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*Research Article*

# Fatty Acid and Sterol Profiles of Commonly Available Street Foods in Sri Lanka: Comparison to Other Countries in the Asian Region

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Informal sector foods are considered a vector of unhealthy fatty acids linked to noncommunicable diseases (NCD). This study is aimed at investigating the hazardous and nutritional fatty acids and sterols in commonly consumed ready-to-eat (RTE) street foods ($n = 108$) in Sri Lanka using modified and validated AOAC and AOCS test methods. Significant variations ($p < 0.05$) were detected in fatty acid composition among different foods. A comparatively higher fat content (>17.5 g/100 g) was observed in 95% of pastry samples, while 51.5% of total foods exceeded the national threshold limit (8 g/100 g) for children. Saturated fatty acid (SFA) was higher than 1.5 g/100 g in 93% of food. SFA was more predominant than polyunsaturated fatty acids (PUFA) in all foods. The most prominent SFA was palmitic acid. Oleic acid was the major unsaturated fatty acid. Total trans fatty acids detected in all foods were in the range of 0.12-1.60 g/100 g. The PUFA/SFA ratios of all analysed street foods (0.16-0.28) were less than the recommended PUFA/SFA ratio of ≥0.4. Omega-6/omega-3 fatty acid ratios of all food were 18 : 1-24 : 1, which is higher than the WHO-recommended ratio of 4 : 1-5 : 1. Mean atherogenicity and thrombogenicity indices were 0.80-1.63 and 1.47-2.76, respectively. The essential fatty acids of $\alpha$-linoleic acid, eicosapentaenoic acid, and docosahexaenoic acid were less than the required nutritional intake. The most prominent phytosterol is the $\beta$-sitosterol in all foods, and total phytosterols were 3.29-136.65 mg/serving. Cholesterol was in the range of 0.36 to 256.85 mg/serving. These results suggest that consumption of these selected street foods may aid in increasing the risks of NCDs in consumers, and findings emphasise the urgency of improving the nutritional quality of street foods by continuously monitoring and regulating the present culinary practices. This study is the first to report a comprehensive fatty acid composition, including sterols, in RTE foods.

## 1. Introduction

The transition of global food consumption patterns towards ready-to-eat (RTE) street foods has been a growing trend not only among Asian populations but all nations of the world [1–3]. Fats and oils are central ingredients in RTE street foods, while deep-frying, frying, and sweetening are general preparation procedures [3, 4]. Reuse of frying oils, use of low-grade fats and oils, and cost-effective commercial food preparation methods create these in-sector RTE foods, the vectors of unhealthy fatty acids [5, 6].

Consumption of foods with unhealthy fatty acids, including high trans fatty acids (TFA) and high saturated fatty acids (SFA), is considered one of the critical drivers of metabolic and physiological changes and risk factors related to diet-related noncommunicable diseases (NCD), including cardiovascular disease (CVD) [7–12]. Globally, NCDs account for around 70% of mortality and mobility, and in

Sri Lanka, NCDs have affected more than 75% of annual deaths [13]. The prevalence of NCDs has increased alarmingly, affecting almost all countries [14–16]. Concerning this emerging health issue, the Sustainable Development Goals (SDG) of the United Nations (UN) for 2030 has stressed avoiding NCDs under goal three in order to ensure the safety and nutritious food of all humans [17–19]. International dietary recommendations with food labelling regulations [20–22] and national regulations [23–26] have been established to control food preparation processes and restrain manufacturers and merchandisers from using unhealthy fat sources and food processing techniques.

Considering various fatty acids available in foods, polyunsaturated fatty acids (PUFA) are vital as they consist of omega-6 (n-6 PUFA) and omega-3 (n-3 PUFA) fatty acids. Omega fatty acids comprise essential fatty acids (EFA), which are not synthesised in the human body, including alpha-linolenic acid (ALA) and linoleic acid (LA) [27]. Additionally, unsaponified fat fraction in foods consists of naturally occurring sterols (primarily phytosterols and cholesterol), which are significant for human health. WHO recommended that the maximum daily cholesterol intake is 300 mg to prevent diet-related chronic diseases [22]. Phytosterols have been heavily studied for their potential to lower the activity in low-density lipoprotein cholesterol (LDL-C) [28–30]. The USA National Cholesterol Education Program (NCEP) recommends 2 g of phytosterol intake per day [31]. Fatty acid compositions of foods were reviewed using different developed fatty acid indices. Ulbricht and Southgate developed both the index of atherogenicity (IA) and the index of thrombogenicity (IT) based on fatty acids with atherogenicity and thrombogenicity potential [32]. Both these indices can be used to understand the potential effect of fatty acid composition on cardiovascular health (CVH) [33]. The fatty acid compositions of foods can be further analysed using these indices.

Studies have been carried out for fatty acid analysis of various foods worldwide [34–36]. Based on these past studies, it is evident that the nutritional content and healthfulness of the informal food sector are rarely studied [3]. Interestingly, information on reliable and comprehensive fatty acid composition in street foods in Sri Lanka has yet to be reported, except for several studies that reported fatty acids in some local foods and recipes [37]. WHO Sri Lanka published a report on trans fats in commonly consumed foods in Sri Lanka [38]. The omega fatty acid composition and fatty acid indices of street foods in Sri Lanka were not presented in that report. Based on literature data, the sterol composition, including cholesterol and phytosterol, is hardly reported for Asian street foods, including Sri Lankan street foods.

Authentically, global informal food patterns and cultures are a complex picture of a heterogeneous blend of trends in various food matrixes specific to a country or region. Following a proper analytical protocol, it is crucial to analyse RTE foods for comprehensive fat composition, including total fat. In this study, a comprehensive fat compositional analysis, including sterol composition, was carried out. Further, studies to determine the compliance of fatty acid composition with the omega-fat ratio, phytosterol, and cholesterol in RTE street foods in Sri Lanka with the WHO nutritional goals and regulations are not available to date. This study evaluates the fat composition, including the sterol profile of RTE foods in the country, to identify the significance among unhealthy and healthy fatty acid ratios, fatty acid indices, and their conformity with WHO/FAO nutrient goals and regulations as the first comprehensive study in Sri Lanka.

## 2. Materials and Methods

*2.1. Reagents, Solvents, and Standards.* Fatty acid methyl ester (FAMEs) standards purchased from Nu-Chek-Prep, INC (Elysian, MN, USA) included GLC744, GLC463, trans fatty acids mixture of GLC 481B with certified quantities of each compound, and an individual triglyceride standard of 1,2,3-triheneicosanoyl-glycerol (TG21:0). Linoleic acid cis/trans isomers, linolenic acid cis/trans isomers, and individual fatty acid standard of C11:0 and triglyceride standard of 1,2,3-tritridecanoylglycerol (TG13:0) were obtained from Supelco (St. Louis, MO, USA). The standard reference material SRM 1544 was purchased from the National Institute of Technology (NIST, USA). Cholesterol, $\beta$-sitosterol, campesterol, stigmasterol and epicoprostanol, and N, O-bis(trimethylsilyl) trifluoroacetamide (BSTFA) + 1% trimethylchlorosilane (TMCS) were purchased from Sigma-Aldrich (St. Louis, MO, USA). All the other chemicals and reagents used for fat extraction and sample preparation were of analytical grade, and heptane and cyclohexane were GC/MS grade. Ultrapure water from a Milli-Q filter system was used for analysis.

*2.2. Samples.* Food samples of different categories of RTE food were randomly collected in the year 2019 and 2021. Each food sample was collected with 2 to 3 subunits, and a total of 300 food samples were collected. Foods were randomly collected from street vendors, including roadside kiosks/stalls, hawkers (trolleys, bicycles, trucks, and mobile stalls), small restaurants, stalls at flea markets, and morning markets without fixed buildings/walls of most urbanised areas of the western province of Sri Lanka. Several field visits were conducted to identify the vendors and streets before random sampling. A sampling form was used to record sample information, including place, food category (main meal or snack), key ingredients, and primary food preparation method. The criteria for selecting the commonly consumed RTE food types were based on past market and food consumption survey studies [39–42]. The selected street food items were fried rice, koththu, rice and curry, fish rolls, pastry, uludu vada, and dhal vada. The details, including the composition and preparation of these food items, are given in Table 1. All these street food types were also available in South Asian countries. Food samples were transported to the laboratory in cool and dry containers at room temperature ($27 \pm 2^{\circ}C$) as soon as possible.

*2.3. Sample Preparation.* Portion size (unit weight) was recorded for all collected samples at the laboratory. A composite homogenised sample was prepared from three or two subunits of each sample. Food samples were homogenised

Table 1: Composition, preparation methods, and serving size of selected ready-to-eat street foods in Sri Lanka.

| Food item | No. of samples (total with subunits) | Category of food | Main ingredients | Preparation method | Serving size* (g) (mean ± SD) |
|---|---|---|---|---|---|
| Fish roll | 13 (39) | Snack | Flour, fish, potatoes, vegetables, bread crumbs, oils, and fats | Oil-fried (deep-fried) spring rolls containing cooked fish with potatoes and or vegetables | 60 ± 14 |
| Fried rice | 20 (52) | A meal | Rice, vegetables, meat or fish, fats, and oils | Stir-fried the cooked rice with vegetables/fish/meat | 500 ± 38 |
| Dhal vada | 12 (36) | Snack | Dhal (split lentils), oil, onions, and spices | Deep-fried the mixture of grounded lentils, onions, and spices | 55 ± 30 |
| Uludu vada | 14 (42) | Snack | Black gram (split black lentil/ uludu, *Vigna mungo*), oil, onions, and spices | Deep-fried the mixture of ground gram, onions, and spices | 66 ± 24 |
| Rice and curry | 17 (45) | A meal | Rice, vegetables, meat or fish, and coconut milk | Cooked rice with several vegetable curries, cooked mainly using coconut oil and spices | 500 ± 37 |
| Koththu | 18 (44) | A meal | Flatbread ("rotty'), fried vegetables, meat/fish, fats, and oil | The chopped flatbread is mixed with fried vegetables and fried/cooked meat/fish or egg | 450 ± 38 |
| Fish pastries | 14 (42) | Snack | Flour, fish, potatoes, vegetables, bread crumbs, oil, and fats | Oil-fried (deep-fried) pastries containing cooked fish (with potatoes and or vegetables) | 62 ± 11 |

*Serving size is determined by the average weight of replicate samples of each food group.

with a food-grade grinder mixture (National, SKU Pride-600). Homogenised samples were sealed after nitrogen purging, labelled, and stored in air-tight containers under -20°C until the analysis of the fat composition.

*2.4. Fat Extraction.* The total fat content of each sample was analysed using techniques of solvent extraction and GC/FID. The Folch method was used to [43] extract the fat from all RTE snacks using methanol chloroform as the extraction solvent mixture. The modified and validated AOAC 996.06 [44] method was used to extract the fat from RTE meals. The method summary is as follows: 5 g of each meal sample was hydrolysed using 10 mL of 8.3 M HCl and subjected to solvent extraction using methanol: chloroform (2 : 1) solvent mixture. The solvent layer was separated and filtered through anhydrous sodium sulphate and evaporated using a rotary evaporator at 45°C. The remaining residue contained the extracted crude fat, which was methylated before being analysed by GC/FID.

*2.5. Determination of Total Fat and Fatty Acids by GC-FID.* The extracted fat was transferred to a glass tube with 2 mL of n-heptane. FAMEs were prepared according to the methods described in AOCS Ce 1h-05 [45] and AOCS Ce 2-66 [46] official methods using an internal standard solution (5 mg/mL) and $BF_3$-methanol reagent. The prepared FAMEs were extracted to n-heptane, and 1 mL of heptane solution was transferred to a test tube. Anhydrous sodium sulphate was added, and the dried heptane layer was filtered (0.22 $\mu$m nylon) to a vial and used for GC analysis.

A gas chromatograph (Trace 1300, Thermo Fisher) equipped with an autosampler (Triplus RSH), a flame ionisation detector, and a capillary column (Supelco-SP 2560 (100 m × 0.25 mm i.d.× 0.20 $\mu$m film thickness)) was used for all fatty acid analysis. Helium was used as the carrier gas (flow rate 1 mL/min). The oven temperature was optimised to have the maximum possible resolution to separate all reference fatty acids, including cis and trans isomers. The initial temperature of 180°C was held for 32 minutes, increased by 20°C/minute to 215°C, and held for 31.25 minutes. The split ratio was 50 : 1, the injector temperature was 235°C, and the detector temperature was 270°C.

Each fatty acid was qualitatively and quantitatively analysed as of the AOCS Ce 1h-05 method using GLC 744, GLC 463, and GLC 481B reference standards. Each FAME was quantified using theoretical flame ionisation detector correction factors (TCFs) for each FAME. Those individual FAMEs were converted to their fatty acids and TAGS using corresponding factors according to AOCS Ce 1h-05. The total fat is calculated as the sum of all triglycerides. After calculating each fatty acid, as per the method AOCS Ce 1h-05, the total TFA, SFA, MUFA, PUFA, n-6 PUFA, and n-3 PUFA were calculated in each test sample and expressed as g/100 g of sample and g/per serving size. All samples were analysed in triplicates.

*2.6. Simultaneous Analysis of Cholesterol and Phytosterols by GC/MS.* Three major phytosterols ($\beta$-sitosterol, campesterol, and stigmasterol) and cholesterols were analysed using the official validated test method of AOCS Ce12-16:2017 [47]. All samples were analysed in triplicates. Saponification was performed under alkaline conditions of 5 mL of 2.3 M NaOH/methanol solution at 100°C for 20 minutes. Sterols were derivatised with 1 mL BSTFA (1% TMCS) according to the method of AOCS Ce 12-16:2017.

A gas chromatograph (Agilent, 6890 series) equipped with an autosampler, a mass selective detector (Agilent, 5973 networks), and a capillary column (HS-5MS (30 m ×

0.25 mm i.d.× 0.20 $\mu$m film thickness)) was used for sterol analysis. Helium was used as the carrier gas (flow rate: 1 mL/min). The oven temperature was programmed as the initial temperature of 200°C, hold for 5 minutes, increased with the rate of 20°C/min to 270°C, and hold for 30 minutes. The split ratio was 50 : 1, the injector temperature was 230°C, the transfer line was 280°C, and the ion source was 230°C. The MS spectra were obtained at 70 eV, and detection was carried out in the SIM mode. The SCAN mode over 50-550 m/Z was used whenever required. The amount of each sterol was determined with factor (TCF) according to the procedure in AOCS Ce12-16 : 2017, and the total phytosterol content of a sample was calculated as the sum of all individually analysed phytosterols without cholesterol.

*2.7. Quality Control and Quality Assurance.* GC column performance was checked using the standard mixture of fatty acid methyl esters (GLC 411,469) covering the range of fatty acids from C12:0 to C21:0 before analysing the sample batch. Standard reference material (SRM), NIST 1544, was used as the quality control (QC) sample and analysed with the same protocol with every batch of samples. The percentages of recoveries for total fat, each certified fatty acid and cholesterol, were calculated. Spiked SRM samples with phytosterols in three levels were used as quality control samples to analyse the recovery of phytosterol.

*2.8. Statistical Analysis.* The results of the content of fatty acid groups SFA, PUFA, MUFA, TUFA, TFA, n-3 PUFA and n-6 PUFA are presented on a sample weight basis (per 100 g of sample) and on a serving size basis for each food type. Data are presented as mean and range to represent the distribution of test results in each food type. Total unsaturated fatty acids (TUFA) were calculated as the cumulative values of MUFA and PUFA. The individual fatty acids are presented as mg/g for each food type as mean and standard deviations. Data on RTE food types were analysed using the statistical package JMP version 16. A one-way analysis of variance (ANOVA) was performed to assess the overall significance of the mean differences among the groups. The Tukey-Kramer HSD test was then applied to perform multiple comparisons between the groups. A family-wise alpha of 0.05 was used as the significance threshold. The results of this analysis provide insight into the differences in mean values among the RTE food groups and offer a comprehensive picture of the significance of these differences.

Fatty acid indices of IA and IT were analysed using the following formulas [32].

IA is a relationship between the sum of SFAs and the sum of total unsaturated fatty acids (TUFA).

$$\mathrm{IA} = \frac{[\mathrm{C12:0} + (4 \times \mathrm{C14:0}) + \mathrm{C16:0}]}{\sum \mathrm{TUFA}}. \quad (1)$$

The IT denotes the relationship between the prothrombogenic fatty acids (C12:0, C14:0, and C16:0) and antithrombogenic fatty acids such as MUFAs, n-3 PUFAs, and n-6 PUFAs. The formula for IT is described as follows:

$$\mathrm{IT} = \frac{(\mathrm{C14:0} + \mathrm{C16:0} + \mathrm{C18:0})}{[(0.5 \times \sum \mathrm{MUFA} + (0.5 \times \sum \mathrm{n-6\ PUFA}) + (3 \times \sum \mathrm{n-3\ PUFA}) + (\mathrm{n-3/n-6})]}. \quad (2)$$

## 3. Results and Discussion

*3.1. Quality Control by SRM.* The test results of SRM 1544 (QC sample) of fourteen numbers of fatty acids, cholesterol, and total fat are presented as mean ± SD of eight replicates in Table 2 with the reference certificate values. All the test results of fatty acids, cholesterol, and total fat have complied with the certified mass fractions values. The recovery results of each analyte were calculated using the certified values of each fatty acid, total fat, and cholesterol and were within the range of 87.7-100.0%. The spiked recovery results of each phytosterol (78.3-90.3%) were also within the satisfactory levels.

*3.2. Total Fat Content and Fatty Acid Composition.* The fatty acid compositions of each street food category are presented in Tables 3 and 4 parts a and b. The TFA and SFA are the primary fat groups interesting in studies of informal sector foods. The present study extensively analysed the spectrum of fatty acids in the selected street foods. The fat composition was presented as g/100 g of the sample and as g/serving size of samples to compare with the different international and local food labelling claims and daily dietary recommendations. Individual fatty acid compositions of each food type were studied separately. Average total fat (TF), SFA, MUFA, total PUFA, n-3 PUFA, n-6 PUFA, and total unsaturated (TUFA) fatty acids (MUFA+PUFA) in g/100 g of each food type with the data ranges are presented in Table 3 part a and in g/serving size in Table 3 part b.

The TF contents of all RTE foods in the study ranged from 2.03 to 26.01 g/100 g, and when presented with the fat contents per serving, results were in the range of 2.03 g to 58.62 g. The highest mean TF of 22.42 g/100 g ($p < 0.05$) was observed in the pastry food group and the lowest in the food group of koththu, fried rice, and rice and curry (6.43 g/100 g, 6.06 g/100 g, and 3.69 g/100 g, respectively) ($p < 0.05$). Figure 1 illustrates the TF contents of samples in each food type distributed among three levels of TF as of labelling and advertising regulations No: 2119/3 of 2019 under Food Act No: 26 of Sri Lanka [26]. The levels are <3 g, 3 g-17.5 g, and >17.5 g. High-fat contents (>17.5 g/100 g) were detected in 93% of the analysed pasty samples. All analysed food samples of fried rice, koththu,

Table 2: Fatty acid composition, total fat, and cholesterol contents of SRM 1544 with certified/standard values and spiked % recovery data of phytosterols.

| Analytes | Test results of SRM 1544[a] | | | Spiked recovery data of phytosterols[b] | | |
|---|---|---|---|---|---|---|
| | Test results mean ± SD (g/kg) ($n = 8$) | Certified mass fractions/mean mass fractions ± SD (g/kg) | % recovery (mean) | Phytosterol | Spiked quantity (ppm) ($n = 8$) | % recovery mean ± SD |
| Caprylic acid (C8:0) | 0.26 ± 0.31 | 0.27 ± 0.35 | 96.3 | | | |
| Capric acid (C10:0) | 0.28 ± 0.24 | 0.28 ± 0.29 | 100.0 | $\beta$-sitosterol | L1-10 | 79.7 ± 0.9 |
| Lauric acid (C12:0) | 1.28 ± 0.11 | 1.31 ± 0.12 | 97.7 | | L2-30 | 89.5 ± 1.8 |
| Myristic acid (C14:0) | 0.96 ± 0.05 | 1.01 ± 0.10 | 95.0 | | L3-100 | 86.4 ± 1.6 |
| Palmitic acid (C16:0) | 5.34 ± 0.32 | 5.77 ± 0.52 | 92.5 | | | |
| Palmitoleic acid (C16:1) | 0.34 ± 0.03 | 0.35 ± 0.03 | 97.1 | | | |
| Stearic acid (C18:0) | 1.98 ± 0.14 | 2.00 ± 0.22 | 99.0 | Stigmasterol | L1-10 | 80.2 ± 2.2 |
| Oleic acid (C18:1 c) | 11.45 ± 0.33 | 11.60 ± 0.94 | 98.7 | | L2-30 | 83.0 ± 0.5 |
| Linoleic acid (C18:2) | 6.54 ± 0.26 | 6.56 ± 0.62 | 99.7 | | L3-100 | 78.7 ± 2.3 |
| Linolenic acid (C18:3) | 0.61 ± 0.07 | 0.61 ± 0.25 | 100.0 | | | |
| Arachidic acid (C20:0) | 0.11 ± 0.08 | 0.11 ± 0.06 | 100.0 | | | |
| Eicosenoic acid (C20:1) | 0.12 ± 0.19 | 0.13 ± 0.32 | 92.3 | Campesterol | L1-10 | 78.9 ± 1.2 |
| Arachidonic acid (C20:4) | 0.07 ± 0.11 | 0.09 ± 0.10 | 77.8 | | L2-30 | 87.5 ± 0.9 |
| Behenic acid (C22:0) | 0.10 ± 0.06 | 0.11 ± 0.06 | 90.9 | | L3-100 | 90.3 ± 1.6 |
| Cholesterol | 0.13 ± 0.0012 | 0.1483 ± 0.0094 | 87.7 | | | |
| Total fat (g/100 g) | 3.5 ± 0.23 | 3.7 ± 0.6 | 94.6 | | | |

[a]Fatty acid composition, total fat, and cholesterol of SRM are presented as mean and recovery. The recovery was calculated with respect to certified/standard mass fraction results of each parameter of SRM. [b]The phytosterol were spiked in three levels/concentrations (L1, L2, and L3), and % spiked recovery is presented as mean ± SD.

dhal vada, and uludu vada contained fat content in the 3-17.5 g/100 g range. The results also revealed that the total fat contents of all samples were higher than 3 g/100 g except for 33% of rice and curry samples, which contained less than 3 g/100 g of fat. TF contents of 95% of the total samples of this study were higher than 3 g/100 g. The nutrient profile model for Sri Lanka for children [25] has placed a threshold of 8 g/100 g for TF. Figure 2 depicts the percentage of samples containing TF greater than the threshold limit and TF less than the threshold limit within each food group. All samples of rice and curry contained TF less than the threshold of 8 g/100 g, and more than 80% of samples from rolls, pastry, uludu vada, and dhal vada food types contained fat more than the threshold limit, while fat content of 100% of samples of pastry exceeded this limit.

The mean SFA of all analysed food samples varied between 1.15 and 15.47 g/100 g. The highest mean SFA content of 12.94 g/100 g ($p < 0.05$) was in the pastry group, while the significantly lowest mean SFA content was present in the food group of koththu, fried rice, and rice and curry (2.74 g/100 g, 3.15 g/100 g, and 1.90 g/100 g, respectively). The mean SFA of all RTE foods types was >1.5 g/100 g, exceeding the low SFA claim limit of <1.5 g/100 g of food regulations [20, 23]. However, 28% of total rice and curry samples and 11% of total fried rice samples contained SFA lower than 1.5 g/100 g (Figure 3(a)). The threshold of SFA has been set to 20 g in the nutrient profile model for children [25], and the maximum nutrient reference value for preventing NCD (NRV-NCD) for SFA is also 20 g [20]. Percentages of samples in each RTE street food meal, exceeding the daily NRV-NCD limit for SFA from one serving and two servings, are presented in Figure 3(b). Consequently, a distinct connection is evident between the proportion of samples with high saturated fatty acid and the frequency of daily servings of koththu and fried rice. The high intake of SFA increases the risk factors for NCDs. Higher unsaturated fatty acids can lower those risk factors by replacing SFA with PUFA in foods [48–50].

The average MUFA, PUFA, and TUFA contents in all the analysed food samples varied in the ranges 0.40-8.43 g/100 g, 0.04-2.77 g/100 g, and 0.68-10.95 g/100 g, respectively. In the study, the highest mean SFA and the highest PUFA and MUFA contents were detected in the pastry food group ($p < 0.05$). The mean PUFA (2.03 g/100 g), MUFA (6.87 g/100 g), and TUFA (8.90 g/100 g) of the pastry were lower than the mean SFA (12.94 g/100 g) of the pastry. According to the results, pastry contained more unhealthy fat (SFA) than the healthy fat components (PUFA, MUFA), even though it contained the highest mean unsaturated fatty acids compared to the other food types in this study. This trend was continued in the other food types as the mean SFA contents of all food types were higher than the PUFA and the MUFA content.

Table 4 part a presents the mean contents of each fatty acid in RTE street foods. The individual SFAs, myristic acid (C14:0), and palmitic acid (C16:0) have the most significant

Table 3: Total fat, saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, total unsaturated fatty acids, and omega fatty acids in ready-to-eat street foods of Sri Lanka: (a) fatty acid content in g/100 g of sample and (b) fatty acid content in g/serving size[#].

| Food types | Fatty acids (g/100 g) Mean (range) (a) | | | | | | | Fatty acids (g/serving size) Mean (range) (b) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TF | SFA | MUFA | PUFA | TUFA | n3-PUFA | n6-PUFA | TF | SFA | MUFA | PUFA | TUFA | n3-PUFA | n6-PUFA |
| Fried rice ($n = 20$) | $6.06^{c}$ (3.03-11.72) | $2.74^{c}$ (1.15-5.68) | $2.44^{c}$ (1.23-4.31) | $0.77^{de}$ (0.43-1.36) | $3.22^{c}$ (1.66-5.67) | $0.04^{b}$ (0.01-0.08) | $0.74^{bc}$ (0.40-1.28) | $30.28^{a}$ (14.38-58.62) | $13.70^{a}$ (5.74-28.41) | $12.21^{a}$ (6.15-21.55) | $3.87^{a}$ (2.15-6.80) | $16.09^{a}$ (8.30-28.35) | $0.18^{a}$ (0.05-0.40) | $3.69^{a}$ (2.00-6.40) |
| Rice & curry ($n = 17$) | $3.69^{c}$ (2.03-6.21) | $1.90^{c}$ (1.29-2.98) | $1.23^{cd}$ (0.40-2.21) | $0.45^{e}$ (0.22-0.69) | $1.68^{d}$ (0.68-2.88) | $0.03^{b}$ (0.01-0.13) | $0.43^{c}$ (0.22-0.68) | $18.44^{b}$ (10.16-31.05) | $9.51^{b}$ (6.45-11.92) | $6.13^{b}$ (2.00-11.05) | $2.26^{b}$ (1.10-3.45) | $8.39^{b}$ (3.40-14.40) | $0.13^{abc}$ (0.05-0.65) | $2.15^{b}$ (1.10-3.40) |
| Koththu ($n = 18$) | $6.43^{c}$ (3.01-10.15) | $3.15^{c}$ (1.51-6.51) | $2.25^{cd}$ (0.65-4.11) | $0.82^{cde}$ (0.21-1.59) | $3.07^{cd}$ (1.01-5.69) | $0.03^{b}$ (0.01-0.08) | $0.73^{bc}$ (0.10-1.49) | $28.93^{a}$ (13.55-45.68) | $14.18^{a}$ (6.80-29.32) | $10.13^{a}$ (2.90-18.49) | $3.67^{a}$ (0.95-7.13) | $13.80^{a}$ (4.53-25.63) | $0.15^{ab}$ (0.05-0.36) | $3.27^{a}$ (0.45-6.71) |
| Rolls ($n = 13$) | $10.81^{b}$ (6.00-21.53) | $4.87^{b}$ (2.65-10.23) | $4.23^{b}$ (2.32-8.43) | $1.23^{bc}$ (0.69-2.52) | $5.46^{b}$ (3.01-10.95) | $0.11^{a}$ (0.01-0.32) | $1.07^{b}$ (0.56-2.21) | $6.48^{c}$ (3.60 -12.92) | $2.92^{c}$ (1.59-6.14) | $2.54^{c}$ (1.39-5.06) | $0.74^{c}$ (0.41-1.51) | $3.27^{c}$ (1.81-6.57) | $0.06^{bcd}$ (0.01-0.19) | $0.64^{c}$ (0.34-1.33) |
| Pastry ($n = 14$) | $22.42^{a}$ (15.03-26.01) | $12.94^{a}$ (7.98-15.47) | $6.87^{a}$ (5.43-8.01) | $2.03^{a}$ (1.31-2.77) | $8.90^{a}$ (6.12-10.25) | $0.09^{a}$ (0.05-0.14) | $1.79^{a}$ (1.08-2.46) | $13.90^{bc}$ (9.77-16.91) | $8.02^{b}$ (5.19-10.32) | $4.26^{bc}$ (3.37-4.97) | $1.26^{bc}$ (0.81-1.72) | $5.52^{bc}$ (3.79-6.36) | $0.06^{cd}$ (0.03-0.09) | $1.11^{bc}$ (0.67-1.53) |
| Dhal vada ($n = 12$) | $11.69^{b}$ (5.32-15.52) | $5.57^{b}$ (2.59-7.87) | $4.54^{b}$ (1.92-5.97) | $1.14^{bcd}$ (0.04-1.62) | $5.68^{b}$ (1.96-7.37) | $0.05^{b}$ (0.01-0.10) | $1.09^{b}$ (0.03-1.53) | $6.43^{c}$ (2.93-8.53) | $3.06^{c}$ (1.42-4.33) | $2.50^{c}$ (1.06-3.28) | $0.63^{c}$ (0.02-0.89) | $3.12^{c}$ (1.08-4.05) | $0.03^{d}$ (0.01-0.06) | $0.60^{c}$ (0.02-0.84) |
| Uludu vada ($n = 14$) | $10.77^{b}$ (5.09-17.36) | $5.08^{b}$ (2.40-8.35) | $4.16^{b}$ (2.05-7.20) | $1.28^{b}$ (0.44-2.54) | $5.45^{b}$ (2.49-9.00) | $0.07^{ab}$ (0.02-0.13) | $1.06^{b}$ (0.42-1.67) | $7.11^{c}$ (3.31-11.28) | $3.35^{c}$ (1.56-5.43) | $2.75^{c}$ (1.33-4.68) | $0.85^{c}$ (0.29-1.65) | $3.59^{c}$ (1.62-5.85) | $0.04^{cd}$ (0.01-0.08) | $0.70^{c}$ (0.27-1.09) |

TF: total fat; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; TUFA: total unsaturated fatty acids (MUFA + PUFA); n3-PUFA: total omega-3 fatty acids; n6-PUFA: total omega-6 fatty acids. [#]Serving size of each food group is presented in Table 1. Results expressed as mean with range of results of all analysed samples of each RTE food type. Values within a column followed by different letters are significantly different at $p < 0.05$.

Table 4: (a) Fatty acid composition, quantity (mg/g), and fatty acid ratios of selected ready-to-eat street foods of Sri Lanka. (b) Trans fatty acid (TFAs) composition and content (mg/g) and total trans fatty acid contents of ready-to-eat street foods of Sri Lanka

(a)

| Fatty acid | Fried rice | Rice & curry | Koththu | Rolls | Pastry | Dhal vada | Uludu vada |
|---|---|---|---|---|---|---|---|
| | | | | mg/g | | | |
| *SFA* | | | | | | | |
| C 6:0 | ND | 0.03 ± 0.01 | 0.11 ± 0.08 | ND | ND | ND | ND |
| C 8:0 | 0.05 ± 0.04 | 0.64 ± 0.17 | 0.77 ± 0.23 | 0.06 ± 0.06 | 0.22 ± 0.10 | 0.30 ± 0.23 | 0.21 ± 0.19 |
| C 10:0 | 0.07 ± 0.05 | 0.42 ± 0.11 | 0.62 ± 0.50 | 0.04 ± 0.02 | 0.27 ± 0.05 | 0.21 ± 0.08 | 0.15 ± 0.10 |
| C 12:0 | 0.68 ± 0.33 | 3.20 ± 0.76 | 5.31 ± 4.51 | 0.37 ± 0.26 | 2.32 ± 0.42 | 1.79 ± 1.09 | 1.30 ± 1.05 |
| C 14:0 | 0.87 ± 0.54 | 1.42 ± 0.25 | 2.67 ± 1.19 | 1.05 ± 0.34 | 2.78 ± 0.55 | 1.65 ± 1.00 | 1.43 ± 1.15 |
| C 15:0 | 0.03 ± 0.01 | 0.02 ± 0.00 | 0.01 ± 0.01 | 0.07 ± 0.02 | 0.10 ± 0.05 | 0.05 ± 0.01 | 0.05 ± 0.02 |
| C 16:0 | 22.68 ± 4.79 | 11.75 ± 1.88 | 18.96 ± 4.49 | 42.95 ± 6.23 | 104.16 ± 19.36 | 45.72 ± 4.47 | 42.99 ± 5.34 |
| C 17:0 | 0.06 ± 0.02 | 0.03 ± 0.01 | 0.06 ± 0.03 | 0.11 ± 0.04 | 0.20 ± 0.07 | 0.09 ± 0.01 | 0.09 ± 0.03 |
| C 18:0 | 2.71 ± 0.63 | 1.37 ± 0.20 | 2.81 ± 0.58 | 3.58 ± 2.09 | 18.60 ± 2.51 | 4.41 ± 0.28 | 4.18 ± 1.34 |
| C 20:0 | 0.16 ± 0.04 | 0.08 ± 0.02 | 0.12 ± 0.03 | 0.29 ± 0.14 | 0.52 ± 0.15 | 1.39 ± 0.99 | 0.33 ± 0.11 |
| C 22:0 | 0.04 ± 0.02 | 0.02 ± 0.00 | 0.03 ± 0.03 | 0.06 ± 0.02 | 0.11 ± 0.05 | 0.07 ± 0.01 | 0.06 ± 0.02 |
| C 23:0 | ND | ND | ND | 0.01 ± 0.00 | ND | ND | ND |
| C 24:0 | 0.01 ± 0.00 | 0.02 ± 0.01 | ND ± 0.02 | 0.06 ± 0.02 | 0.05 ± 0.03 | 0.05 ± 0.01 | 0.01 ± 0.01 |
| Total SFA | 27.36 ± 1.20 | 18.98 ± 0.65 | 31.47 ± 1.44 | 48.64 ± 1.67 | 129.35 ± 2.24 | 55.73 ± 1.47 | 50.8 ± 1.89 |
| *cis-MUFA* | | | | | | | |
| C 14:1 | 0.03 ± 0.01 | 0.01 ± 0.00 | 0.05 ± 0.04 | 0.01 ± 0.01 | 0.02 ± 0.01 | ND | ND |
| C 15:1 | ND | ND | ND | ND | 0.01 ± 0.01 | ND | ND |
| C 16:1 | 0.68 ± 0.36 | 0.36 ± 0.00 | 0.75 ± 0.23 | 0.36 ± 0.21 | 0.43 ± 0.05 | 0.19 ± 0.07 | 0.19 ± 0.02 |
| C 17:1 | 0.02 ± 0.01 | ND | ND | 0.03 ± 0.02 | 0.03 ± 0.00 | 0.02 ± 0.01 | 0.02 ± 0.00 |
| C 18:1n-9 | 22.96 ± 5.11 | 11.29 ± 0.64 | 20.9 ± 6.58 | 40.84 ± 18.89 | 66.55 ± 4.31 | 44.02 ± 13.14 | 40.35 ± 5.26 |
| C 18:1n-11 | 0.57 ± 0.24 | 0.37 ± 0.04 | 0.65 ± 0.32 | 0.87 ± 0.93 | 1.39 ± 0.38 | 1.01 ± 0.35 | 0.98 ± 0.36 |
| C 20:1n-9 | 0.12 ± 0.08 | 0.15 ± 0.03 | 0.18 ± 0.00 | 0.13 ± 0.19 | 0.19 ± 0.08 | 0.14 ± 0.10 | 0.10 ± 0.09 |
| C 22:1n-9 | 0.05 ± 0.02 | 0.03 ± 0.01 | ND | 0.05 ± 0.02 | 0.09 ± 0.03 | ND | ND |
| C24:1 n-9 | 0.01 ± 0.01 | 0.01 ± 0.00 | 0.02 ± 0.01 | 0.02 ± 0.01 | 0.01 ± 0.00 | ND | ND |
| Total MUFA | 24.44 ± 0.93 | 12.22 ± 0.57 | 22.56 ± 0.99 | 42.31 ± 1.62 | 68.72 ± 0.95 | 45.39 ± 1.29 | 41.65 ± 1.70 |
| *cis-PUFA* | | | | | | | |
| C 18:2 n-6 | 7.23 ± 1.70 | 4.17 ± 0.16 | 7.73 ± 2.45 | 11.12 ± 1.26 | 19.2 ± 5.38 | 10.94 ± 3.19 | 12.06 ± 1.47 |
| C 18:3 n-6 | 0.01 ± 0.00 | 0.01 ± 0.00 | 0.03 ± 0.02 | 0.02 ± 0.01 | 0.02 ± 0.01 | 0.04 ± 0.01 | 0.03 ± 0.01 |
| C 18:3 n-3 | 0.25 ± 0.17 | 0.13 ± 0.03 | 0.15 ± 0.12 | 0.22 ± 0.07 | 0.40 ± 0.29 | 0.32 ± 0.27 | 0.55 ± 0.16 |
| C 20:2 n-6 | 0.02 ± 0.01 | 0.01 ± 0.00 | 0.03 ± 0.02 | 0.04 ± 0.02 | 0.03 ± 0.02 | 0.02 ± 0.02 | 0.01 ± 0.01 |
| C 20:3 n-6 | 0.05 ± 0.01 | 0.02 ± 0.01 | 0.11 ± 0.00 | 0.02 ± 0.01 | 0.02 ± 0.01 | ND | 0.01 ± 0.01 |
| C 20:4 n-6 | 0.01 ± 0.00 | ND | ND | 0.02 ± 0.01 | ND | 0.01 ± 0.00 | 0.02 ± 0.01 |
| C 22:2 n-6 | ND | ND | ND | 0.08 ± 0.02 | 0.08 ± 0.02 | ND | 0.01 ± 0.00 |
| C 20:5 n-3 | 0.02 ± 0.00 | 0.01 ± 0.00 | 0.03 ± 0.01 | 0.05 ± 0.02 | 0.06 ± 0.02 | 0.02 ± 0.01 | 0.03 ± 0.02 |
| C 22:4 n-6 | 0.01 ± 0.00 | ND | ND | 0.01 ± 0.00 | 0.01 ± 0.01 | ND | ND |
| C 22:5 n-6 | 0.02 ± 0.01 | 0.01 ± 0.00 | 0.01 ± 0.00 | 0.04 ± 0.01 | 0.04 ± 0.02 | ND | 0.01 ± 0.01 |
| C 22:5 n-3 | 0.01 ± 0.00 | 0.01 ± 0.00 | ND | 0.03 ± 0.01 | 0.02 ± 0.01 | ND | ND |
| C 22:6 n-3 | 0.05 ± 0.03 | 0.15 ± 0.10 | 0.03 ± 0.02 | 0.60 ± 0.11 | 0.38 ± 0.06 | ND | 0.04 ± 0.01 |
| Total PUFA | 7.72 ± 0.27 | 4.55 ± 0.15 | 8.24 ± 0.41 | 12.28 ± 0.48 | 20.27 ± 0.34 | 11.37 ± 0.40 | 12.79 ± 0.58 |

Table 4: Continued.

| Fatty acid | Fried rice | Rice & curry | Koththu | Rolls | Pastry | Dhal vada | Uludu vada |
|---|---|---|---|---|---|---|---|
| | | | | mg/g | | | |
| *Fatty acid ratios; means* | | | | | | | |
| PUFA:SFA | 0.28 | 0.24 | 0.26 | 0.25 | 0.16 | 0.20 | 0.25 |
| PUFA:MUFA | 0.32 | 0.37 | 0.37 | 0.29 | 0.29 | 0.25 | 0.31 |
| n6-PUFA: n3-PUFA | 27 | 34 | 24 | 19 | 21 | 26 | 18 |

The content of each fatty acid is expressed as means ± SD for each food type. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids. ND: not detected; limit of determination: 0.01 mg/g.

(b)

| TFA | Mean TFA content (mg/g) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fried rice | Rice & curry | Koththu | Rolls | Pastry | Dhal vada | Uludu vada |
| C 14:1t | ND | ND | 0.02 | 0.01 | ND | ND | ND |
| C16:1t | 0.07 | 0.02 | 0.06 | 0.06 | 0.19 | 0.06 | 0.05 |
| C 17:1n-8t | 0.01 | ND | ND | 0.01 | 0.02 | ND | ND |
| C 18:1n-9t | 0.07 | 0.06 | 0.12 | 0.16 | 0.17 | 0.23 | 0.11 |
| C 18:2n-6t,9t | ND | ND | ND | 0.01 | ND | ND | ND |
| C18:2n-6t,9c | 0.08 | 0.05 | 0.06 | 0.15 | 0.24 | 0.24 | 0.24 |
| C18:2n-6c, 9t | 0.08 | 0.06 | 0.06 | 0.16 | 0.26 | 0.26 | 0.26 |
| C18:3n-3t, 6t, 9t | 0.02 | ND | 0.02 | 0.02 | 0.04 | 0.04 | 0.02 |
| C 18:3n-3t, 6t, 9t | 0.02 | ND | ND | 0.02 | 0.04 | 0.03 | 0.02 |
| C 22:1t | 0.01 | ND | 0.02 | ND | ND | ND | ND |
| Total TFA (mg/g) | 0.36 | 0.19 | 0.36 | 0.60 | 0.96 | 0.86 | 0.70 |
| Total TFA (g/100 g) | 0.04 | 0.02 | 0.04 | 0.06 | 0.10 | 0.09 | 0.07 |
| Range | (0.01-0.12) | (0.01-0.02) | (0.01-0.11) | (0.03-0.13) | (0.06-0.29) | (0.02-0.14) | (0.02-0.12) |
| Total TFA (% total fatty acids) | 0.57 | 0.23 | 0.04 | 0.55 | 0.43 | 0.75 | 0.65 |
| Range | (0.25-1.05) | (0.12-0.38) | (0.18-1.60) | (0.32-0.89) | (0.25-1.12) | (0.34-1.12) | (0.32-1.03) |

ND: not detected; limit of determination: 0.01 mg/g; t: trans isomers; c: cis isomer.

effect on increasing the CVD risks compared to other SFAs, and the linoleic acid is considered the most effective PUFA to replace the SFAs [48, 51, 52]. In this study, palmitic acid was the most abundant fatty acid in all samples, including rice and curry. Palmitic acid presented in the range of 5.35-134.66 mg/g (0.53 to 13.47 g/100 g), and in this study, pastry had the highest mean palmitic acid content (104.16 mg/g). According to WHO market survey data, coconut oil is the most consumed vegetable oil in Sri Lanka [38], and in general, the major fatty acid of coconut oil is lauric acid (45.1-53.2% of total fatty acids) [53]. The mean lauric acid content in each RTE food type of this study was in the range of 0.37-5.31 mg/g (0.04-0.53 g/100 g), indicating that the contribution of lauric acid to the total fatty acid composition of foods analysed was comparatively lower than that of palmitic acid. Utilizing vegetable oil with a high palmitic acid content, such as palm olein (the second most utilized oil in Sri Lanka) as the oil source for frying, may have contributed to the significantly higher palmitic acid content than lauric acid content. The contribution of palmitic acids from other food ingredients may also be attributed to increased palmitic acid contents in RTE foods. The most prominent MUFA in all the samples was the oleic acid (C18:1n-9), and the highest mean content (66.55 mg/g) of oleic acid was detected in pastry, while the lowest (11.27 mg/g) in rice and curry. Linoleic acid (C18:2n-6) was the major PUFA as well as the central n-6 PUFA detected in all samples, and the mean content was in the range of 4.14 to 19.20 mg/g, while pastry contained the highest mean linoleic acid content than other foods.

The TFA contents are presented in Table 4 part b. All RTE food types contained mean TFAs of 0.19 to 0.96 mg/g (0.12% to 1.60% of total fat). The highest mean TFA was detected in the pastry (0.96 mg/g), while dhal vada contained 0.870 mg/g of mean TFAs. The prominent TFAs detected were elaidic acid (C18:1n-9t) and trans isomers of C18:2n (C18:2n-6t,9c and C18:2n-6c,9t) while C16:1t, C17:1t, and trans isomers of C18:3 were also detected in trace amounts in some of the food groups. Trans fat should be as low as possible, according to the European Food Safety Authority (EFSA) [21]. However, all the tested samples had TFA, which may be fused into the food during the food frying or preparation process from the frying medium. In the WHO Sri Lanka report for trans fats [38], the TFA contents in all foods are presented as per 100 g of total fat (% total fatty acids). The TFA contents reported were patty samples 0.7-2.0, fried rice 0-1.6, koththu 0-0.76, rolls 0-1.23, dhal vada 0-0.5, and uludu vada 0-1.23 of % total fatty acids. Interestingly, in the WHO Sri Lanka report, the TFA contents were not detected in the same food types chosen for the current study for the Colombo district. The reported

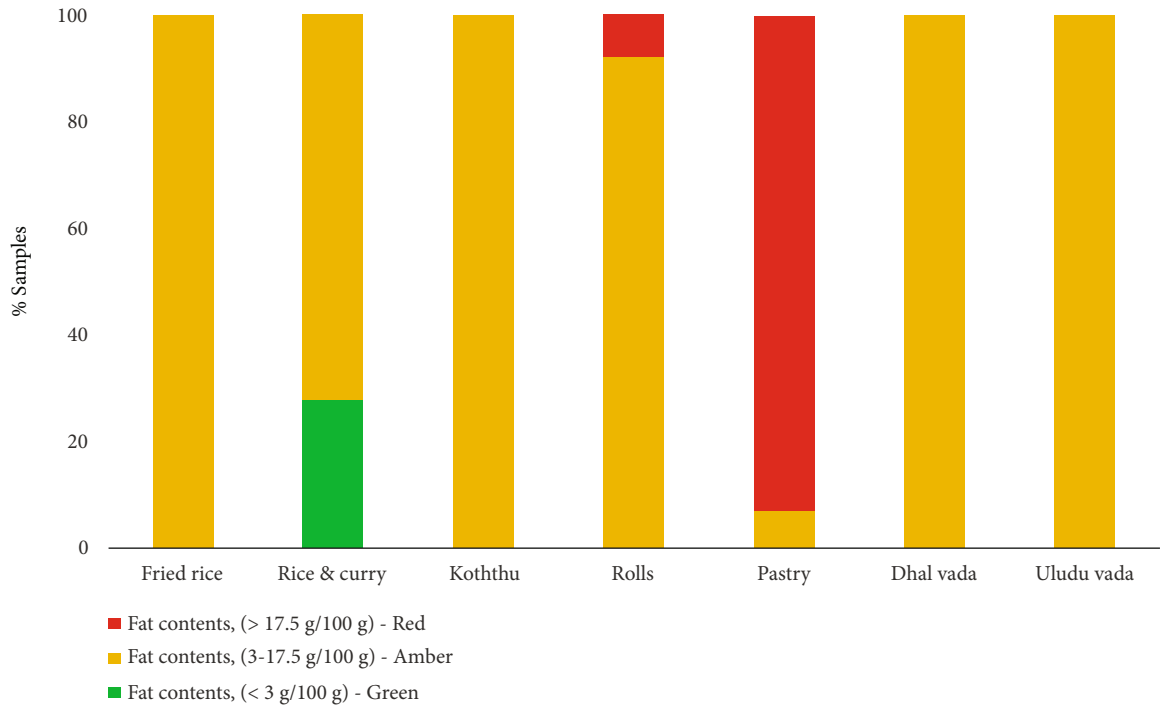


Figure 1: Percentage of Sri Lankan street food samples having total fat contents of <3 g/100 g, 3-17.5 g/100 g, and >17.5 g/100 g in each ready-to-eat street food types in Sri Lanka.

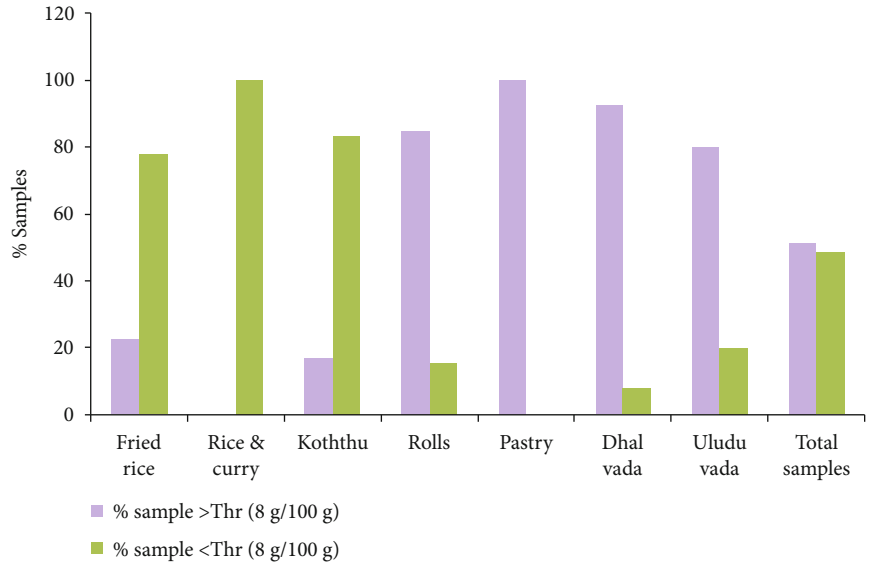


Figure 2: Percentage of Sri Lankan ready-to-eat street food samples in each food type having a total fat content of more than and less than the threshold limit (8 g/100 g) for children in Sri Lanka. >Thr = more than threshold; <Thr = less than threshold.

TFA isomers in this report were elaidic acid (18:1n-9t) and linolelaidic acid (18:2n-6t,9t) only. However, in the current study, a total of ten numbers of TFAs were analysed. Thus, this study reports comparatively more accurate and comprehensive TFA contents in the RTE foods in Sri Lanka.

*3.3. Evaluation of Fat Compositions with WHO/FAO and FDA Daily Nutritional Requirements.* Each fatty acid content is presented as per serving size to evaluate the fatty acid data of food with the recommended daily values (DV), percentage daily values (%DVs), and daily nutritional goals set by international food organisations. DVs are the recommended amounts of nutrients to consume or not exceed daily. The %DV is how much a nutrient in a single serving of an individually packaged food or dietary supplement contributes to a daily diet [54]. Moreover, WHO/FAO has recommended population nutrient intake goals (NIGs) to prevent diet-related chronic diseases [3]. The recommended NIGs for

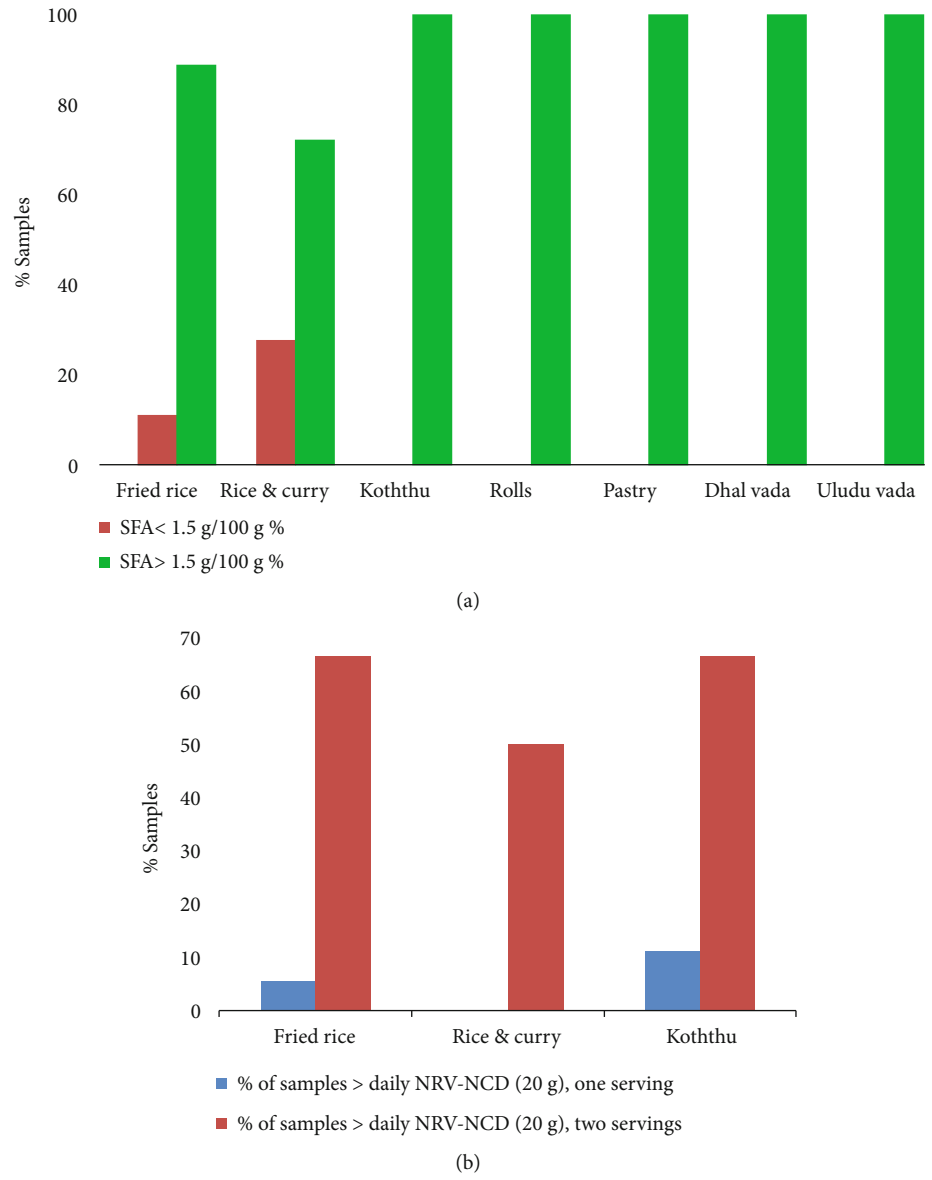


Figure 3: Percentages of Sri Lankan ready-to-eat street food samples having SFA (saturated fat) content: (a) greater and/or less than 1.5 g/100 g in each food group and (b) exceeded the daily NRV- (nutritional recommended value-) NCD limit per one and two servings of each street food meals.

fatty acids as a %E and those NIGs in grams for reference daily energy intake of 8400 kJ (2000 kcal) diet are in Table 5. The energy from each fat component was calculated using the conversion factor of 37.6 kJ/g (9 kcal/g) [20]. The average weight of one unit of rolls, pastry, uludu vada, or dhal vada was considered to be the serving size of each snack type. The mean weights of the study samples of fried rice, rice, curry, and koththu were used as the serving size.

None of the samples contained total fat more than the upper recommended daily NIG value (U-NIG). All tested samples in each RTE food, except in fried rice and koththu food groups, contained fat less than the lower level of NIG (L-NIG) or lower level of RI: 33 g or 44 g, respectively (Table 5). On the other hand, the TF contents of each food type as % daily value (%DV) of each food type are presented in Figure 4. The %DV of each food sample indicated that some food types of fried rice and koththu contained more than 50% of %DV. Thus, people may have a high-fat content (more than the recommended DV) when having two servings (meals) of fried rice or koththu or one serving of fried rice and the other from koththu.

The NIG for total PUFA is 6-10%E (for daily intake of reference 8370 kJ diet NIGs in grams: 13-22 g). The PUFA in each studied RTE food per serving contains 0.2 g to 7.13 g. Therefore, the intakes of PUFA from these RTE foods are lesser than the recommended lower limit. All the RTE meals of fried rice, rice and curry, and koththu per serving contained lower n-3 PUFA contents than the recommended L-NIG of 2.2 g (Table 5). Mean n-3 PUFA contents per serving of all foods were comparatively much lower (<10% of the

Table 5: WHO/FAO nutritional daily intakes (NIGs), percentage samples to lower and upper limits (L_NIG, U_NIG) of NIGs.

| Fatty acid | NIG, %E | For 2000 kcal daily intake NIGs in grams | | Food group (meals) | % samples of each group having each fat component | |
|---|---|---|---|---|---|---|
| | | L_NIG (g) | U_NIG (g) | | <L_NIG | >U_NIG |
| TF | 15-30 | 33.0 | 67.0 | Fried rice | 65 | 0 |
| | | | | Rice and curry | 100 | 0 |
| | | | | Koththu | 67 | 0 |
| SFA | <10 | — | 22.2 | Fried rice | — | 6 |
| | | | | Rice and curry | | 0 |
| | | | | Koththu | | 11 |
| PUFA | 6 -10 | 13.33 | 22.22 | Fried rice | 100 | 0 |
| | | | | Rice and curry | 100 | 0 |
| | | | | Koththu | 100 | 0 |
| n6-PUFA | 5-8 | 11.1 | 17.8 | Fried rice | 100 | 0 |
| | | | | Rice and curry | 100 | 0 |
| | | | | Koththu | 100 | 0 |
| n3-PUFA | 1-2 | 2.2 | 4.4 | Fried rice | 100 | 0 |
| | | | | Rice and curry | 100 | 0 |
| | | | | Koththu | 100 | 0 |

L_NIG: lower limit of WHO-recommended population nutrient intake goals; U_NIG: upper limit of WHO-recommended population nutrient intake goals; %E: daily total energy intake percentage. TF: total fat; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; n3-PUFA: total omega-3 fatty acids; n6-PUFA: total omega-6 fatty acids.

L-NIG), possibly due to the absence of n-3 PUFA-rich fat sources in these foods. Hence, individuals regularly consuming these prepared meals cannot reach the L-NIG for n-3 PUFA fatty acids. As a result, it becomes vital for consumers to procure 90% of their n-3 PUFA fatty acid requirement from other primary meals to fulfil the daily stipulated recommendation. The lack of n-3 fatty acids in these RTE street meals becomes apparent compared to the established dietary guidelines. The mean n-6 PUFA contents per serving size of koththu and fried rice were significantly higher than in other groups. However, these two food groups of koththu and fried rice contained mean n-6 PUFAs per serving, less than the L-NIG of 11.1 g.

The mean and the range of beneficial omega fatty acids of linoleic acid (LA), alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA); contents of foods with EFSA-recommended adequate intake (AI) per day; and %AI (how much percentage of a nutrient in a single serving contributes to an AI) of studied RTE meals are in Table 6. The most elevated mean %AI for LA (40%) was detected in the fried rice food group from all samples in this study. Conversely, rice and curry contained the lowest %AI of LA compared to other meals. Notably, the results of %AI for ALA of all samples in this study revealed that ALA contents in all street food meals are considerably lower. Further, the recommended AI for the other two main beneficial n-3 fatty acids, EPA and DHA, is 250 mg/day, based on the health benefits for cardiovascular considerations. The %AI for EPA + DHA indicates that all analysed samples of fried rice and koththu contained notably less than the recommended daily consumption level for EPA and DHA.

*3.4. Fatty Acid Indices.* In this study, various fatty acid indices were analysed to understand the contribution of RTE foods to NCD incidence in Sri Lanka.

*3.4.1. PUFA/SFA Index.* The recommended PUFA to SFA ratio of foods has to be ≥0.4 for better cardiovascular health (CVH) [55, 56]. In this study, the PUFA/SFA ratios of the RTE foods were in the range of 0.16-0.28. The lowest mean ratio was detected in the pastry sample, which contained the highest SFA and the highest PUFA (g/100 g) contents than other foods. As the PUFA/SFA indices of all the foods were lower than 0.4, it can be concluded that the street foods in Sri Lanka have a lesser protective effect against cardiovascular risk factors. Further, the PUFA/MUFA ratio of <1 (0.29-0.37) of PUFA/MUFA indicates that consumers have a fat source with more MUFA than the more beneficial PUFA in Sri Lankan street foods.

*3.4.2. n-6 PUFA: n-3 PUFA Ratio.* The average omega fatty acid ratios (n-6 PUFA: n-3 PUFA) of all these street foods ranged from 18 : 1 to 34 : 1, which is much higher than the recommended ratios of 4 : 1-5 : 1 by WHO. Maintenance of n-6 : n-3 ratios below ten is advocated as a constructive measure to reduce NCDs, including cardiovascular diseases, colorectal and breast cancers, and the incidence of asthma [57, 58].

*3.4.3. Index of Atherogenicity (IA) and Index of Thrombogenicity (IT).* The IA of each food type in this study is presented in Table 7. The mean IA of all of the food items was more than 0.8. The highest mean IA of 1.63 was detected in koththu, and the IA of all pastry samples analysed in this study was

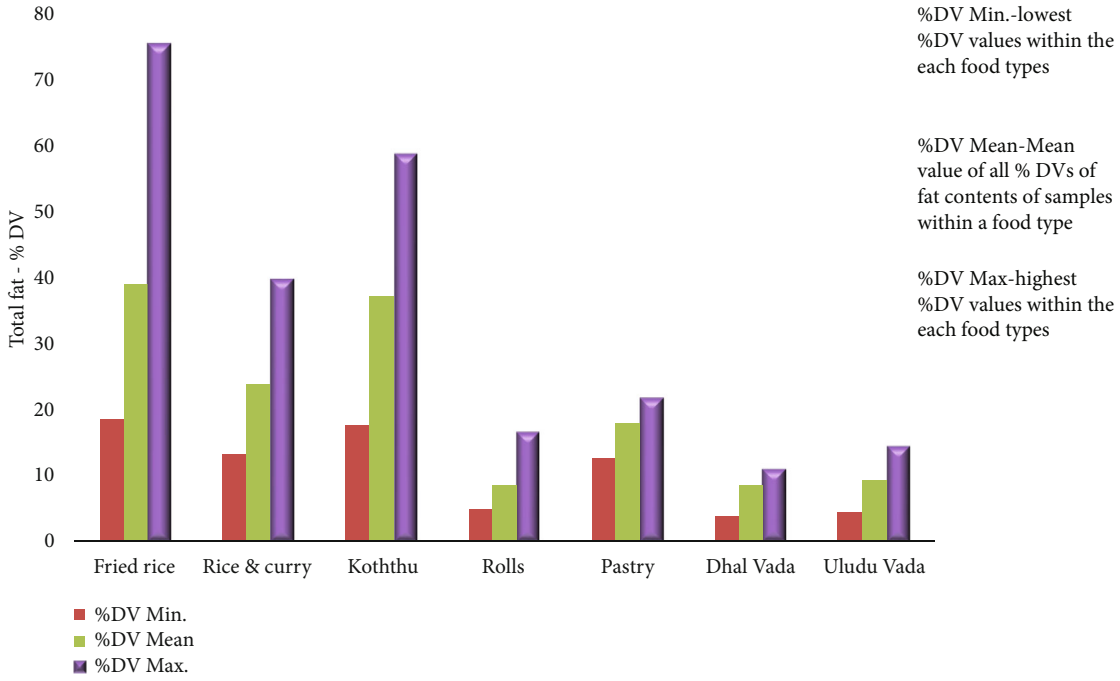


Figure 4: Total fat content of each food type of Sri Lankan ready-to-eat street foods expressed as a % daily value (%DV) of each food type (%DV = total fat of a sample as a percentage of the recommended daily value of 78 g).

more than 1.00. The scientific evidence so far has revealed that some SFAs of C12:0, C14:0, and C16:0 favour the adhesion of lipids to cells of circulatory and immunological systems, and these SFAs are considered proatherogenic [33]. On the other hand, TUFA inhibits the accumulation of plaques and reduces phospholipids, cholesterol, and essential fatty acids, thus being considered antiatherogenic [33, 59]. Consuming foods with lower IA can reduce total cholesterol and LDL-cholesterol levels in human blood plasma [60].

It is beneficial for CVH to consume foods with lower IT [33]. However, the mean IT of all food types analysed was higher than 1.0 (IT >1.0) and in the range of 1.47-2.76 (Table 7). According to the literature, the IA and IT of Eskimo diets were 0.39 and 0.28, respectively, while in the British diet, they were 0.93 and 1.21 [32]. Comparatively, the IT is higher in the Sri Lankan RTE street meals analysed in this study.

### 3.5. Sterol Composition

*3.5.1. Cholesterol.* The cholesterol was detected in fried rice, rice and curry, koththu, rolls, and pastry only; in the uludu vada and dhal vada, cholesterol was not detected. The mean cholesterol contents of each food were presented in Figure 5(a). The cholesterol content of fried rice, rice and curry, koththu, rolls, and pastry were in the ranges of 7.74-32.44, 4.36-14.53, 1.43-57.08, 0.60-47.08, and 2.01-47.73 mg/100 g, respectively.

Cholesterol contents per serving in each food type of fried rice, rice and curry, koththu, rolls, and pastry were in the ranges of 38.7-162.21, 21.80-72.65, 6.43-256.85, 0.36-28.25, and 1.25-29.59 mg, respectively. The recommended daily value for cholesterol is 300 mg [54]. 17% of koththu and 22% of fried rice samples contained more than 50% of %DV (>150 mg) of cholesterol per serving. As the primary sources of cholesterol were animal fat sources, koththu and fried rice food groups contained relatively more animal fat than other food sources. Neither uludu vada nor dhal vada contained animal fat sources as an ingredient or frying fat source.

*3.5.2. Phytosterol Composition.* The three main phytosterols, $\beta$-sitosterol, stigmasterol, and campesterol, were detected in almost all samples. Figure 5(a) presented the total mean phytosterol content in mg per 100 g of each RTE food and in mg per serving size. Total phytosterol contents (mg) per serving size of studied food fried rice, rice and curry, koththu, rolls, pastry, dhal vada, and uludu vada were in the ranges of 12.25-77.30, 21.25-136.65, 13.55-45.68, 3.63-15.54,6.99-18.36, 3.29-16.32, and 3.29-23.96 mg, respectively.

Figure 5(b) presents the mean phytosterol composition in each food item. The most prominent phytosterol is $\beta$-sitosterol, and the mean content in all the food types ranged from 3.75-14.17 mg/100 g. The mean stigmasterol content in all food types was 1.36-3.77 mg/100 g, and campesterol was 1.07-3.80 mg/100 g. The National Cholesterol Education Program (NCEP) of the USA has recommended a daily intake of 2 g of phytosterols to protect against cardiovascular disease risk [31]. The intake of phytosterols from all RTE food types is far less than this recommended limit. The highest total phytosterol content reported in this study (136.65 mg) is only 6.8% of the daily recommended level.

Overall, the fatty acid compositions of RTE foods have significant variations, and most importantly, the SFA was higher than the PUFA. Thus, the unhealthy fat content is

Table 6: Major omega fatty acids (mean and range) in RTE street meals, recommended adequate intake (AI) for omega fatty acids, and %AI (mean & range) in each food group.

| Food group (meal) | LA | | | ALA | | | EPA + DHA | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean (range) (g/serving size) | AI (g) | %AI mean (range) | Mean (range) (mg/serving size) | AI (mg) | %AI mean (range) | Mean (range) mg/serving size | AI (mg) | %AI mean (range) |
| Fried rice | 3.64 (2.01-6.37) | 9 | 40 (22-71) | 120.77 (5.69-340.32) | 1100 | 11 (0.5-31) | 31.73 (4.68-56.58) | 250 | 13 (2-23) |
| Rice & curry | 2.09 (1.09-3.28) | 9 | 23 (12-36) | 58.89 (11.74-166.31) | 1100 | 5 (1.1-15) | 56.56 (2.38-238.50) | 250 | 23 (1-95) |
| Koththu | 3.41 (0.80-6.55) | 9 | 38 (9-73) | 97.22 (ND-257.90) | 1100 | 9 (0-23) | 31.43 (2.30-80.29) | 250 | 13 (1-32) |

ND: not detected; limit of determination: 0.01 mg; LA: linoleic acid; ALA: alpha-linolenic acid; EPA: eicosapentaenoic acid; DHA: docosahexaenoic acid. AI: adequate intake per day according to EFSA (EFSA, 2017); %AI: mean omega fatty acid/serving size content as a percentage of adequate intake.

Table 7: Indices of atherogenicity and thrombogenicity of ready-to-eat street foods of Sri Lanka.

| Food item | Index of atherogenicity | | Index of thrombogenicity | |
|---|---|---|---|---|
| | Mean | Range | Mean | Range |
| Fried rice | 0.80 | 0.62-0.97 | 1.47 | 1.18-1.61 |
| Rice & curry | 1.28 | 0.77-3.64 | 1.52 | 1.07-1.81 |
| Koththu | 1.63 | 0.70-7.22 | 1.66 | 0.98-3.71 |
| Rolls | 0.92 | 0.83-1.25 | 1.64 | 1.30-2.10 |
| Pastry | 1.39 | 1.13-1.93 | 2.76 | 2.39-3.55 |
| Dhal vada (DH) | 0.97 | 0.83-1.74 | 1.73 | 1.62-2.06 |
| Uludu vada (UV) | 0.95 | 0.83-1.45 | 1.70 | 1.58-1.96 |

higher than healthier fatty acids, and certain RTE food types cannot be recommended to children as TF and SF contents exceeded the nutrient model threshold limits for children in Sri Lanka. Both fried rice and koththu have a considerable proportion of samples with higher unhealthy fat content (TF, SFA), which should be limited to one meal. Interpreting each fat component against serving size is essential to clarify the differences between daily recommendations and actual consumption. Interestingly, each unhealthy and healthy fat component per serving and its %DV or %RI or % NIG are noteworthy in forecasting the daily unhealthy fat consumption by consumers. Nutritional information on PUFA, MUFA, and omega fatty acids was not mandatory by the current version of food regulations. Undoubtedly, this vital nutrient information must be made visible to consumers. The regulations, such as colour code regulations on TF and SFA, were not followed by the informal food sector merchants and have yet to be regulated by relevant bodies. Therefore, regulating institutes and health sector authorities must be concerned about these findings to reconsider the country's food safety regulations.

*3.6. Comparison with Similar Street Food Studies in Asia.* In this study, all street foods contained TFAs, less than 2% of total fatty acids. Similar studies on fatty acid compositions of street foods in Asia, including India [5], Malaysia [61], and Central Asia [62–64], have reported the presence of TFAs in RTE street foods. Higher TFA contents (0.29-22.96% of total fatty acids) are present in street foods from India, while TFA was not detected in street foods from Malaysia. In India, vegetable ghee with high TFAs (2.5-29.9% of fatty acids) was mainly used for deep-frying and frying [5], and in Malaysia, palm oil and tub margarine, which do not contain TFAs, are used for frying [61]. Also, a review on the influence of heating during cooking on the TFA content of edible oils reported that TFAs were not produced during the heating of edible oils below 200°C [65]. A recent study revealed that the most consumed oils in Sri Lanka are coconut and palm olein [38]. The presence of TFAs in all street foods in this study could described as having higher frying temperatures and may be due to quality and malpractices of oil sources such as the presence of TFAs and reused oil.

In this study, the total TUFAs (PUFA + MUFA) were lower than SFAs in all analysed street foods from Sri Lanka. Findings from two fatty acid studies in Asia presented higher TUFAs than SFAs in street foods. Those are savoury snacks and street food meals analysed in Malaysia, and savoury pastries fried and filled with meat, vegetables, or potato (samsa, pirozhki, bellyache, chebureki, and sausage rolls) analysed in Kazakhstan. The central Asian country of Kyrgyzstan reported high SFA, TFA, and fat in fried and steamed dishes and snacks. The TUFAs were higher in street food from Malaysia; the most abundant fatty acid group from all three fatty acid groups of SFA, MUFA, and PUFA is SFAs, which is similar to this study. Frying and deep-frying with various fat sources are the primary cooking methods for preparing street foods in this region. Diversity and variations in fatty acids were apparent due to the oil or fat source, its fatty acid composition, quality, and preparation methods or frying temperature.

Compared to Asian countries, similar studies have been carried out in non-Asian countries. A study was conducted in urban Bosnia and Herzegovina for takeaway and street food [66]. Primary takeaway food purchases were identified as pastries, bread, and main dishes. The main street foods were compromised with industrial sweets and beverages. Street food contained higher TF content (12.6 g vs. 8.8 g, $P < 0.001$) and SFA content (8.9 g vs. 3.9 g/100 g, $P < 0.001$) than takeaway food. TFA and PUFA contents were higher in takeaway foods than in street food purchases (0.19 vs. 0.11 g/100 g and 1.9 vs. 1.0 g/100 g, $P < 0.001$, respectively). The deep-fried street foods from Chile (French fries, cheese empanadas, vegetarian empanadas, spring rolls, sopapillas, and churros) reported total fat content from 5.9% to 32.1% [67]. Regarding the fatty acid profile of these foods, PUFA (45.5-59.3% fatty acids) was higher than SFA (13.9-26.5% fatty acids). The polyene index (PUFA to SFA ratio) of all food samples (1.72 to 3.78), linoleic acid contents (2.7-6.3%), and linoleic to palmitic fatty acid ratios (2.64 to 5.89, where 71% samples contained <4.37) were not complied with the recommended levels (>4%, <2%, and >4.37%, respectively). The fried foods from Egypt (chicken wings, nuggets, broasted chicken, fish, shrimp, octopus, french fries, mashed potato, falafel, eggplant, and onion rings) have been analysed in a recent study [68]. The study presented high TFA contents in fish, French fries, falafel, and eggplant (4.21-5.34% fatty acids). The fatty acid indices of all foods in the above study failed to meet the recommended values. PUFA/SFA ratios of all foods were 0.16-0.34 (recommended value is >0.4) except for French fries (0.54). The n-6 PUFA: n-3 PUFA ratios ranged from 22.14 to 95.28, where the recommended value is <10. Higher

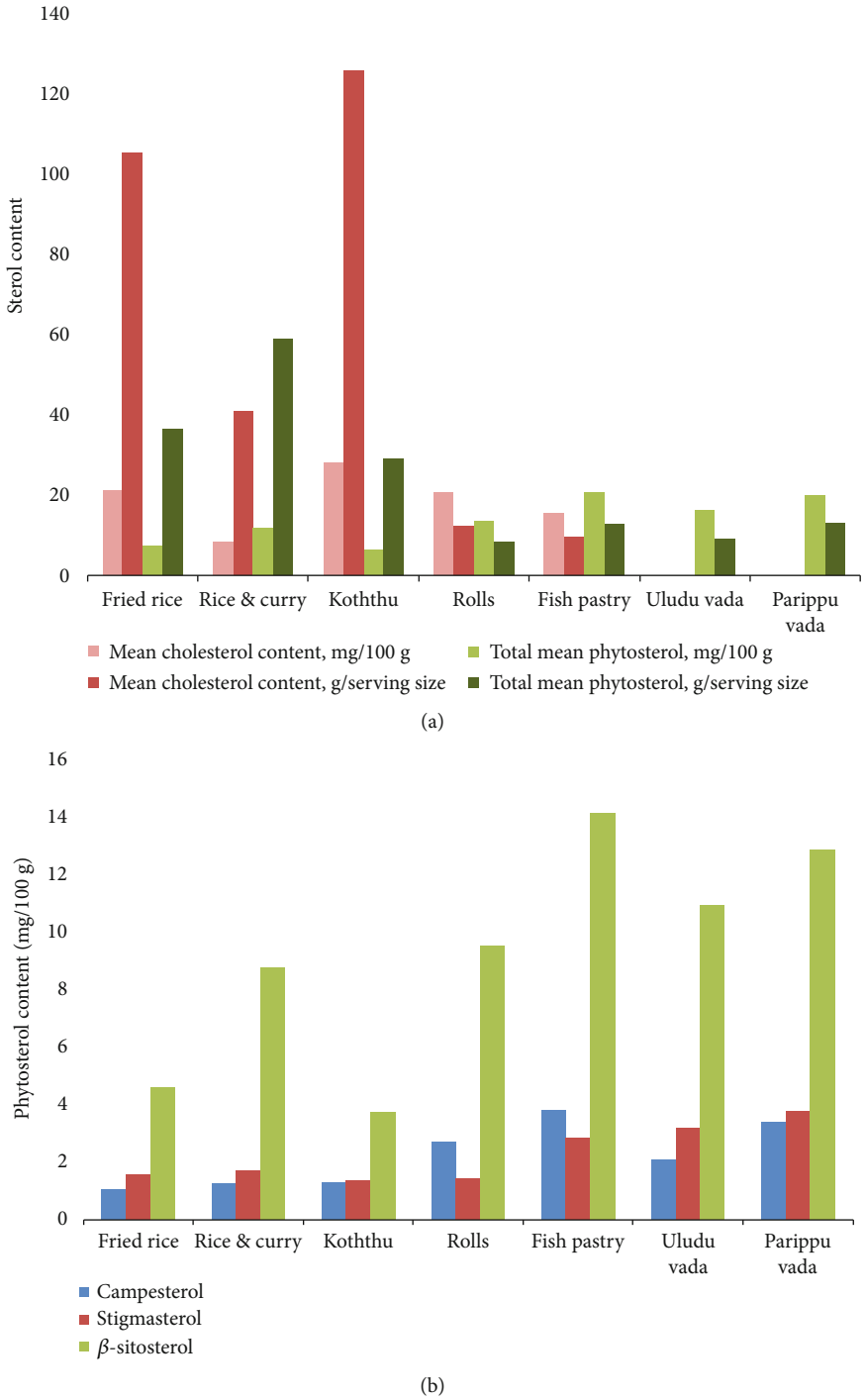


Figure 5: Total sterol composition in each food type of Sri Lankan ready-to-eat street foods. (a) Mean cholesterol and total phytosterol contents. (b) Mean campesterol, stigmasterol, and $\beta$-sitosterol contents.

variations in the fried food diversity were apparent in street foods in Asia and non-Asian countries, and the quality of fatty acid composition in all these foods was alarming the immediate actions from the food regulators.

## 4. Conclusions

This study reports a comprehensive analysis of the fat composition of street foods in Sri Lanka. The most prominent fat group was SFA in all the food types analysed. The PUFA/SFA ratios of all foods were lower than 0.4. Further, n-6 PUFA/n-3 PUFA ratios of all the foods analysed were higher than the recommended WHO ratios. The indices of atherosclerosis and thrombosis were higher in these RTE foods, indicating the possible risks associated with the fatty acid composition of these foods to cardiovascular health. The essential fatty acid, ALA, was less than the recommended daily intake in all the RTE meals analysed. Therefore, all

these RTE foods had lower levels of healthy and essential fatty acids than the recommended intake. However, the hazardous fat components of TFA were less than the recommended maximum. Cholesterol was also detected in all the foods except vada samples (UV and DH). The phytosterols were less than the recommended level in all food types tested. The nutrient label or locally recommended colour codes were not contained in any of these informal sector food samples and must be considered highly by the local health authorities. Distinct variations were detected in compositions of fatty acids of local street foods when compared to fatty acids of street foods from countries of Asia with different culinary practices. This study is the first comprehensive study of all fatty acids and sterol composition of RTE street foods, including their indices of atherosclerosis and thrombosis in Sri Lanka and their evaluation concerning WHO/FAO- and EFSA-recommended nutrient goals and intake. The findings of this study are vital to government authorities and researchers to characterise and improve the quality of street foods and local culinary practices. Additionally, the results of the present study support an evidence-based platform for collaborating with the national and international nutritional policies and regulations coping with NCDs.

## Data Availability

All references which include support data have been cited.

## Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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