Mal J Nutr 30(3): 323-334, 2024

# Determinants of knowledge, attitude, and practice towards aflatoxin contamination in food and aflatoxin biomarker levels among healthy Malaysian adults

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## ABSTRACT

**Introduction:** Limited information exists regarding the factors that determine the levels of knowledge, attitude, and practice (KAP) towards aflatoxin contamination in food, including aflatoxin biomarker levels in populations at risk. This study examined the associations between KAP levels with sociodemographic characteristics and weight status of 359 healthy Malaysian adults. **Methods:** The study was conducted among residents and workers in Selangor, Malaysia. Sociodemographic characteristics and KAP levels were collected using a self-administered questionnaire, and body weight was measured. Urine and fasting blood samples were collected for aflatoxin $M_1$ and aflatoxin $B_1$ analyses, respectively. **Results:** Most respondents were females, Chinese, aged 25–44 years, with poor knowledge but positive attitudes and acceptable practices in controlling aflatoxin contamination in food. Univariate and multivariate analyses revealed that the knowledge level was remarkably high among females, unemployed, underweight or normal weight individuals, and those with a monthly income of >RM 10,000. The attitude score was high in those with tertiary education and those who were unemployed, while the practice score was high in those with tertiary education. The levels of aflatoxin biomarkers varied significantly according to ethnicity or age. **Conclusion:** These findings demonstrated that sociodemographic characteristics and body weight status partly determined the levels of KAP and aflatoxin biomarkers; this may aid in identifying populations that would benefit from educational interventions to prevent aflatoxin contamination.

**Keywords:** aflatoxins, attitude, healthy Malaysian adults, knowledge, practice

## INTRODUCTION

Aflatoxins are toxic metabolites produced by the *Aspergillus* species of fungi. These toxins have gained attention worldwide because of their highly toxic and carcinogenic effects (International Agency for Research on Cancer, 1987). An outbreak of severe aflatoxicosis, resulting in 13 deaths among children, caused a medical

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doi: https://doi.org/10.31246/mjn-2023-0089

emergency in Malaysia (Lye *et al.*, 1995). Humans are exposed to aflatoxins mainly by consuming contaminated food. Because aflatoxins are stable and heat resistant, conventional chemical and physical approaches, including heating and washing, are ineffective to remove aflatoxins from food, making them practically irremovable. Efforts to mitigate these toxins for food safety purposes have become challenging. Nonetheless, many countries have imposed a regulatory limit on aflatoxins in foods because repeated exposure to low doses of aflatoxins over a lifetime could impact human health, such as liver cancer (International Agency for Research on Cancer, 1987).

Unlike the *Aspergillus* species, aflatoxins cannot be easily identified because they are colourless, odourless, and tasteless. To minimise dietary exposure to aflatoxins, expired and mouldy food should be avoided. Successful prevention of aflatoxin exposure is proportional to the public's knowledge, attitude, and practice (KAP); effective prevention requires public awareness and adherence. Studying the population's KAP is important to identify the gaps between knowledge and behavioural patterns that may hamper prevention efforts. Mohd Redzwan *et al.* (2012b) explored the factors affecting knowledge, but not attitude and practice on fungal and aflatoxin contamination in the diet. Good attitude and practice are crucial for preventing aflatoxin exposure. Another local study by Sulaiman *et al.* (2021) examined the factors affecting short-term aflatoxin exposure (urinary aflatoxin $M_1$, $AFM_1$), but not long-term exposure (such as serum aflatoxin $B_1$, $AFB_1$). Therefore, data on the factors affecting aflatoxin biomarker status and KAP levels towards aflatoxin contamination in food among the population remains fragmented. This study aimed to examine the associations between sociodemographic characteristics and body weight status with KAP levels towards aflatoxin contamination in food and aflatoxin biomarker levels among healthy Malaysian adults.

## MATERIALS AND METHODS

### Study design and population

The current study employed a cross-sectional design, utilising data from respondents screened for an intervention study. Respondents were required to sign an informed consent before data collection. Ethical approval was obtained from the Ethics Committee for Research Involving Human Subjects of Universiti Putra Malaysia (JKEUPM-2018-403) on 10 January 2019. The respondents were recruited from residents and workers in Selangor, Malaysia, using purposive sampling method. The recruitment was conducted in two phases: September–October 2020 and April–June 2021. Interested individuals were registered through an online screening form with project details included. The screening form comprised four sections: (a) age verification, (b) self-reported medical history, (c) Rome III diagnostic criteria for functional constipation, and (d) self-reported anthropometric measurements. The inclusion criteria were Malaysians, aged 20–60 years, without any major health problems, such as cardiovascular disease, hypertension, and diabetes, without functional constipation, and not pregnant or lactating.

### Data and sample collection

Data and sample collection were conducted at Hospital Sultan Abdul Aziz Shah (HSAAS), Serdang, Selangor, Malaysia. During the screening appointment, preventive safety measures for COVID-19 were implemented. These included social distancing, compulsory wearing of face masks, proper ventilation, and temperature monitoring. Individuals with symptoms of COVID-19 had their appointments rescheduled. Work surfaces were cleaned and disinfected regularly between appointments. To ensure adherence to social distancing, each time slot was limited to five appointments. This helped in maintaining adequate physical distance between individuals, which was crucial for preventing the spread of COVID-19.

Data collection was conducted using a self-administered questionnaire. Sociodemographic characteristics, including gender, age, ethnicity, marital status, education level, occupation, and household income, were identified. Knowledge, attitude, and practice towards aflatoxin contamination in food were assessed through 17 closed-ended questions based on Jolly *et al.*'s (2006) model, which was revalidated by Sulaiman *et al.* (2021). The questionnaire was formulated with eight questions in the knowledge section, four in the attitude section, and five in the practice section. A correct answer was scored "1", while any incorrect answer or those who answered "do not know" were scored "0" for knowledge. A four- and five-point Likert scale was used to measure attitude and practice scores, respectively. The possible scores for KAP ranged from 0 to 8, 4 to 16, and 5 to 25, respectively. The scores obtained from the respondents were divided into possible maximum scores and transformed into percentage scores. The sum score of each category was grouped into low (<50%), moderate (50%–79%), and high (80%–100%) score levels based on the modified Bloom's cut-off points (Chand *et al.*, 2022). Respondents with low score levels indicated poor knowledge, negative attitude, or poor practice; moderate score levels represented moderate knowledge, neutral attitude, or acceptable practice; and high score levels showed high knowledge, positive attitude, or proper practice towards aflatoxin control (Al-Makhroumi *et al.*, 2022).

Body weight and height were measured using digital scale (Seca 813, Seca GmbH & Co. KG., Hamburg, Germany) and portable stadiometer (Seca 213, Seca GmbH & Co. KG., Hamburg, Germany), respectively according to the NHANES anthropometry procedure manual (Centers for Disease Control and Prevention, 2007). Body mass index (BMI) was calculated as follows: BMI=weight (kg) / height$^2$ (m$^2$). Body weight status was classified based on the World Health Organization (WHO, 2000) BMI cut-offs as follows: underweight (<18.5 kg/m$^2$), normal weight (18.5–24.9 kg/m$^2$), overweight (25.0–29.9 kg/m$^2$), and obese (≥30.0 kg/m$^2$).

A morning midstream urine sample (15 mL) was collected in a sterile container. A fasting blood sample (5 mL) was taken into a serum separator tube by a medical laboratory technologist. Serum was obtained by centrifugation of whole blood at 3,000 ×*g* for 15 minutes to separate the serum (Mohd Redzwan *et al.*, 2014). All biological samples were aliquoted and stored at –80°C for further analysis.

## Determination of urinary and serum aflatoxin levels

Urinary $AFM_1$ levels were quantified using a commercial enzyme-linked immunoassay (ELISA) kit (Aflatoxin $M_1$ ELISA quantitative test kit, catalogue number 991AFLM01U-96, Helica Biosystems Inc., Santa Ana, CA, USA). The procedure was followed according to the manufacturer's instructions with slight modifications (Mohd Redzwan *et al.*, 2012). Before the analysis, urine samples were centrifuged at 3000 ×*g* for 5 minutes to remove debris and precipitates. The limit of detection (LOD) was set at 0.029 ng/mL and any values below LOD were assigned as half of the LOD value.

Serum $AFB_1$ levels were measured using the competitive ELISA method (RIDASCREEN Aflatoxin $B_1$ 30/15, R-Biopharm AG, Darmstadt, Germany) (Saad-Hussein *et al.*, 2021). The values were normalised to serum albumin content and expressed as pg $AFB_1$/ mg albumin. Serum albumin levels were determined using a commercial bromocresol green colorimetric assay kit (catalogue number ab235628, Abcam, Cambridge, MA, USA) according to the manufacturer's instructions. The LOD was 2.264 pg/mg albumin and values below LOD were replaced with half of the LOD value.

### Statistical analysis

All data were analysed using IBM SPSS Statistics for Windows version 22.0 (IBM Corp., Armonk, New York, USA). Descriptive statistics such as frequency, percentage, mean, and median were determined. Because the sample size exceeded 300, the normality of data was tested based on absolute values of skewness and kurtosis, whereby variables with either a skewness value of ≤2 or a kurtosis (excess) value of ≤4 were considered normal (Mishra *et al.*, 2019). The associations between KAP scores and aflatoxin levels were tested for inferential statistics using Spearman's correlation. Independent sample *t*-test and one-way analysis of variance (ANOVA), followed by Tukey's post-hoc test, were used to measure the associations between independent variables and normal variables (KAP scores), whereas the Mann–Whitney *U* and Kruskal–Wallis *H* tests, followed by pairwise comparisons, were used for non-normal variables (aflatoxin levels). Dependent variables associated with more than one independent variable underwent further multiple linear regression analysis to estimate the independent association of predictor variables with the outcome variable. Multicollinearity test was performed based on the tolerance value and variance inflation factor (VIF). Multicollinearity between predictors existed if the tolerance value was <0.1 and VIF was >10 (Kim, 2019). The statistical results showed that multicollinearity did not exist for the selected variables. The statistical significance level was set at $p<0.05$.

## RESULTS

Of 890 registrations received, 535 individuals who met the eligibility criteria were invited to the screening appointment. Unfortunately, 135 individuals did not show up for the scheduled appointment. Approximately 41 individuals were further excluded from the study as their measured BMI deviated from self-reported values ($n$=40) or did not reveal cardiovascular disease history before the screening session ($n$=1), thus not meeting the inclusion criteria. A total of 359 respondents were recruited in the study. The sociodemographic characteristics and body weight of respondents are described in Table 1. Most respondents were females (65.5%), aged 25–44 years (62.1%), Chinese (60.7%), unmarried (71.6%), had tertiary education (93.0%), employed (66.6%), with a household income of RM 5,001-10,000 (34.0%), and had a BMI of 14.1-–24.9 kg/$m^2$ (72.4%).

Based on Table 2, the mean scores of KAP towards aflatoxin contamination were 3.79±2.51, 12.78±2.27, and 15.34±2.69, respectively. Surprisingly, almost half of the respondents (49.0%) had poor knowledge levels, but most of them had positive attitudes (57.4%) and acceptable practices (78.8%) towards controlling aflatoxin contamination. Of the 359 samples, urinary $AFM_1$ and serum $AFB_1$ had median values of 0.19

ng/mL [interquartile range (IQR)=0.09–0.44] and 21.27 pg/mg albumin (IQR=5.55–42.91), respectively.

Table 3 shows the associations between sociodemographic factors and body weight status with aflatoxin biomarker levels. There was a significant difference in urinary $AFM_1$ levels among ethnic groups ($\chi^2(2)$=9.659, $p$=0.008). Pairwise comparisons showed that Indians had significantly higher $AFM_1$ levels in urine samples (mean rank=220.19) than Chinese (mean rank=167.86). Meanwhile, for serum $AFB_1$ level, a significant difference was observed in different age groups ($\chi^2(2)$=9.898, $p$=0.007). Respondents aged 45–60 years had lower serum $AFB_1$ levels than those aged 20–24 and 25–44 years.

While exploring the factors associated with KAP scores (Table 4), it was found that the knowledge score was high in female respondents ($t$=-2.89, $p$=0.004), including those unemployed ($t$=-2.21, $p$=0.028) and underweight/normal

**Table 1.** Respondents' sociodemographic characteristics and body weight status ($n$=359)

| *Sociodemographic characteristics* | *n* | *%* |
|---|---|---|
| Gender | | |
| Male | 124 | 34.5 |
| Female | 235 | 65.5 |
| Age (years)† | | |
| 20–24 | 99 | 27.6 |
| 25–44 | 223 | 62.1 |
| 45–60 | 37 | 10.3 |
| Ethnicity | | |
| Malay | 105 | 29.2 |
| Chinese | 218 | 60.7 |
| Indian | 36 | 10.0 |
| Marital status | | |
| Single/ divorced/ widowed | 257 | 71.6 |
| Married | 102 | 28.4 |
| Education level | | |
| Primary/ secondary | 25 | 7.0 |
| Tertiary | 334 | 93.0 |
| Occupation | | |
| Unemployed | 120 | 33.4 |
| Employed | 239 | 66.6 |
| Household income (RM)‡ | | |
| ≤2,500 | 88 | 24.5 |
| 2,501–5,000 | 96 | 26.7 |
| 5,001–10,000 | 122 | 34.0 |
| >10,000 | 53 | 14.8 |
| Body weight status§ | | |
| Underweight/ normal weight | 260 | 72.4 |
| Overweight/ obese | 99 | 27.6 |

†Classified based on Dyussenbayev (2017)
‡Classified based on Department of Statistics Malaysia (2020); RM=Ringgit Malaysia; USD 1=RM 4.77 as of February 8, 2024
§Classified based on World Health Organization (2000)

**Table 2.** Descriptive statistics of KAP scores and aflatoxin levels among respondents (*n*=359)†

| | *Knowledge score* | *Attitude score* | *Practice score* | *$AFM_1$ (ng/ml)* | *$AFB_1$ (pg/mg albumin)* |
|---|---|---|---|---|---|
| Mean±*SD* | 3.79±2.51 | 12.78±2.27 | 15.34±2.69 | 0.50±0.81 | 31.71±39.07 |
| Median | 4 | 13 | 15 | 0.19 | 21.27 |
| Range | 0–8 | 4–16 | 6–22 | 0.015–6.93 | 1.13–333.26 |
| Percentile | | | | | |
| $5^{th}$ | 0 | 9 | 11 | 0.01 | 1.13 |
| $25^{th}$ | 2 | 12 | 14 | 0.09 | 5.55 |
| $75^{th}$ | 6 | 14 | 17 | 0.44 | 42.91 |
| $95^{th}$ | 8 | 16 | 20 | 2.12 | 100.42 |
| Group, *n* (%) | | | | | |
| Low | 176 (49.0) | 11 (3.1) | 51 (14.2) | - | - |
| Moderate | 76 (21.2) | 142 (39.6) | 283 (78.8) | - | - |
| High | 107 (29.8) | 206 (57.4) | 25 (7.0) | - | - |

$AFB_1$: Aflatoxin $B_1$; $AFM_1$: Aflatoxin $M_1$; KAP: Knowledge, attitude, and practice towards minimising aflatoxin exposure; SD: Standard deviation

†Spearman's correlation between KAP scores and aflatoxin levels indicated that practice scores had significant positive correlations with knowledge ($r_s(357)=0.362$, $p<0.001$) and attitude scores ($r_s(357)=0.349$, $p<0.001$). No significant association was found between KAP scores and aflatoxin levels ($p>0.05$).

weight ($t=2.705$, $p=0.007$). One-way ANOVA showed a statistically significant difference in knowledge score across monthly household income groups [$F(3, 355)=3.069$, $p=0.028$]. Respondents with household earnings of above RM 10,000 monthly had higher knowledge scores than those earning between RM 5,001 and RM 10,000. Respondents with tertiary education had higher attitude ($t=-2.629$, $p=0.009$) and practice ($t=-2.047$, $p=0.041$) scores than those with primary or secondary education. Employed respondents scored better in the attitude section than those unemployed ($t=-2.333$, $p=0.020$).

Because knowledge and attitude scores were associated with more than one independent variable, further analysis was conducted. Multiple linear regression was performed to predict knowledge scores based on gender, occupation, monthly household income, and body weight status, whereas attitude scores were based on education and occupation (Table 5). Results showed that 7.1% of the variance in knowledge score could be collectively accounted for by these predictors [$F(6, 352)=4.516$, $p<0.001$]. Looking at the individual contribution of the predictors, it was found that the selected variables significantly predicted the knowledge and attitude scores in controlling aflatoxin contamination. Monthly household income was modelled as a set of three dummy or indicator variables, with the highest monthly household income group (>RM 10,000) as the reference group. Household earnings of RM 5,001–10,000 were likely to have knowledge score that is approximately 1 point lower than the highest income group after adjusting for gender, occupation, and body weight status. The knowledge scores among household earnings of below RM 2,500, between RM 2,501–5,000, and above RM 10,000 did not differ significantly.

**Table 3.** Association between sociodemographic factors and body weight status with aflatoxin biomarker levels ($n$=359)

| | $AFM_1$ | | $AFB_1$ | |
|---|---|---|---|---|
| | *Mean rank* | *p-value* | *Mean rank* | *p-value* |
| Gender | | 0.645 | | 0.535 |
| Male | 176.53 | | 175.34 | |
| Female | 181.83 | | 182.46 | |
| Age (years) | | 0.988 | | 0.007* |
| 20–24 | 178.66 | | 184.15[a] | |
| 25–44 | 180.57 | | 186.56[a] | |
| 45–60 | 180.14 | | 129.38[b] | |
| Ethnicity | | 0.008* | | 0.685 |
| Malay | 191.42[ab] | | 176.16 | |
| Chinese | 167.86[a] | | 179.62 | |
| Indian | 220.19[b] | | 193.49 | |
| Marital status | | 0.631 | | 0.106 |
| Single/ divorced/ widowed | 181.66 | | 185.56 | |
| Married | 175.82 | | 165.98 | |
| Education level | | 0.797 | | 0.593 |
| Primary/ secondary | 174.86 | | 169.32 | |
| Tertiary | 180.38 | | 180.80 | |
| Occupation | | 0.524 | | 0.352 |
| Unemployed | 175.08 | | 172.82 | |
| Employed | 182.47 | | 183.61 | |
| Monthly household income (RM) | | 0.791 | | 0.468 |
| ≤2,500 | 170.41 | | 184.23 | |
| 2,501–5,000 | 183.44 | | 188.51 | |
| 5,001–10,000 | 181.80 | | 178.34 | |
| >10,000 | 185.54 | | 161.39 | |
| Body weight status | | 0.872 | | 0.489 |
| Underweight/ normal weight | 179.45 | | 182.33 | |
| Overweight/ obese | 181.43 | | 173.88 | |

*Mann–Whitney $U$ test/ Kruskal–Wallis $H$ test ($p$<0.05) for aflatoxin levels

## DISCUSSION

This study aimed to determine the associations between sociodemographic characteristics and body weight status with KAP levels towards aflatoxin contamination in food and aflatoxin biomarker levels among healthy Malaysian adults. The present study showed that most respondents had poor knowledge of combating aflatoxin contamination in food. The findings concurred with most studies reporting poor knowledge among the general population, food handlers, and farmers (Hassan, Kamarulzaman & Nawi, 2018; Holakouie Naieni *et al.*, 2020; Matumba *et al.*, 2016; Mohd Redzwan *et al.*, 2012b; Toma, 2019). Adequate knowledge about aflatoxin contamination enhances safe food selection, reduces risky food consumption caused by negligence, and minimises exposure to aflatoxin. Several studies have discussed ways to improve knowledge concerning

**Table 4.** Association between sociodemographic factors and body weight status with KAP levels towards aflatoxin contamination (*n*=359)

| | *Knowledge score* | | *Attitude score* | | *Practice score* | |
|---|---|---|---|---|---|---|
| | *Mean±SD* | *p-value* | *Mean±SD* | *p-value* | *Mean±SD* | *p-value* |
| Gender | | 0.004* | | 0.925 | | 0.140 |
| Male | 3.27±2.39 | | 12.80±2.29 | | 15.05±2.76 | |
| Female | 4.06±2.54 | | 12.77±2.27 | | 15.49±2.64 | |
| Age (in years) | | 0.250 | | 0.553 | | 0.759 |
| 20–24 | 3.77±2.51 | | 12.95±1.95 | | 15.30±2.62 | |
| 25–44 | 3.69±2.52 | | 12.76±2.35 | | 15.30±2.75 | |
| 45–60 | 4.43±2.43 | | 12.49±2.59 | | 15.65±2.52 | |
| Ethnicity | | 0.216 | | 0.465 | | 0.239 |
| Malay | 3.52±2.49 | | 12.57±2.48 | | 15.70±2.60 | |
| Chinese | 3.82±2.52 | | 12.90±2.06 | | 15.16±2.57 | |
| Indian | 4.36±2.46 | | 12.69±2.83 | | 15.39±3.53 | |
| Marital status | | 0.867 | | 0.072 | | 0.326 |
| Single/divorced/ widowed | 3.77±2.555 | | 12.94±1.973 | | 15.25±2.580 | |
| Married | 3.82±2.415 | | 12.38±2.863 | | 15.56±2.947 | |
| Education | | 0.104 | | 0.009* | | 0.041* |
| Primary/ secondary | 3.00±2.74 | | 11.64±2.77 | | 14.28±3.10 | |
| Tertiary | 3.85±2.49 | | 12.87±2.21 | | 15.42±2.64 | |
| Occupation | | 0.028* | | 0.020* | | 0.190 |
| Unemployed | 4.20±2.44 | | 12.59±2.41 | | 15.21±2.67 | |
| Employed | 3.58±2.53 | | 13.18±1.91 | | 15.60±2.73 | |
| Monthly household income (RM) | | 0.028* | | 0.998 | | 0.238 |
| ≤2,500 | 4.13±2.52[ab] | | 12.76±2.15 | | 15.57±2.47 | |
| 2,501–5,000 | 3.72±2.50[ab] | | 12.76±2.14 | | 14.99±2.97 | |
| 5,001–10,000 | 3.33±2.41[a] | | 12.80±2.50 | | 15.23±2.48 | |
| >10,000 | 4.42±2.61[b] | | 12.83±2.21 | | 15.83±2.93 | |
| Body weight status | | 0.007* | | 0.896 | | 0.943 |
| Underweight/ normal weight | 4.01±2.49 | | 12.77±2.30 | | 15.33±2.72 | |
| Overweight/ obese | 3.21±2.48 | | 12.81±2.21 | | 15.35±2.61 | |

*Independent-samples *t*-test and one-way ANOVA ($p<0.05$) for KAP scores. Different letters indicate significant differences among the groups

aflatoxin contamination in food. Hassan *et al.* (2018) indicated that mass media, practicing standards, packaging information, experience, and official government websites greatly influenced consumers' knowledge of aflatoxin contamination in peanut-based products. Similarly, Toma (2019) ranked media as the primary source, followed by health workers, in providing knowledge of aflatoxin contamination among farmers. However, it remains inconclusive whether these platforms are effective for vulnerable groups, especially those with less education or those living in rural areas.

**Table 5.** Predictors of knowledge and attitude scores in controlling aflatoxin contamination (*n*=359)

| | *B-coefficients* | *95% CI* | | *p-value* |
|---|---|---|---|---|
| | | *Lower bound* | *Upper bound* | |
| Knowledge score | | | | |
| Gender (female) | 0.76 | 0.22 | 1.30 | 0.006* |
| Occupation (unemployed) | 0.61 | 0.05 | 1.17 | 0.032* |
| Body weight status (underweight/ normal weight) | 0.62 | 0.05 | 1.19 | 0.034* |
| Monthly household income† | | | | |
| <RM 2,501 | -0.47 | -1.32 | 0.38 | 0.282 |
| RM 2,501–5,000 | -0.70 | -1.53 | 0.13 | 0.099 |
| RM 5,001–10,000 | -0.99 | -1.79 | -0.20 | 0.014* |
| Attitude score | | | | |
| Education (primary/ secondary) | -1.13 | -2.05 | -0.21 | 0.016* |
| Occupation (unemployed) | 0.53 | 0.03 | 1.02 | 0.037* |

CI: confidence interval

†Monthly household income compared with the group of >RM 10,000

*Multiple linear regression ($p<0.05$)

Despite poor knowledge levels, most respondents had positive attitudes and acceptable practice levels to combat aflatoxin contamination in food. Although the respondents may not be aware of aflatoxins, they may have relatively good practices regarding general food safety. For example, the present study found that approximately 61.3% of the respondents were unaware that foods, such as nuts, cereals, and dairy products, are susceptible to aflatoxin contamination. However, most respondents (74.9%) frequently/always ensured that milk and dairy products bought from shops or hypermarkets were fine and high in quality (data not shown). Moreover, since the study was conducted during the COVID-19 period, consumers' attitudes and food practices may have changed. According to Bolek (2021), approximately 58% of respondents were willing to buy fresh products. The expiry date of products was primarily considered when purchasing food products (Erol *et al.*, 2023). As the aflatoxin content in food gradually increases, consuming expired food must be avoided to minimise aflatoxin exposure.

The present study proved that sociodemographic factors affected KAP regarding aflatoxin contamination. Specifically, females, the unemployed, those with a monthly household income of >RM 10,000, and the underweight/ normal weight groups were more knowledgeable about aflatoxins than the other groups. The results of multiple linear regression indicated the importance of targeting men, employed individuals, those with a monthly household income of RM 5,001–10,000, and overweight/ obese groups for improving public awareness of aflatoxins. Existing evidence determining whether females or males had higher knowledge related to aflatoxins remains controversial. Mohd Redzwan *et al.* (2012b) and the current study, which targeted the Malaysian population, concurred that females were likely more aware of aflatoxins, whereas a study from Malawi reported otherwise (Matumba *et al.*, 2016). These observations have led to other studies assessing whether geographical variation plays a role in the association between gender and aflatoxin-related knowledge level, especially in low- to middle-income countries. According to Azanaw *et al.* (2021), knowledge level may differ by years of education. If this is true, it could explain the higher knowledge score observed in unemployed individuals than employed individuals because unemployed individuals in the present study included college students, especially postgraduate students, who probably had longer years of education than other individuals with tertiary education. A significant difference was found between the level of education and occupation with the attitude score of respondents, whereby individuals with tertiary education and who were employed had higher attitude scores in minimising aflatoxin contamination in food. A similar trend was observed in a previous study conducted by Holakouie Naieni *et al.* (2020), which assessed the attitude concerning aflatoxin contamination, particularly in pistachio, and its pathogenicity among Iranians.

Urinary $AFM_1$ measures short-term exposure to $AFB_1$, whereas serum $AFB_1$-albumin adduct measures long-term exposure (Chen *et al.*, 2018). The mean level of urinary $AFM_1$ identified in this study (0.50 ng/mL) was comparable with that reported by Ahmad, Jamaluddin & Esa (2020) (0.589 ng/mL), but lower than that detected by Sulaiman *et al.* (2018) (1.23 ng/mL) among the Malaysian population. Past studies (Sulaiman, Jamaluddin & Sabran, 2018; Ahmad *et al.*, 2020) as well as the current study have shown a decreasing trend in aflatoxin exposure among Malaysians. Serum $AFB_1$ levels detected in the current study (median=21.27 pg/mg albumin) were lower than those reported from areas at high risk of liver cancer, for example, Tanzania (median=47.3 pg/mg albumin) (Chen *et al.*, 2018). According to Kimanya *et al.* (2021), there were 1,480 new cases of aflatoxin-induced liver cancer in Tanzania, equating to 2.95 cases per 100,000 population in 2016. Meanwhile, the estimated liver cancer risks attributed to aflatoxin contamination in common food with peanuts as the main contributor in Malaysia were less than 1 case per 100,000 population per year (Chin, Abdullah & Sugita Konishi, 2012). Despite that, attention is still required to control aflatoxin exposure in Malaysia because prevention is better than cure.

Higher levels of urinary $AFM_1$ and serum $AFB_1$ were observed among Indians and young people, respectively. Our results do not coincide with those of previous Malaysian studies. For example, Chinese were reported to be at a higher risk of aflatoxin exposure than non-Chinese in the study by Sulaiman *et al.* (2021). Leong *et al.* (2012) found that the age group of 31–50 years was threefold more likely to have aflatoxin exposure than the age group of 18–30 years. Several other interrelated factors, such as eating patterns, may have contributed to the observed variation in this study. Sulaiman *et al.* (2018) reported that a high intake of egg and dairy products was associated with a high level of urinary $AFM_1$. A positive association between milk and dairy product consumption with urinary $AFM_1$ was also observed by Mohd Redzwan *et al.* (2012a). No significant difference was shown between nut consumption and serum $AFB_1$-lysine adduct levels in a study by Leong *et al.* (2012). Several studies are needed to answer these controversial findings.

The present study has some limitations. The respondents were selected among healthy adults in specific areas. Aflatoxin production is highly affected by environmental factors and exposure varies according to region/

geographic area (Khalid *et al.*, 2022). Thus, the results of this study should not be generalised to the entire population. The possibility of underestimating aflatoxin exposure in the study population cannot be completely ruled out. Nevertheless, the results of this study are useful for policymakers in developing effective strategies to mitigate the health impacts of aflatoxin exposure among the population. It also allows healthcare decision-makers to improve people's KAP levels through properly allocated resources. Because aflatoxins are common contaminants in food, the outcome of this study may have implications for public awareness worldwide.

## CONCLUSION

Most respondents in the current study had poor knowledge but positive attitudes and acceptable practice levels in aflatoxin control. Adequate knowledge and a positive attitude are important factors that could translate into good practices to minimise aflatoxin exposure. These findings indicated the roles of sociodemographic characteristics and body weight status on KAP and aflatoxin exposure. Prioritising the implementation of educational interventions can be effective to improve the KAP levels of the population and minimise aflatoxin exposure.

**Acknowledgements**

We would like to express our extended gratitude to all respondents for their support in this study. This work was funded by Yakult Honsha Co., Ltd.

**Authors' contributions**

Chang WL, conducted the study, data analysis and interpretation, and drafted the manuscript; Rosita J, conceptualised the study, made funding acquisition, and reviewed the manuscript; Hazizi AS, co-supervised the study and reviewed the manuscript; Mohd Redzwan, principal investigator, conceptualised the study, and reviewed the manuscript.

**Conflicts of interest**

The authors declare that there are no conflicts of interest.

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