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CONSUMER DEMAND FOR AFLATOXIN-FREE RAW MILK IN PAKISTAN

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ABSTRACT

Aflatoxins are highly toxic compounds in raw milk and pose serious risks to human health. Growing awareness among consumers about safe food is encouraging researchers, suppliers, and policymakers to investigate consumers' demand for aflatoxin-free raw milk. In this background, this study estimates consumers' willingness to pay for varying levels of aflatoxin in raw milk in Pakistan. A discrete choice experiment was conducted on 360 randomly selected urban households in the Punjab province. We employed the latent class multinomial logit model to uncover the heterogeneity in consumers' preferences for different quality and safety attributes of raw milk. Empirical findings suggest that consumers want to pay the highest premium of US$ 1.9/liter for milk having the lowest concentration of aflatoxin. Based on these findings, we suggest that there is considerable scope for the rapid development of aflatoxin-free milk in Pakistan, even though it is marketed at higher prices than the prices of status-quo milk.

Key words: Milk, Aflatoxin, Choice experiment, heterogeneous preferences, Pakistan
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INTRODUCTION

Milk is a vital constituent of the human diet. Nevertheless, its contamination with aflatoxin M_1 (AFM_1), excreted due to ingestion of feed contaminated with *Aspergillus* genus fungi (Nazar *et al*. 2018), has been recognized as a significant milk safety challenge (Pecorelli *et al*., 2020; Muaz and Riaz, 2021). According to an estimate, 4.5 billion people in Asia and Africa have chronic exposure to AFM_1, which is the main cause of liver cancer, heart diseases, abortion, immune suppression, and impaired growth (CDC, 2013; Liu and Wu, 2010). Hence, mitigating AFM_1 in milk is imperative to minimize consumers' health risks. The US Food Safety Regulations and the Codex Alimentarius have set a maximum safe limit for AFM_1 in milk at 0.5 micrograms per liter (ug/L) (FAO, 2019). Nonetheless, Pakistan Standard and Quality Control Authority has fixed the permissible limit for aflatoxin in food at 10 ug/L (Ashiq, 2014), which raises serious concerns about the government policies to provide safe milk to consumers.

Minimizing AFM_1 level in milk is beneficial not only from an economic but also from the health and productivity perspectives of both humans and livestock. For this purpose, several strategies have been devised to prevent AFM_1 contamination in animal feed during storage stages (Yunus *et al*., 2020). Farmer's adoption of these strategies demands an increment in milk prices to compensate for additional handling costs. Recently, different dairy companies are also focusing to devise various production schemes to deliberate this issue of AFM_1 contamination at the farm gate. But the supply of safe milk depends on the consumer's demand and price premium. Consumption theory hypothesizes that a product is consumed for its attributes of quality and safety, which further explain consumers' preference for one product over another (Lancaster, 1966). Therefore, evaluating consumers' willingness to pay (WTP) a premium for the attribute of safe milk is essential for such investment by farmers and dairy companies. The price premium for aflatoxin-free milk could lead to a market-based solution for the provision of safe milk to consumers.

This article aims to assess consumers' preferences and WTP for varying levels of AFM_1 in raw milk in Pakistan, by conducting stated preference choice experiment on 360 randomly selected raw milk consumers of Punjab province in 2016.

Milk production, consumption and safety concerns: Pakistan is the world's fourth largest milk producer, with an annual production of nearly 52.6 million tons valued at US$ 13.4 billion, which is substantially higher than the cumulative share of all major crops (GoP, 2019). About 50 million small farmers contribute 95% to the total raw milk produced in the country and millions of milkmen are involved in the milk supply chain (GoP, 2006). Milk is mainly (97%) marketed in raw form by the informal sector (Jawaid *et al*., 2015). Household consumption of raw milk is very common in both rural and urban areas. The per capita consumption of milk and dairy products is ranging between 150 to 200 liters per annum, indicating their highest share in the food expenditures (Malik *et al*., 2014). However, drinking contaminated milk with aflatoxin may pose serious risks to consumer's health.

Many studies have detected higher AFM_1 concentration in the raw milk of Pakistan. For instance, Yunus *et al*. (2019) have estimated AFM_1 concentration of 0.26 ug/L, 0.94 ug/L, and 1.5 ug/L in UHT, pasteurized, and raw milk, respectively, sampled from 21 different sources of milk in Islamabad. AFM_1 contamination was found to be greater than the permissible limits in pasteurized and raw milk; however, raw milk was the most contaminated. Iqbal *et al*. (2014) and Yunus *et al*. (2020) have concluded that AFM_1 in milk samples from urban and peri-urban farmhouses is higher than those from rural areas of Lahore, Faisalabad, and other cities of Punjab province. Asi *et al*. (2012) have documented higher contamination of AFM_1 in winter milk than in summer milk, which could be due to improper storage conditions in winter and better availability of fresh feed in summer. Hussain *et al*. (2010) examined AFM_1 in the milk of five dairy species and observed higher AFM_1 contamination in the milk of buffalo and cow. These studies provide empirical evidence on the existence of aflatoxicosis in the raw milk of Pakistan and stress the immediate attention for a solution.

Recent studies have used discrete choice experiments to evaluate consumers' preferences for different quality and safety attributes of food products. However, we have found only one choice experiment conducted to examine consumers' preferences for aflatoxin-free milk certification in Kenya (Walke *et al*., 2014). This study builds on existing literature by adding several innovations. First, the study introduces the safety attribute, the concentration of AFM_1 in raw milk, by uniquely specifying its three hypothetical levels: high, medium, and low. These levels would help consumers to make realistic choices keeping in view their own health safety. Second, this article analyzes the demand for aflatoxin-free milk by using representative data compiled from raw-milk consumers across Punjab's higher educational/research institutions. This permits the exploration of heterogeneity in consumers' preferences using an advanced latent class multinomial logit model. Consumers with high education and income levels may be more willing to pay than their counterparts, since they may better understand the associated health benefits of aflatoxin-free milk. However, uncertainties regarding the future availability of aflatoxin-free milk may curb their WTP premium. Third, this article provides valuations of quality attributes such as fat content and bad odour, which are germane to Pakistan's milk sector. Consequently, the study findings have far-reaching impacts on research, development, and marketing of aflatoxin-free milk, besides the formulation of policies and regulations articulated for consumer milk safety in Pakistan.

The rest of this article is structured as follows: the next section deliberates the choice experiment approach and data collection procedure. The third section discusses the econometric results. The last section concludes and suggests policy recommendations.

MATERIALS AND METHODS

Theoretical framework: The discrete choice experiment (DCE) approach is a quantitative method to elicit potential consumers' preferences over hypothetical attributes of a good, service or program without directly asking them to state their preferred option. During the DCE survey, a respondent is repeatedly presented with a set of hypothetical alternatives of a good, where he is asked to choose the most preferred one (Skedgel *et al*., 2015; Ali and Ronaldson, 2012). DCE is increasingly used in applied economics to investigate consumers' demand for quality and safe food (Simone *et al*., 2019: Walke *et al*., 2014;), for weather index insurance (Dehmel *et al*., 2021), health related issues (Soekhai *et al*., 2019) and job location (Fields *et al*., 2018),

Hence, this article uses a DCE method to elicit consumers' stated preferences for aflatoxin-free raw milk in Pakistan. The DCE allows evaluating consumers' demand for hypothetical goods with non-market attributes, similar to real market options. The DCE is preferred over other stated preference elicitation methods like contingent valuation and conjoint analysis by eliminating various biases (Louviere *et al*., 2000). It is based on the theory of consumer choice (Lancaster, 1966), where consumers derive utility from the attributes of a good, rather than from the good itself. The DCE method has an econometric grounding in random utility theory, which allows integrating behavior with economic valuations.

This article models urban consumer's choice of raw milk embodying varying levels of AFM_1 trait and other attributes. Suppose consumer i chooses among J raw milk alternatives enclosed in a choice set C during choice situation t. Consumer's utility of this choice is denoted by a latent variable U_{ij}^* . Given the budget constraint, consumer i will opt for a specific raw milk $k \in J$ if and only if $U_{ij}^* > U_{ij}^* \quad \forall k \neq m$ and $k, m \in J$. The latent utility U_{ij}^* can be observed indirectly if a particular alternative is chosen or not within a choice set C and utility maximizing decision is illustrated in Eq. 1:

$$U_{ij} = \begin{cases} 1 \text{ if } U_{ij}^* = \max\left(U_{i1t}^*, U_{i2t}^*, \dots, U_{i}^*\right) \\ 0 \quad \text{Otherwise} \end{cases} \tag{1}$$

Following the existing stated preference literature, U_{ij}^* presumes a linear functional form (Eq. 2). Therefore, marginal utility being monotonic in choice attributes provides a corner solution, inferring that only one raw milk is selected in a defined choice set.

$$U_{ij}^{*} = X_{ij}'\beta + \varepsilon_{ij} \quad (2)$$

The utility function U_{ij}^{*} comprises two components: deterministic component ($X_{ij}'\beta$) embodies vectors of attributes (X_{ij}') and their associated parameters (β) for k^{th} alternative in a choice situation t, while stochastic component/error term (ε_{ij}) represents the unobservable random variable, implying that predictions cannot be made with certainty. Hence, unobserved preference heterogeneity has been widely recognized as a critical issue not only for modelling choice behavior, but also for policy analysis (Wedel *et al*., 2012; Bujosa *et al*., 2010) The more advanced latent class multinomial logit (LCML) model has been applied to identify the sources of heterogeneity at the latent preference classes identified in the population (Hess, 2014; Louviere *et al*., 2000). Examination of preference heterogeneity for different classes is important for policy purposes, especially when estimating welfare impacts of introducing a new product (aflatoxin-free milk). The probability ($P_{ij|s}$) of consumer i belonging to a particular class s choosing alternative k among j choice alternatives in choice situation t is expressed as:

$$P_{ij|s} = \frac{e^{\beta_s X_{i}'}}{\sum_{j-1}^{J} e^{\beta_s X_i'}}, s = 1, \dots, S \quad (3)$$

where β_s is a vector of class specific preference parameters? Class membership is conditioned by observable consumers' characteristics. The probability (P_{i}) of consumer i belonging to class s is given by:

$$P_{i} = \frac{e^{\alpha_s Z_i'}}{\sum_{s-1}^{S} e^{\alpha_s Z_i'}} \quad (4)$$

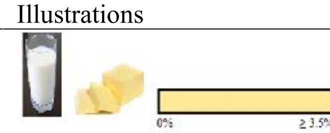
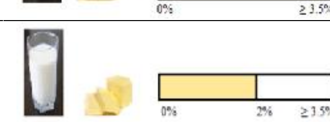
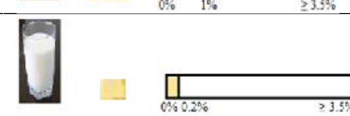
where Z_i' represents consumers' social, economic and demographic characteristics and α_s is the class specific parameter capturing the relative importance of each of these characteristics with respect to class membership. Alternatively, we can assume that P_{i} is random, which is a special case of (4) in which Z_i' is simply a null vector. In any case, P_{i} sums to 1 across S latent classes. The joint probability (P_{ij}) can be computed by assuming independence between probabilities of Eqs. 3 and 4 as:

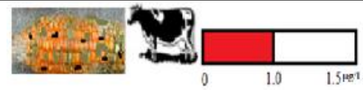
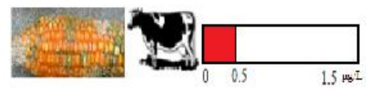
$$P_{ij} = \left[\frac{e^{\alpha_s Z_i'}}{\sum_{s-1}^{S} e^{\alpha_s Z_i'}}\right]\left[\frac{e^{\beta_s X_{ij}'}}{\sum_{j=1}^{J} e^{\beta_s X_i'}}\right] \quad (5)$$

where the first term in brackets denotes the probability of observing consumers in class s and the second term symbolizes the probability of choosing k alternative conditional on belonging to class s. This composite LCML model permits homogenous preferences within heterogeneous classes of consumers.

Choice experiment design: The DCE design defines the good (milk) in terms of its attributes and associated levels. Based on the previous literature (FAO, 2019; Ashiq, 2014; Walke *et al*., 2014), informal discussions with consumers and dairy firms, and intensive consultations with experts on livestock and microbiology, we identified four important attributes (fat, odour, aflatoxin and price) and their respective levels as shown in Table 1.

Table 1: Milk attributes and their levels used in the choice experiment.

Attributes	Attribute levels	Illustrations
1. Fat content	1. Whole milk (≥ 3.5% fat)	
	2. Reduced fat milk (≤ 2% fat)	
	3. Low fat milk (≤ 1% fat)	
	4. Non-fat milk (≤ 0.2% fat)	
2. Bad smell	1. Yes	

		2.	No	
3.	Aflatoxin concentration	1.	High (1.5 ug/liter)	
		2.	Medium (1 ug/liter)	
		3.	Low (0.5 ug/liter) *	
4.	Milk price	1.	Rs 80/liter	
		2.	Rs 100/liter	
		3.	Rs 120/liter	
		4.	Rs 140/liter	

* The permissible limit set by the US Food Safety Regulations for aflatoxin safe milk is 0.5 µg/liter.

From consumers' health perspective, the safety attribute in hypothetical milk choice is the concentration of AFM_1, which is measured in ug/L. Based on previous work on AFM_1 contamination of milk marketed in Pakistan, we generate three hypothetical levels: high (1.5 ug/L), medium (1.0 ug/L) and low (0.5 ug/L) (Yunus *et al*., 2019, 2020). This attribute and its levels would help us to investigate consumers' preferences for safe milk.

The second quality attribute included in the DCE is fat content, represents the proportion of butterfat in raw milk and varies from whole fat milk (fat ≥ 3.5%), reduced fat milk (fat ≤ 2%), low fat milk (fat ≤ 1%) to non-fat milk (fat ≤ 0.2%) based on Frøst *et al*. (2001). Consumers, who extract butterfat from raw milk, may prefer whole fat milk, though health-conscious consumers may prefer low/non-fat milk. Hence, this invisible attribute enables us to value consumers' utility or disutility for milk quality.

The third attribute, bad odour, also represents milk quality but contrary to fat content, it is immediately observable (Biolatto *et al*., 2007). We generate two hypothetical levels: yes (presence of bad odour) and no (absence of bad odour).

The fourth and last attribute is price of milk, which is used as a payment vehicle. This portrays the amount of money (Pak Rs.) required to buy one liter (L) of milk. It has four levels ranging between Rs.80/L (actual price of status quo raw milk) to Rs.140/L (an assumed increment of 25% is added to the actual price (Rs.120/L) of highest quality (UHT) milk in the country to manage aflatoxin, fat and odour in hypothetical milk alternative). This price range is simply divided into four equal intervals with an assumed increment of Rs.20/L. This monetary attribute allows computing welfare estimates of consumers' willingness to pay (WTP) a premium or willingness to accept (WTA) a discount for safety and quality attributes of milk. An experimental design is deployed to randomly combine the levels of these four attributes into choice sets. Following Kuhfeld (2010), an information efficient (D-optimal) design with D-efficiency of 0.96 is adopted to construct a fractional factorial design, from a full factorial design, having minimum D-error. Our efficient design was comprised of 48 choice sets and to minimize respondents' cognitive burden, these choice sets were randomly grouped into six blocks. Each block encompasses eight choice sets, while each set contains two hypothetical milk profiles and one status quo option to opt out if neither of the alternative milk presented is acceptable to the respondent (example of one choice set is given in Figure 1). Theses blocks were randomly assigned among respondents. To facilitate visual differentiations of different levels of milk attributes, suitable and colored illustrations were used. Moreover, choice cards were prepared in national language (Urdu). The remaining survey instrument was kept short and simple to minimize respondents' fatigue.

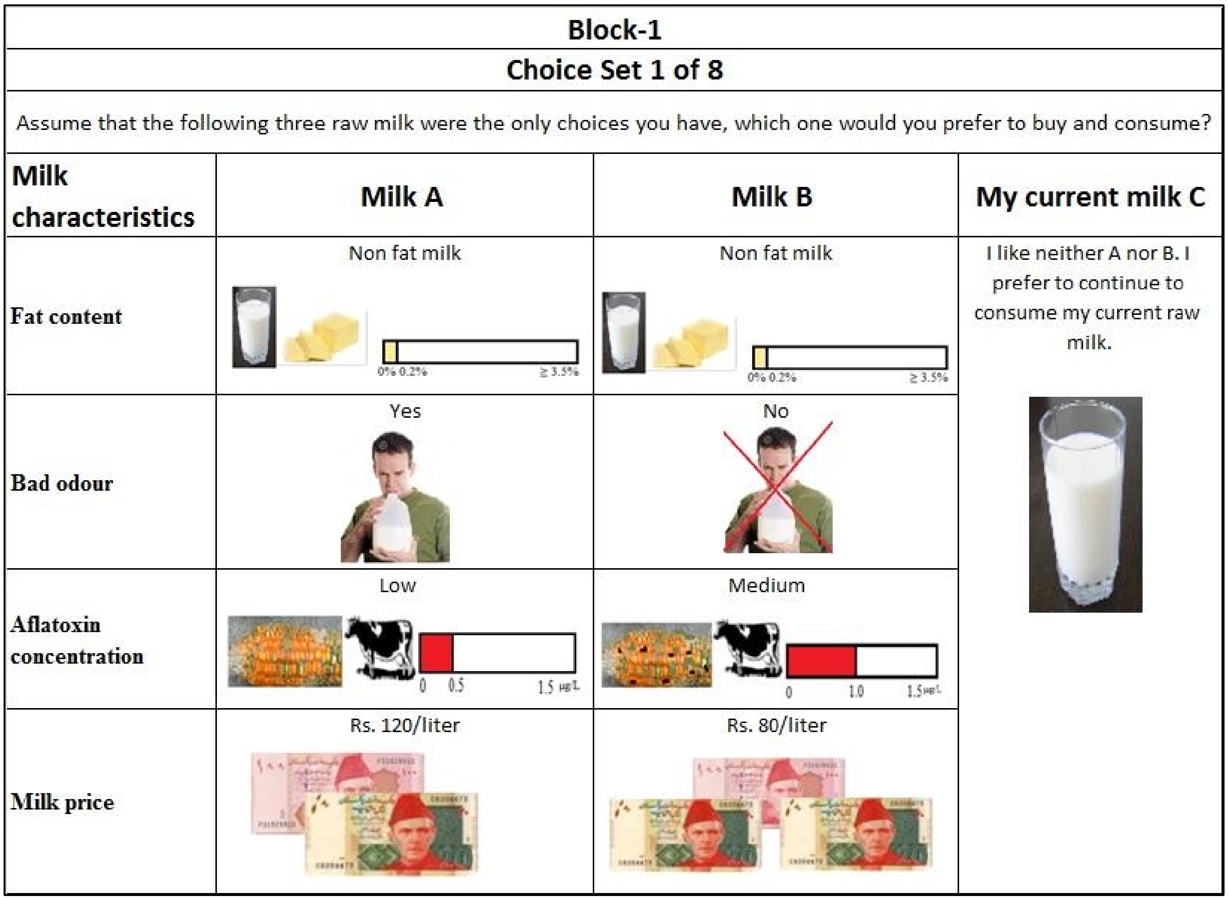


Figure 1: Example of choice set

Data collection and description: The DCE survey was conducted by two trained enumerators and a supervisor between January and March, 2016. The primary unit of analysis was raw-milk urban consumers of the Punjab province, which was selected on the basis of previous literature for repeatedly reporting of milk contamination with AFM_1 for this province (Ashiq, 2015). The sample was obtained using a four-stage sampling procedure. First, we purposively selected three largest populous cities of Punjab: Lahore, Faisalabad, and twin cities of Rawalpindi and Islamabad. Second, four public universities/research institutes were randomly selected in each city. Third, we stratified employees into three strata belonging to different socio-economic groups: teaching/research faculty, administrative staff, and lower-grade staff. Lastly, we randomly selected 10 employees from each stratum, generating 30 observations for each university/institute. This leads to a total sample of 360 raw milk consumers. The overall response rate was very high due to face-to-face nature of the survey instrument.

A pre-tested and well-structured questionnaire was used to obtain primary data on respondent's socioeconomic characteristics, milk consumption habits and purchasing behavior, perceptions about AFM_1, and DCE. Prior to survey, awareness about AFM_1 in raw milk and its negative health impacts were carefully discussed through cheap talk. Further, respondents were informed about the hypothetical situation and to ensure uniform understanding among respondents, the attributes and their levels were elucidated carefully.

Descriptive statistics of sampled consumer's socio-economic characteristics are reported in Table 2. Average age of respondents was 49 years, with mean formal qualification of 12 years. Female respondents were 11% in our sample. Average family size was 6 members including children. Average monthly income was about Rs. 41,102 (US$ 403). In terms of income categories, there were 55% respondents falling in low income category (≤ Rs. 30,000), 31% in middle income category (Rs. 30,000 - Rs. 90,000) and 14% in high income category (≥ Rs. 90,000), indicating the largest proportion of our sample belongs to low income category. The average raw milk consumption was around 2 liters per day per family and 0.39 liter per day per capita. Only 11% respondents in our sample had heard about AFM_1 contamination. However, compared to country statistics

(GoP, 2019), sampled consumers on an average were older, better educated, having large household size and higher monthly income. These differences can be explained by the fact that we had sampled from higher educational/research institutes of mega cities, where education and income levels are high compared to that in small towns and villages.

Table 2: Descriptive statistics of sampled consumers.

Variables	**Total (N=360)**
Age (years)	48.975 (13.7536)
Education (years)	11.199 (5.801)
Gender (%)	10.556 (30.729)
Family size (number)	5.861 (2.607)
Monthly income (Rs)	41101.700 (44328.800)
Low income class (Rs ≤ 30,000) (%)	55.000 (49.752)
Middle income class (Rs > 30,000 to < Rs 90,000) (%)	30.556 (46.067)
High income class (≥ Rs 90,000) (%)	14.444 (35.156)
Raw milk consumption (liter/day)	2.290 (1.217)
Awareness about aflatoxin (%)	10.556 (30.729)

Note: Standard deviations are given in parentheses.

RESULTS AND DISCUSSION

From 360 interviews, we have 2,880 valid choice observations to estimate heterogeneity in consumers' preferences by employing LCML model. The LCML models can be broadly categorized as either random latent class models or conditional latent class models. These models are estimated for up to five classes. Since there are no absolute statistical criteria for selecting the optimal number of classes, we use the balancing approach suggested in the literature (Louviere *et al.*, 2000). With the increase in the number of classes, the log-likelihood function value and McFadden's pseudo-R^2 increase monotonically, but the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) decrease as shown in Table 3. Comparing these various statistics and estimated results across models, we observe that a four-class model performs the best. The results of the four class model are reported in Table 4.

Table 3: Latent Class Diagnostics.

Types	**Classes**	**K**	**Log-likelihood**	**Pseudo-R^2**	**AIC**	**BIC**
Random class membership	1	6	-2237.826	0.260	1.558	1.571
	2	13	-2011.970	0.364	1.406	1.433
	3	20	-1923.205	0.392	1.350	1.391
	4	27	**-1852.939**	**0.414**	**1.306**	**1.361**
Conditional class membership	1	6	-2237.826	0.260	1.558	1.571
	2	20	-1951.868	0.383	1.369	1.411
	3	34	-1873.531	0.408	1.325	1.395
	4	48	**-1764.964**	**0.442**	**1.259**	**1.358**

Note: These statistics are calculated for a sample of 2880 choices from 360 raw milk consumers. McFadden's Pseudo R^2 is calculated as *1-LL/LL(0)*, where *LL(0)* represents the log-likelihood for a restricted model having only intercept. The Akaike Information Criterion (AIC) is calculated as *-2(LL-K)*, where *K* represents the number of estimated parameters. The Bayesian Information Criterion (BIC) is calculated as *–LL+(K/2)*ln(N)* where *N* represents the sample size.

The first four columns of Table 4 report the results of the random LCML model. Almost all utility coefficients for all attributes are significant within all classes, implying that consumers in these classes value these hypothetical attributes of raw milk. Consumers in class 1 have marginal disutility for quality attributes like fat content and bad odour; though their marginal utility increases with the safety attribute of reduced concentration of AFM_1 in hypothetical milk than that in status quo raw milk. Consumers in class 2 have marginal disutility for bad odour but have marginal utility for reducing fat content and AFM_1 concentration. Nevertheless, class 2 is pronounced as more odour conscious than any other class. Consumers in class 3 have no preference for fat contents but have marginal disutility for bad odour. However, these consumers have the highest marginal utility for lowering concentration of AFM_1 in milk compared to those in any other class.

Consumers in class 4 prefer raw milk free from bad odour and AFM_1, and are the least price conscious.

The next four columns of Table 4 report the result of the conditional LCML model. The upper panel shows utility coefficients of hypothetical raw milk attributes, while the lower panel reports the coefficients for conditioning participants' membership in various classes. Membership coefficients for the fourth class are normalized to zero, facilitating the identification of the sources of variation among classes (Boxall and Adamowics, 2002). The utility coefficients for class 1 are significant and positive for lowering the concentration of AFM_1. Membership coefficients for this class reveal that these consumers are less educated males belonging to the low-income class and residing in Faisalabad and Lahore. Most of the studies have reported AFM_1 contamination of milk for these cities, as discussed in section 1. Members of class 2 exhibit the highest marginal utility for lowering levels of AFM_1, and based on the class conditioning variables, they are evidently less educated and more likely to live in Rawalpindi and Islamabad. We note, however, that 20% of the consumers in the sample are members of this group. Members of class 3 have significant marginal utility for safety attributes and bad odour and are less educated and residing in Rawalpindi and Islamabad. The utility coefficients for class 4 are significant for all attributes except high aflatoxin level, implying that consumers belonging to this class have no preference for this level of safety attribute. However, they have marginal disutility for bad odour and marginal utility for falling levels of fat content and AFM_1. Membership coefficients of this class can be indirectly interpreted from the significant coefficients for other three classes. Accordingly, consumers in class 4 are more likely to be highly educated females belonging to the high-income group and residing in three selected cities of Punjab province.

Table 4: Results of latent class model.

Variables	Random latent class model				Conditional latent class model			
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Utility parameters								
Fat content	-0.137*	0.381***	0.082	-0.0003	-0.145*	0.046	-0.025	0.395***
	(0.073)	(0.092)	(0.135)	(0.046)	(0.078)	(0.111)	(0.046)	(0.087)
Bad odour	-1.677***	-4.340***	-1.149***	-0.756***	-1.936***	-0.987***	-0.733***	-2.920***
	(0.199)	(0.259)	(0.263)	(0.082)	(0.228)	(0.216)	(0.085)	(0.221)
High aflatoxin	2.635***	-30.459	11.001***	0.534**	3.236***	9.291***	0.359	-23.135
	(0.545)	(806982)	(1.178)	(0.236)	(0.577)	(0.857)	(0.244)	(13855.082)
Medium aflatoxin	4.911***	2.786***	18.511***	2.067***	5.598***	15.750***	1.835***	1.875***
	(0.565)	(0.549)	(1.508)	(0.241)	(0.607)	(1.070)	(0.249)	(0.509)
Low aflatoxin	5.137***	4.263***	19.127***	2.840***	5.860***	16.531***	2.500***	3.291***
	(0.557)	(0.609)	(1.525)	(0.247)	(0.618)	(1.104)	(0.252)	(0.567)
Milk price	-0.053***	-0.024***	-0.158***	-0.005***	-0.060***	-0.135***	0.003*	-0.017***
	(0.005)	(0.004)	(0.012)	(0.002)	(0.005)	(0.009)	(0.002)	(0.004)
Parameters conditioning class membership								
Constant					0.508	1.489	1.835*	
					(1.134)	(1.232)	(1.021)	
Education					-0.135***	-0.167***	-0.083*	
					(0.050)	(0.054)	(0.050)	
Gender					-2.328***	-70.755	0.510	
					(0.912)	(0.582+15)	(0.469)	
Low income class					1.757**	1.205	-0.108	
					(0.731)	(0.928)	(0.631)	
Middle income class					0.183	0.644	-0.453	
					(0.660)	(0.852)	(0.497)	
Faisalabad					1.734***	-1.923**	-0.992**	
					(0.541)	(0.911)	(0.484)	
Lahore					1.031*	0.591	-0.513	
					(0.611)	(0.581)	(0.548)	
Probability of class membership	0.398	0.182	0.183	0.236	0.381	0.203	0.231	0.184
Sample size	2880				2880			

Note: $^{*, **, ***}$Significant at 10%, 5% and 1% levels, respectively. Standard errors are given in parentheses.

Consumers' WTPs for conditional LCML model are estimated with parametric bootstrapped procedure and reported in Table 5. Members in class 1 are willing to accept a discount for quality attributes and willing to pay premium for safety attribute. Members in class 2 are relatively willing to pay higher premium for lowering levels of AFM_1 in hypothetical milk. Though the highest premium is placed for low aflatoxin in raw milk. Class 3 members are not willing to pay for the hypothesized attributes but they represent small proportion of the sample. Members in class 4 are willing to accept a discount for bad odour and willing to pay premium for falling fat content and aflatoxin. This class is willing to pay a highest premium of Rs 109/L (US$ 1.1/L) and Rs 191/L (US$ 1.9/L) for medium and low levels of AFM_1 in raw milk, respectively. However, these WTP are relatively large and should be interpreted cautiously. In general, these findings are consistent with Walke *et al.* (2014).

Table 5: Willingness to pay (WTP) for milk attributes based on conditional latent class model.

WTP (Rs/liter)	Class 1	Class 2	Class 3	Class 4
Fat content	-2.411* (1.260)	0.343 (0.824)	-7.958 (106.420)	22.864** (9.744)
Bad odour	-32.118*** (4.329)	-7.331*** (1.548)	-233.961 (4603.437)	-171.765*** (67.868)
High aflatoxin	53.687*** (5.964)	68.999*** (3.076)	114.735 (788.869)	-1339.336 (895089.726)
Medium aflatoxin	92.858*** (4.220)	116.968*** (2.760)	585.738 (9965.186)	108.555*** (16.104)
Low aflatoxin	97.216*** (4.181)	122.766*** (2.023)	798.166 (13821.524)	190.547*** (25.999)

Note: *, **, ***Significant at 10%, 5% and 1% levels, respectively. Standard errors are given in parentheses.

Conclusions: Milk contamination with AFM_1 is posing serious risks to human health. Many studies have reported contamination of raw milk with AFM_1 in Pakistan. The provision of safe milk may contribute to achieving the Sustainable Development Goals of improving human health and food security.

This article contributes to the existing literature by investigating consumers' heterogeneous preferences for lowering levels of AFM_1 in raw milk in Pakistan. A discrete choice experiment survey was conducted on 360 randomly selected raw milk consumers from megacities of Punjab province. This experiment entails four attributes including fat content, bad odour, AFM_1 concentration, and milk price. The LCML model was employed to identify the sources of heterogeneity at group levels. Our study confirms the presence of substantial heterogeneity in consumers' preferences for aflatoxin-free milk, which is at large preferred over the currently available option. Furthermore, we observe that consumers differentiate between the quality and safety attributes of raw milk and are willing to pay a significant premium of US$ 1.9/L for a safe level of AFM_1 in milk, indicating there is nascent demand for safety attributes of raw milk. Consumers' premium for safety attributes may compensate for farmers' extra cost required for the supply of a low level of AFM_1 in milk. Although consumers are willing to accept a discount for bad odour in milk. In short, consumers' higher price premium reveals demand for aflatoxin-free milk if it would be available in the future market. However, price premium should be cautiously interpreted as consumers could have overstated the values due to hypothetical bias in the provision of safe milk. Future studies may use experimental auctions to explore consumers' willingness to pay.

Milk quality and safety standards are not only poorly defined but also ineffectively enforced in Pakistan. Under such circumstances, our empirical findings may be used as a starting point to formulate effective policies for the provision of safe milk in particular. Moreover, the labeling of desired attributes would facilitate consumers to make better choices of milk. This article also provides financial incentives to farmers and dairy firms to introduce self-regulated standards to provide safe milk in the country. Besides, more valuation studies aided with rigorous laboratory-based parameters may be conducted to expedite aflatoxin-free milk supply. Nonetheless, awareness campaigns regarding prevention and detoxification strategies may help farmers and suppliers effectively control AFM_1 in milk. For brevity, the consumer's demand-led mechanism adopted in this article may contribute to improving the quality and safety attributes of milk along its entire supply chain.

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