lehr R. (1992). Sixteen S-squared over D-squared: a relation for crude sample size estimates. *Statisticsinmedicine*, *11*(8), 1099-1102. Doi: 10.1002/sim.4780110811.

Low, J. W., & van Jaarsveld, P. J. (2008). The potential contribution of bread buns fortified with β-carotene-rich sweet potato in Central Mozambique. *Food and Nutrition Bulletin*, *29*(2), 98-107. doi: 10.1177/156482650802900203.

Lebwohl, B., Cao, Y., Zong, G., Hu, F. B., Green, P. H. R., Neugut, A. I., Rimm, E. B., Sampson, L., Dougherty, L. W., Giovannucci, E., Willett, W. C., Sun, Q., & Chan, A. T. (2017). Long term gluten consumption in adults without celiac disease and risk of coronary heart disease: prospective cohort study. *BMJ (Clinical research ed.)*, *357*, j1892. Doi: 10.1136/bmj.j1892.

Lebwohl, B., Sanders, D. S., & Green, P. H. R. (2018). Coeliac disease. *Lancet (London, England)*, *391*(10115), 70-81. Doi: 10.1016/S0140-6736(17)31796-8.

Lobanov, V. G., Slepokurova, Y. I., Zharkova, I. M., Koleva, T. N., Roslyakov, Y. F., & Krasteva, A. P. (2018). Economic effect of innovative flour-based functional foods production. *Foods and Raw Materials*, *6*(2), 474-482. Doi: 10.21603/2308-4057-2018-2-474-482.

List, J. A., Sadoff, S., & Wagner, M. (2011). So you want to run an experiment, now what? Some simple rules of thumb for optimal experimental design. *Experimental Economics*, *14*(4), 439-457. Doi: 10.1007/s10683-011-9275-7.

Liu, R., Solah, V.A., Wei, Y., Wang, X., Crosbie, G., & Fenton, H. (2019). Sensory evaluation of Chinese white salted noodles and steamed bread made with Australian and Chinese wheat flour. *Cereal Chem*, *96*(1), 66-75. Doi: 10.1002/cche.10089.

Lusk, J. L., Daniel, M. S., Mark, M.D., & Lusk, C.L. (2001). Alternative calibration and auction institutions for predicting consumer willingness to pay for nongenetically modified corn chips. *Journal of Agricultural and Resource Economics*, *26*(1), 40-57. Doi: 10.22004/ag.econ.31160.

Lusk, J. L., & Shogren, J. F. (2007). *Experimental auctions, Methods and applications in economic and marketing research*. Cambridge, UK: Cambridge University Press.

Margier, M., Georgé, S., Hafnaoui, N., Remond, D., Nowicki, M., Du Chaffaut, L., Amiot, M. J., & Reboul, E. (2018). Nutritional Composition and Bioactive Content of Legumes: Characterization of Pulses Frequently Consumed in France and Effect of the Cooking Method. *Nutrients*, *10*(11), 1668. Doi: 10.3390/nu10111668.

Miskelly, D. M., & Moss, H. J. (1985). Flour quality requirements for Chinese noodle Manufacture. *Journal of Cereal Science*, 3(4), 379-387. Doi: 10.1016/S0733-5210(85)80010-2.

Nganje, W. E., Kaitibie, S., Wachenheim, C. J., Acquah, E. T., Matson, J., & Johnson, G. (2008). Estimating price premiums for breads marketed as "Low-carbohydrate breads". *Journal of Food Distribution Research*, *39*(2), 66-76. Doi: 10.22004/ag.econ.55976.

Noordzij, M., Tripepi, G., Dekker, F. W., Zoccali, C., Tanck, M. W., & Jager, K. J. (2010). Sample size calculations: basic principles and common pitfalls. *Nephrology, dialysis, transplantation: official publication of the European Dialysis and Transplant Association-European Renal Association*, *25*(5), 1388-1393. Doi: 10.1093/ndt/gfp732.

Ouazib, M., Dura, A., Zaidi, F., & Rosell, C. M. (2016). Effect of partial substitution of wheat flour by processed (germinated, toasted, cooked) chickpea on bread

quality. *International Journal of Agricultural Science and Technology*, *4*(1), 8-18. Doi: 10.12783/ijast.2016.0401.02.

Perrin, L., Allès, B., Buscail, C., Ravel, C., Hercberg, S., Julia, C., & Kesse-Guyot, E. (2019). Gluten-free diet in French adults without coeliac disease: sociodemographic characteristics, motives and dietary profile. *The British journal of nutrition*, *122*(2), 231-239. Doi: 10.1017/S0007114519001053.

Ranaivoson, R. L., Adebayo, A., Antasoa, R., & Rasoaharaona, J. (2012). High quality cassava flour, promis-ing raw material for bread, biscuit and pastry industries: lessons from a pilot study in Madagascar. In *11th Triennial Symposium of The ISTRC-AB* (pp. 617-624). -- https://hdl.handle.net/10568/80464 [Accessed August 6, 2023].

Röös, E., Bajželj, B., Smith, P., Patel, M., Little, D., & Garnett, T. (2017). Greedy or needy? Land use and climate impacts of food in 2050 under different livestock futures. *Global Environmental Change*, *47*:1-12. Doi: 10.1016/j.gloenvcha.2017.09.001.

Rousu, M., Huffman, W. E., Shogren, J. F., & Tegene, A. (2004). Are United States consumers tolerant of genetically modified foods? *Review of Agricultural Economics*, *26*(1), 19-31. -- http://www.jstor.org/stable/1349785.

Schwarz, G. (1978). Estimating the dimension of a model. *The Annals of Statistics*, *6*(2), 461-464.

Sgroi, F., Sciortino, C., Baviera-Puig, A., & Modica, F. (2024). Analyzing consumer trends in functional foods: A cluster analysis approach. *Journal of Agriculture and Food Research*, 15, 1-8. Doi: 10.1016/j.jafr.2024.101041.

Shogren, J. F., Margolis, M., Koo, C., & List, J. A. (2001). A random *n*th-price auction. *Journal of Economic Behavior & Organization*, *46*(4), 409-421.

Smewing, J. (2016). Navigating noodle texture: Taking the rheological route. *Cereal Foods World*, *61*(3), 92-95. Doi: 10.1094/CFW-61-3-0092.

Tharanathan, R. N., & Mahadevamma, S. (2003). Grain legumes - a boon to human nutrition. *Trends in Food Science & Technology*, *14*(12), 507-518. Doi: 10.1016/j.tifs.2003.07.002.

Wang, Y., & Jian, C. (2022). Sustainable plant-based ingredients as wheat flour substitutes in bread making. *npj Science of Food*, *6*(1), 49. Doi: 10.1038/s41538-022-00163-1.

Wilson, C., & Tisdell, C. A. (2002). OLS and Tobit estimates: When is substitution defensible operationally? *Economic Theory, Applications and Issues (Working Paper No. 15)*. The University of Queensland. Doi: 10.22004/ag.econ.90519.

World Instant Noodles Association (2023, August 5). *Global Demand for Instant Noodles*. -- https://instantnoodles.org/en/noodles/demand/table/.

Appendix - *Sample size calculations*

To determine the optimum number of sample size per flour-based treatment, the study employed the approach proposed by Canavari *et al.* (2018); Drichoutis *et al.* (2015); Lehr (1992); and List *et al.* (2011). This approach calculates the sample size based on three key elements, which are: (1) a level of Type I error α, (2) the power of the statistical test $1 - \beta$, and (3) the minimum detectable size of the treatment effect ($\mu_1 - \mu_2$). This sample size calculation is commonly known as a Sixteen S-squared over D-squared (Lehr, 1992), which is defined as:

$$n = \frac{2\left[Z_{1-\alpha/2} + Z_{1-\beta}\right]^2 \sigma^2}{[\mu_1 - \mu_2]^2} \tag{1}$$

where, n is the number of samples per group, σ is a pool variance estimate, α is a Type I error level, β is Type II error, and $\mu_0 - \mu_1$ is the difference to be detected between the mean response of treatments.

By given a specific values of two-tailed α 0.05 and power $(1 - \beta)$ 0.80, the values of $Z_{1-\beta}$ and $Z_{1-\alpha/2}$ are equal to 0.84 and 1.96, respectively. Then, the numerator, $2[Z_{1-\alpha/2} + Z_{1-\beta}]$, is approximately equal to 16. The equation (1) becomes:

$$n = \frac{16\sigma^2}{[\mu_1 - \mu_2]^2} \tag{2}$$

This crude sample size estimate can only apply when the values of alpha and power are 0.05 and 0.80, respectively. In our study, the alpha and power values were set at 0.01 and 0.90, with an expected detectable effect size of 10 and a pool variance estimate of 100. The given coefficient '30' proposed by Lehr (1992) was applied into the equation (2) to substitute for '16' – i.e., the values of σ and μ are 1.28 and 2.58, respectively.. The sample size per treatment of our study was 30. Table 1 presents the sample size for different values of alpha and statistical power, with the detectable effect size and pool variance of the study.

Table A1 - The sample size for different values of alpha (α) and power (1 − β)

Power of the statistical test (1 − *β*)	**The sample size at**		
	***α* = 0.01**	***α* = 0.05**	***α* = 0.10**
0.80	23.5	16	12.5
0.90	30	21	17.5
0.95	36	26	22