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Chapter 3

FRUIT AND VEGETABLES CONSUMPTION AND THEIR EFFECTS ON HUMAN HEALTH: CURRENT RESEARCH IN MALAYSIA

Nurul Izzah Ahmad*[*], PhD,
Nur Suffia Sulaiman*[†], DrPH,
Norhayati Mustafa Khalid*[‡],
Wan Nurul Farah Wan Azmi*[¶],
Nur Hayati Azizul*[#], MBBS
and Mohd Fairulnizal Md Noh*[•], PhD
Institute for Medical Research, Jalan Pahang,
Kuala Lumpur, Malaysia

ABSTRACT

Fruits and vegetables play an important role in human nutrition and health. Research on their consumption helps guide public health policies. Promotion of fruits and vegetables (FV) consumption is vital in many healthy lifestyle interventions. There are many areas pertaining to FV and their benefits to human health that have been explored by Malaysian

[*]Corresponding Author Email: nurul@imr.gov.my.
[†] Corresponding Author Email: nursuffia@imr.gov.my.
[‡] Corresponding Author Email: norhayati@imr.gov.my.
[¶] Corresponding Author Email: nurulfarah@imr.gov.my.
[#] Corresponding Author Email: nurhayati.azizul@imr.gov.my.
[•] Corresponding Author Email: mofaini@gmail.com.

researchers. This review highlights research on FV and health effects among Malaysians, between the years 2007 and 2017. We will also discuss the current direction and progress of the national research priorities in this area. Information was collected by searching electronic databases and hand searches of both published and unpublished data/reports. Three important areas of focus were FV consumption, nutrition and dietary interventions within the Malaysian setting. It is pertinent to determine if children and adults are meeting the national dietary requirements. Macro- and micro-nutrients found in fruits and vegetables contribute much towards growth, maintenance of health and prevention of disease. Evaluation of dietary interventions guides national efforts to improve public consumption of the recommended intake. We reviewed research and dietary surveys from various backgrounds such as the community, work places, schools and other sub-populations. New research and direction for studies on FV consumption and health effects will contribute towards the health of Malaysians.

Keywords: fruit and vegetables, Malaysia, health effects, consumption

ABBREVIATIONS

AA	ascorbic acid
ABTS	2,2'-azino-*bis*(3-ethylbenzothiazoline-6-sulphonic acid)
BCB	β-carotene bleaching assays
BCLAM	β-carotene/linoleic acid model
BMI	body mass index
BPP	bambangan peel powder
BW	body weight
CAE	catechin equivalents
CIA	Central Intelligence Agency
DPPH	2,2-diphenyl-1-picrylhydrazyl
DW	dry weight
EC_{50}	dose required for reducing the absorbance of DPPH control solution by 50%
EEU	endosperm extract of unripe fruits
EGFR	epidermal growth factor receptor
FAMA	Federation of Agricultural Malaysia

FAO	Food and Agriculture Organization
Fe (II)	ferrous iron
FRAP	ferric reducing antioxidant power
FV	fruit and vegetable
FW	fresh weight
GAE	gallic acid equivalents
GPx	glutathione peroxidase
HDL-c	high density lipoprotein
HSI	Her Shape Intervention
IC_{50}	concentration of the ACE inhibitor required to inhibit 50% of ACE activity
IFN-γ	interferon-gamma
K-11	upland type with narrow leaves
K-25	the low land and aquatic type with broader arrow-shaped leaves
K-88	bamboo shaped leaves
LC–MS/MS	liquid chromatography–mass spectrometry
LDL-c	low-density lipoprotein
LPS	lipopolysaccharide
IL-4	interleukin-4
MANS	Malaysian Adult Nutrition Survey
MDA	malondialdehyde
MDA-MB-231	human breast carcinoma cell lines
MMP-9	matrix metalloproteinase
MOH	Ministry of Health Malaysia
MPJP	*M. pajang* juice powder
NEI	nutrition education intervention
NF-κB	nuclear factor kappa beta
NHMS	National Health Morbidity Survey
$(NH_4)_2SO_4$	ammonium sulfate
NO	nitrite oxide
ORAC	oxygen radical absorbance capacity
PCM	paracetamol
PLM	pulp methanol extract

PLP	pulp PBS extract
PURE	Perspective Urban, Rural, Epidemiology
QE	quercetin equivalents
QOWL	quality or working life
SKM	skin methanol extract
SKP	skinphosphate buffered saline (PBS) extract
SOD	superoxide dismutase
STZ	streptozotocin
TAS	total antioxidant status
TBARS	thiobarbiturate reactive substances
TC	total cholesterol
TCC	total carotenoids content
T2D	Type 2 diabetes
TE	trolox equivalent
TEAC	trolox equivalent antioxidant capacity
TFC	total flavonoid content
TG	triglyceride
TPC	total phenolic content
TNF-α	tumour necrosis factor-α
WFM	whole fruit methanol extract
WFP	whole fruit PBS extract
WHO	World Health Organization

1. INTRODUCTION

Fruits and vegetables (FV) are important for health due to their low fat, sodium and calorie content [1]. These foods are also a source of a wide range of vital micronutrients [2], such as vitamins, minerals, proteins, fibers and bio-functional components compared to many other foods [3]. Inadequate consumption of FV is an important modifiable risk factor contributing to the rising global burden of chronic non-communicable diseases, such as cardiovascular disease, diabetes and various forms of cancers [4, 5, 6] which are responsible for about 63% of deaths globally

[7]. A meta-analysis conducted by Wang and colleagues [8] supports the theory that higher consumption of FV is associated with reduced risk of both all-cause and cardiovascular disease mortality. Risk of mortality decreases by 5% for each additional serving of FV per day; (6% and 5% decrease for vegetables and fruits, respectively). They also observed a threshold for risk reduction of 5 servings per day, i.e., higher intakes resulted in no further reduction in risk. High FV intake is also associated with lower risk of obesity [9], however, a more recent review reported no empirical evidence that increasing FV intake will have a discernible effect on body weight (bw), at least for the studies that had longer than 8 weeks follow-up [10]. Moreover, fiber from FV may contribute to a decreased incidence of Type 2 Diabetes (T2D) due to their low-energy density and glycemic load and high micronutrient content. Green leafy vegetables, in particular, are rich in bioactive phytochemicals that are known for their antioxidant properties and have been hypothesized to improve insulin sensitivity and protect against diabetes. In addition to that, the magnesium content of FV may also reduce the risk of T2D [11].

The theoretical minimum risk distribution for FV intake is estimated to be 600 g/day in adults, 480 g/day in children aged 5-14 years, and 330 g/day in children aged 0-4 years [12] where the protective effects of FV are expressed as relative risk estimates associated with an 80 g/day increase in FV intake. The nutritional guidelines contained in the World Health Organization (WHO) report entitled ‘Diet, nutrition and the prevention of chronic diseases’, recommends a minimum intake of 5 portions or 400 g of FV per person per day, excluding potatoes and other starchy tubers [2]. The recommended healthy diet includes at least 2 daily servings of fruits (160 g) and 3 daily servings of vegetables (240 g) with at least one serving of vegetables consisting of dark green and leafy or orange vegetables (nutrient-rich vegetables) [13].

While benefits of FV consumption have received much attention, global studies indicated that most adults do not meet the recommended daily minimum servings [4, 12]. Lock and colleagues [12] reported on the low FV consumption globally and when doing so, they divided all countries within a sub-region displaying similar FV availability from FAO

food balance sheet information and demographic and health characteristics classified by the World Health report and the CIA (Central Intelligence Agency) World Fact book in their analysis on mean dietary intakes of FV. Findings from this global assessment revealed the highest intake of FV was by the European sub-region EUR (Europe)-A; which comprised of countries like Belgium, Denmark, Finland, France, Germany, Ireland, Israel, Italy, Norway, United Kingdom. This was followed by the Western Pacific sub-regional WPR (Western Pacific)-A which comprised Australia, Japan and Singapore. The lowest intakes of FV were found in the American B sub-region, AMR (America)-B, EUR (Europe)-C, SEAR (South-East Asia)-B, SEAR (South-East Asia)-D and AFR (Africa)-E. The sub-region grouping is according to the global assessment of disease burden as reported by the WHO [14]. A study on the global variability in FV consumption in 2009 reported similar results where 77.6% of men and 78.4% of women from 52 mainly low- and middle-income countries consumed less than the minimum recommended five daily servings of FV [4]. Their results also described great variability FV consumption across countries, settings, between the genders, ages and income levels.

Public health actions at national and international levels that include targeting public health education and health promotion programs to the specific context and priority groups within each country are necessary [4]. Healthy eating is currently a growing concern among many countries worldwide including Malaysia due to rises in overweight and obesity rates [15]. In this country, the Ministry of Health Malaysia has conducted the Healthy Lifestyle Campaign since 1991 carrying the theme “Be Healthy for Life” emphasizing on community roles, regardless of age and sex, to lead a healthy and wholesome lifestyle. The campaign emphasizes on five main components, i.e., healthy eating, managing stress, adequate exercise, and physical activity and avoidance of smoking [16]. Despite the proliferation of these campaigns, they have not produced much success at achieving the desired behavior of the general population. While there is growing awareness of the importance of healthy eating among the general public, there is still a wide gap between knowledge and behavior [15].

This review aims to examine current research topics on FV consumption and its sociodemographic determinants in Malaysia, dietary intervention studies and nutritional studies related to FV and its effects on human health in the country. It also touches on the macro- and micronutrients found in FV contributing towards growth, maintenance of health and prevention of diseases. Finally, the review concludes with recommendations for future areas of research in FV consumption that need to be explored.

2. FRUIT AND VEGETABLES CONSUMPTION IN MALAYSIA

Diets rich in FV have been found to be protective against many diseases [17]. However, many local studies have shown that the FV intake among Malaysians is well below the recommended intake outlined in the Malaysian dietary guidelines as well as the global guidelines [16, 18, 19]. An example of the earlier years where the Federation of Agricultural Malaysia (FAMA) reported the total vegetable consumption among Malaysians was 36 kg annually per capita or 98.6 g per day [20] while the consumption of fruits was 44.88 kg annually per capita or 124.7 g per day [21]. Aimed at promoting to increase vegetable consumption among Malaysian, in the year 1996, the Ministry of Agriculture of Malaysia launched the 'Eat more vegetables' campaign [22]. In conjunction with this campaign, the Ministry of Health Malaysia (MOH) also started a Healthy Lifestyle Campaign earlier in 1991 and the theme 'healthy eating' was selected as one of the four basic elements for the campaign. Healthy eating remained as one of the important basic elements in the following Healthy Lifestyle Campaign in the country [16, 23].

An annual media campaign has been conducted since the year 2006 to assess the achievements of the 'Healthy Lifestyle Campaign' and the results showed that 74% of Malaysians practice healthy eating [24]. A positive impact from these campaigns evident elsewhere in the literature was an increment of 7.7% for household expenditure on fresh vegetables in surveys from the year 1985 to 1995 [25]. There has also been an increment

in the mean daily calorie intake from vegetables consumption among Malaysians from 26.1 calories in 1990 to 49.2 calories in 2005 [26]. However, the 2002-2003 World Health Survey showed the prevalence of low FV consumption among men (85%) and women (85.5%) in this country [4]. The Prospective Urban Rural Epidemiology (PURE) study in 2016 reported consumption of 4.31 servings in upper-middle income countries which includes Malaysia. This PURE study was conducted among 157,254 adults aged 35-70 years in 667 communities from 18 countries in 5 continents and the four income strata were according to the classification by the World Bank in 2006 on the basis of gross national income per person [27]. Their interpretation was, the consumption of FV is low worldwide particularly in low-income countries and this is associated with low affordability [27].

Statistics from the Food and Agriculture Organization (FAO) indicate that from 1980 to 2003, the average fruit consumption in Malaysia was 150 grams per capita per day [28]. However, the combination between FV consumption was only 228 grams per day which was far below the target of 400 grams, or five servings [29]. Findings from the Malaysian Adult Nutrition Survey (MANS) in 2003 also showed that only 40% of Malaysian adults consumed 1 cup (96 g) of green leafy vegetables daily [18] and which is only 40% of the 240 g per day recommendation by WHO [13]. Another study conducted by Nurul Izzah and colleagues in 2012 [19] also showed similar results where the total consumption of FV among adults in the state of Selangor was only 173 g/day, with significantly higher FV consumption among Malays (202 g/day), compared to Chinese (159 g/day) or Indians (126 g/day). Individually, the consumption of fruits (179 g/day) met the minimum requirement as suggested by the dietary guidelines, but, for vegetables (133 g/day), the amount was only half of the recommended intake [19]. Earlier, the same group of researchers suggested consumption of ‘ulam’ (salad or raw vegetables consumed with ‘sambal’) can help to increase vegetable intake especially among the Malays [30].

A recent study by Suriani and colleagues [31] on food consumption among overweight and obese working women in urban settings revealed that only 24.8% of those surveyed met the Malaysian Dietary Guideline

2010 for FV consumption and the highest consumption was among the higher education group (2.35 servings per day). A study on FV consumption among Malaysian elderly showed that 81.9%, 87.6%, and 91.9% of elderly people did not consume adequate fruit, FV and vegetables, respectively [32]. Among Malaysian children aged 1-6 years old, the average FV consumption were 0.91 and 1.07 servings of fruits and vegetables per day respectively, and less than one fifth of the children received the daily recommended servings of fruits (11.7%) and vegetables (15.8%) [33]. A study among university students in Selangor reported that most of the students consumed FV between 1-4 times a week. Less than half of the respondents consumed vegetables daily (43.3% and 41.8% of males and females, respectively).

3. FV CONSUMPTION FROM THE SECOND MALAYSIAN ADULT NUTRITION SURVEY (MANS) 2014

The National Health and Morbidity Survey (NHMS) is a nationally representative health survey of the Malaysia population. The NHMS was initiated in 1986. Initially, it was conducted every ten-years, but from 2011 it was changed to every four years due to concerns regarding untimely planning of health programs [16]. The first MANS was conducted in 2003 which encompassed the entire country. The survey was based on a national representative sample of 6,928 Malaysian adults in selected households aged between 18 and 59 years. The second MANS was conducted in 2014 using the NHMS platform and involved a total of 4,044 nationally representative samples of Malaysian adults with the same age range. The data collection was carried out between March and June 2014. The survey examined food insecurity, meal patterns, intake by food groups, habits in relation to food consumption, reading of food labels, vitamin/mineral and supplement intakes, physical activity, food consumption, nutritional status and nutrient intake. A semi-quantitative food frequency questionnaire (FFQ) which consisted of 126 food items was used to evaluate the food consumption pattern (habitual food intake) of the respondents during the

previous one-year period. MANS 2014, achieved 80.0% response rate for the whole country [16].

Findings from MANS 2014 showed that the mean frequency of fruit consumption was 3.70 days per week and there was a significant difference between the fruit intake by adults in Peninsular Malaysia (3.79 days per week) compared to East Malaysia (3.28 days per week). The mean consumption was slightly higher among adults in urban areas (3.85 days per week) compared to rural areas (3.33 days per week). Overall, results showed that mean consumption of fruits was 1.40 servings per day by study subjects. Specifically, adults from urban areas consumed less fruits (1.36 servings) compared to adults in rural areas (1.49 servings per day) [16].

The mean frequency intake of vegetables is 5.90 days per week and there was no significant difference in intakes between Peninsular Malaysia (5.88 days per week) and East Malaysia (5.98 days per week). The mean frequency of intake of vegetables in urban areas (6.00 days per week) was slightly higher compared to intake in the rural areas (5.68 days per week). The overall, mean intake of vegetables among adults was 1.51 servings per day, however the mean intake in Peninsular Malaysia was lower (1.43 servings per day) when compared to East Malaysia (1.80 servings per day) [16].

Findings from MANS also showed some differences between gender and ethnicity. Mean vegetable intake was 1.62 servings per day in men and 1.59 servings per day in women. Results also showed that adults from urban areas consumed more FV (6% vegetables; 3.88% fruits) compared to rural areas (5.68% vegetables; 3.33% fruits). Only 3.7% of Malaysian adults consumed fruits daily (3.88% in women; 3.51% in men) [34]. Mohd Hasnan [35] compared the mean intake of green leafy vegetables between MANS 2003 and MANS 2014 and found that it had more than doubled from 50 g/day to 118.6 g/day. However, the findings of MANS 2014 showed that Malaysian adults still had not met the recommended intake of FV in terms of its amount and frequency. Results showed that 59.1% of respondents consumed fruits less than the recommended 2 servings per

day, and 81.7% consumed vegetables less than the recommended 3 servings per day [16].

4. THE SOCIODEMOGRAPHIC DETERMINANTS AND OTHER FACTORS OF FV CONSUMPTION IN MALAYSIA

A comprehensive data analysis from the national survey in Malaysia on FV consumption related to the social demographic determinants was conducted recently through local and international research collaborations [1, 29, 36, 37, 38]. The results indicated that household (income bracket, family size, ethnicity) and head of household (age, education level) characteristics played key roles in determining consumption likelihoods and expenditure patterns of fresh and preserved vegetables among urban and rural households in the country [37]. In their observations, Malaysians with high household incomes, showed lower tendencies to purchase fresh vegetables and this can be attributed to the wider availability of food types and eating establishments in urban compared to rural areas. In addition, affluent urban households may be better able to afford pricier alternatives such as fish and meat products. Low income urban households may not be able to afford fresh vegetables, as healthy fresh vegetable consumption may not be considered as a basic necessity. Urbanites with higher education and income levels have more hectic work schedules resulting in different lifestyles and cooking habits. This population may be more accustomed to dining outside the home on meals that lacked fresh vegetables. A general observation in their findings revealed age as a significant and positive contributor to the demand for vegetables in this country. This is explained in essence where with age, individuals become more health conscious. In these studies, there was also a positive relationship between household size and expenditure; whereby the bigger the household size (more individuals in the family), the higher likelihood of purchase and thus the household expenditure proportionally increases [1, 29, 36, 37, 38].

Further analysis on implementing marginal effects of explanatory variables on the mean day of serving per week based on bivariate count model for days per week indicated that education levels play an important role in promoting consumption of fruits [29]. Specifically, those with tertiary education consumed more days of fruits per week compared to those with only primary education. Respondents of retirement age and Chinese ethnicity consumed more days of fruit per week. Population with less days of consuming fruits per week were impoverished, smokers and metropolitan residents in Peninsular Malaysia. Interestingly, the findings showed that metropolitan residents of East Malaysian states (Sabah and Sarawak) consumed more days of fruits. They also reported association between health conditions and FV consumption. It was found that patients diagnosed with hyperchosterolemia consumed higher amount of FV compared to diabetic patients [36].

A study among 1,049 adults in seven selected cities in Malaysia evaluated the personnel and environmental factors influencing FV consumption behavior [39]. The findings revealed four significant attributes related to intention of eating FV which were availability of FV, followed by influences by family members and friends, the values for attitudes towards eating FV and habits of eating FV. These results supported many earlier studies on the importance of FV availability and accessibility on FV consumption behavior. The normal practice in the country is that adults are responsible for purchasing FV and this leads to higher consumption. Additional results on FV consumption behavior with demographic factors showed that there are significant differences in fruits consumption by age and marital status. Older people, tend to be more concerned with their food consumption, consume more FV than younger people. On the other hand, married couples are known to have greater income compared to single persons and hence have more purchasing power for fruits. For vegetable consumption, significant differences were shown by these two factors with an additional two factors of ethnicity and household income. Their results showed that Indians consume more vegetables due to cultural culinary practices and vegetarianism, whereas

those with low income tend to spend their income on other more basic needs, other than FV [39].

Findings from an analysis of data on 2,752 Malaysian elderly, 60 years old and above obtained from the National Health Morbidity Survey 2011 (NHMS 2011) revealed some interesting factors on FV consumption among the study subjects [32]. More than half of the respondents were married, lived in urban areas and reported good self-rated health status with the majority having no history of chronic diseases. Those who were elderly, single, with low education level and low self-rated health status were more likely to consume inadequate FV. The elderly, aged more than 80 years and lived in rural areas were more likely to consume inadequate FV. Inadequate consumption of vegetables may due to edentulism and lack of education. There is evidence that the presence of companionship and accessibility to the sources of FV are associated with higher consumption of FV. In addition, their discussion also touched on the food beliefs or taboos among Malaysian elderly especially from rural areas. Traditional beliefs among Malaysian elderly are that each fruit or vegetable has their own characteristics such as it is cool, hot, 'causes wind' or sharp/astringent and able to cause joint pains or numbness, poor blood circulation and gastrointestinal discomfort. These beliefs are common excuses for not consuming FV. There are contradictory results from the findings of this study compared to a previous study which reported no significant association between subjects having a history of chronic diseases (diabetes, hypertension, and hypercholesterolemia) with inadequate FV consumption [32].

Another study on the association between FV consumption and mild cognitive impairment among older persons living in low-cost residential areas in Kuala Lumpur also revealed the main motivating factor for FV consumption is belief in its health benefits while barriers were dental problems and a dislike for its taste [40]. A study on stages of change to increase FV intake, its relationship with FV intake and related psychosocial factor was conducted in the year 2014 by a group of Malaysian researchers. In this study, they concluded that intervention strategies have to emphasize on increasing perceived benefits and building

self-efficacy by providing knowledge and skills to consume diets high in FV among adults in this country [41]. The most important perceived barriers to healthy eating were unavailability and limited choice of healthy food, being away from home, time constraint and a busy lifestyle [15].

An association between maternal dietary intake in pregnancy and birth size was studied, focusing on FV consumption and micronutrients during pregnancy. The findings showed no significant association between these parameters. However, positive associations with birth size were found for consumption of leafy, tuber vegetables and fruits [42]. Chong and colleagues [33] studied FV intake patterns and their associations with sociodemographic characteristics, anthropometric status and nutrient intake profiles among Malaysian children aged 1-6 years. They found that fruit intake was associated with age, parental education levels and geographical regions while vegetable intake was associated with ethnicity and geographical regions only [33]. There was little evidence of any association between FV intake and anthropometric status among children. However, an adequate intake of FV contributed significantly and differently to children's micronutrient intake depending on types of FV consumed.

5. HEALTH-RELATED OUTCOMES OF FV INTAKE INTERVENTIONS IN MALAYSIA

A total of eight dietary interventions with FV intake components were reviewed (Table 1). The intervention duration ranged between one day to two years. The study populations were workers, obese women, security guards, university and special needs students and pre-school children. Study designs included quasi-experimental randomized and cluster randomized controlled trials [43, 44, 45, 46, 47, 48, 49, 50]. Three out of eights studies combined dietary and physical activity interventions [43, 45, 48]. Common intervention strategies included health education and counseling. The Malaysian Dietary Guidelines was mentioned as a guide for dietary intervention in the studies [47, 48]. Half of the studies were conducted in the Federal Territories and Selangor, one in the southern state

of Johor and another in the east coast. Two studies did not mention their location (Table 1).

Significant effects related to health included increased FV intake [44, 45], increased liking for vegetables [46], improved nutrition scores [47] and decreased processed food intake [44]. Participants also showed weight and body mass index (BMI) reduction [43, 48], reduced cholesterol [43, 45], and increased in vitamin C [43, 44, 48] and thiamine intake [44]. More carotenoid intake also resulted in increased skin yellowness and redness which may enhance a person's healthy appearance [49, 50]. Out of the three studies which combined dietary and physical activity intervention [43, 45, 48], sustainability of health effects was reported in one study [48]. Table 1 summarizes these FV interventions in Malaysia and their main outcomes.

5.1. Studies Focused on Interventions for Dietary Intake Only

For the past 10 years, there have been few studies on FV dietary intervention in Malaysia. The interventions were carried out in various groups of the community. Two studies were carried out among children; one among preschool children [46] and the other among teens with special needs (sight and hearing impairment) [47]. Another study, the Nutrition Education Intervention (NEI) was conducted among university students in the east coast of Malaysia [44].

Noradilah and colleagues [46] in Muar, Johor, conducted a study to determine the effects of multiple exposures on the acceptance of a targeted vegetable among Malay pre-school children. In the first phase, a cross-sectional study was used to determine the selection of the most suitable test vegetable. A total of 68 Malay children from six kindergartens in Muar, Johor participated in this phase. Information on the commonly used cooking methods, frequency of serving vegetables and consumption by the children at home and parents' perception of the children's liking towards vegetables were obtained through a questionnaire. Subsequently, the round cabbage was chosen as the test vegetable to be used in the second phase.

Table 1. Recent FV intervention studies in Malaysia

Study location/ Subjects	Study description	Outcomes	Ref
Klang Valley/31 obese women aged 40-60 years old with high breast adiposity (16 intervention; 15 controls).	Study design: Randomised controlled study. Duration/type of intervention: 4 months (dietary intake and physical activity intervention) Intervention: *"Her Shape Intervention (HSI)" program:* group meetings for diet consultation (including to increase fruit and vegetable intake) and physical activity training, home based health education package, "Daily Success Checklist" booklets and weekly telephone calls to ensure compliance. Controls: brief dietary consultation at beginning of the study.	Energy intake reduced by 35%, increased activity score by 11%, reduction of breast adiposity, increase in vitamin C intake, greater reduction of body mass index (BMI), reduction in matrix metallopeptidase 9 (MMP9) (a protein associated with obesity and breast cancer) and reduction of total cholesterol/HDL level.	[43]
Federal territories of Putrajaya and Kuala Lumpur/ Overweight and obese government workers (intervention =	Study design: Quasi-experimental Duration/type of intervention: 6 months (dietary intake and physical activity intervention) Intervention: "Healthy Worker Programme" for physical activity and dietary intake intervention	Significant weight loss of 5% initial body weight: 14% among intervention vs. 4% among controls. The intervention group was 1.6 times more likely to lose 5% body weight compared to controls (RR = 1.6; 95% CI: 1.2, 2.2). Significant reduction of 0.5 kg/m^2 among intervention group.	[48]

Study location/ Subjects	Study description	Outcomes	Ref
132, controls = 151)	based on the Socio-Ecological Model. Intervention was delivered at the organisational, inter- and intrapersonal levels (e.g., poster displays, monthly health information, telephone motivation, motivation from co-workers, healthier foods at the cafeteria and organisational support for a healthier lifestyle). Health information included recommended intake of fruits and vegetables and healthy recipes. Controls: health talks and pamphlets	Sustainable changes (3 months after programme ended): Intervention group 1.8 times more likely to achieve 10,000 steps/day compared to controls Mean daily vitamin C intake increased at post-programme, among the intervention group, that is from 58 mg to 69 mg (but not significant statistically). Significant improvement of quality of working life, through a reduction of 'Stress At Work' and increase in 'General Well-Being' components in the intervention group.	
Selangor/78 Malaysian Chinese participants from a university (intervention = 34, controls = 34)	Study design: Experimental trials Duration/type of intervention: 4 weeks (dietary intake intervention) Intervention: 500 ml freshly prepared fruit and vegetable smoothie, (with average of 25mg carotenoids) every weekday for 4 weeks. Controls: bottled filtered water.	There is an optimal carotenoid skin colour for a healthy appearance. Optimal carotenoid skin colour appears to be constrained to averageness. Optimal dose of carotenoid supplementation for enhancing health appearance was observed to be approximately 8.5mg a day.	[50]

Table 1. (Continued)

Study location/ Subjects	Study description	Outcomes	Ref
East coast/417 university students (intervention = 178; controls = 202)	Study design: Cluster randomized controlled study Duration/type of intervention: 10 weeks (dietary intake intervention) Intervention: *Nutrition Education Intervention (NEI)* multimodal intervention using three modes (conventional lecture, brochures, and text messages) Control: did not receive any intervention	Intervention group significantly increased fruits and 100% fruit juice intake, that is fruit intake increased from 0.4 to 1.2 servings a day. However, did not achieve the recommended two servings per day. No change seen for vegetable intake. There was also a significant increase in vitamin C intake from 56 mg to 102 mg per day. The intervention group also increased their energy, carbohydrate, calcium, thiamine, fish, egg, milk, and dairy products intakes and decreased their processed food intake.	[44]
Selangor/81 Malaysian Chinese participants from a university (intervention = 41, controls = 40)	Study design: randomized controlled trial Duration/type of intervention: 6 weeks (dietary intake only) Intervention: carotenoid-rich, fresh fruit smoothie, every weekday for 6 weeks. Controls: bottled, filtered water.	Large increment in skin yellowness and slight increase in skin redness after 4 weeks which remained elevated after 6 weeks.	[49]

Study location/ Subjects	Study description	Outcomes	Ref
Muar, Johor/First phase: 68 Malay children from 6 kindergartens in Muar Second phase: 42 preschoolers from 3 kindergartens from phase 1	Study design: First phase: cross-sectional Second phase*:* randomized experimental trial Duration/type of intervention: 3 days (dietary intake only) Intervention: Meals consisting of the test vegetable (round cabbage) were provided to the children during lunch time at the kindergartens for 3 days consecutively. Leftover stir-fried cabbage served was weighed Controls: no controls	Significant increase test vegetable intake from the first (21.58 ± 9.55 g) to the third day of exposure (28.26 ± 8.35 g). Based on parents' feedback, level of liking the test vegetable was significantly increased after the intervention.	[46]
Not stated/80 students (aged 13 to 17 years) with special needs (intervention = 40; controls = 40).	Study design: Quasi-experimental Duration/type of intervention: one day (dietary intake only) Intervention: 'Jom Sihat' nutrition education programme which consisted of two sessions- a group discussion and games session (to understand nutrition better). Controls: nutrition booklets	Significant improvement in students' nutrition and attitude scores among the intervention group after attending the nutrition education programme. No change for practice scores.	[47]

Table 1. (Continued)

Study location/ Subjects	Study description	Outcomes	Ref
Not stated/150 security guards (intervention = 102, controls = 83)	Study design: Quasi-experimental Duration/type of intervention: 2 years (dietary intake and physical activity intervention) Intervention: Intensive individual & group counselling for diet and physical activity. Self-monitoring booklets, tailor-made brochures, modified recipes, focus group discussions with role models and quizzes to raise awareness. Controls: standard brochures on healthy lifestyle, yearly group sessions, health check results via mail.	Diet: Reduced fat intake, increased fruit & vegetables intake in intervention group. Reduced total cholesterol (mean difference = -0.38 mmol/L, 95% CI: -0.63, -0.14)	[45]

In the second phase of the study, 42 pre-school children (20 boys and 22 girls) participated from three kindergartens, randomly selected from the first phase. Meals consisting of the test vegetable (round cabbage) were provided to the children during lunch time at the kindergartens for three consecutive days. Leftovers of the stir-fried cabbage that was served were weighed. A significant increase in the test vegetable intake was observed from the first (21.58 ± 9.55 g) to the third day of exposure (28.26 ± 8.35 g). Based on the parents' feedback, the level of liking of the test vegetable was significantly increased after the intervention [46].

A one-day intervention based on the 'Jom Sihat' nutrition program was conducted among 13 to 17-year old students with special needs. The program consisted of two sessions, that is a group discussion on nutrition (with questions and answers) and a games session to reinforce understanding of nutrition. A pre- and post-intervention questionnaire was used to determine any changes in nutrition knowledge, attitude and practice scores. Three weeks after the intervention, nutrition knowledge and attitude scores significantly improved among the intervention groups, but not among controls. However, nutrition practice scores did not change significantly [47].

In a cluster randomized controlled study by Mohd Razif and colleagues [44], a 10-week Nutrition Education Intervention (NEI) was carried out among 417 university students in the east coast of Malaysia. The NEI consisted of three modes: conventional lecture, brochures and text messages. There was a large, significant increase in fruit and 100% fruit juice intake among university students after their 10-week NEI program (adjusted effect size, Cohen's d = 1.03), from 0.4 to 1.2 servings a day. However, they did not reach their recommended two servings of fruits in a day (NCCFN, 2010). There was also a significant increase in their vitamin C intake (adjusted effect size, Cohen's d = 0.93). There appeared to be no change in the trend of vegetable intake. Other improvements after the NEI were significant increased intakes of calcium, thiamine, fish, egg, milk, and dairy products, while a reduction was seen in processed food intake [44].

Increased motivation to consume FV can also be encouraged from the aesthetic point of view that is more carotenoid deposition in the skin will add more color (yellow and redness) to the face. Tan and colleagues [49, 50] conducted two interventions among Malaysian Chinese participants from a university in Selangor [49, 50]. In the first study, on a randomized controlled trial, the intervention group was supplemented with carotenoid-rich, fresh fruit smoothie, every weekday for six weeks, while controls were given bottled, filtered water. Six different types of smoothies with different combinations of fruits and vegetables were provided to the intervention group. These included carrot (*Daucus carota L*), kedondong (*Spondias dulcis*), lemon (*Citrus limon* L.), orange (*Citrus sinensis*), pineapple (*Ananas comosus*), pulasan (*Nephelium mutabile)*, starfruit (*Averrhoacarambola)*, banana (*Musa acuminate*), chiku (*Manilkara zapota*) and red dragonfruit (*Hylocereus costaricensis*). Each smoothie contained 3% lipids in the form of cream, milk or palm oil to ensure bioavailability of carotenoids. A reflectance spectrophotometer was used to measure skin yellowness, redness and luminescence at the cheeks and forehead of participants. The intervention group exhibited change in the skin reflectance in the 450 to 510 nm spectrum range, consistent with a deposition of yellow and red carotenoids. Significant and large increments in skin yellowness and a slight increase in skin redness was observed after four weeks in the intervention group, which remained elevated after six weeks [49].

In a following study by Tan and colleagues [50], among a similar study population and four weeks of smoothie supplementation, three experiments were conducted. In experiment 1, perceived health of faces before and after supplementation was observed. In experiment 2, preferences for faces with smoothie-induced carotenoid coloration were observed while in experiment 3, an optimal amount of carotenoid-induced skin coloration was explored. The results showed that there was an optimal carotenoid skin color for a healthy appearance perceived by observers. The optimal carotenoid skin color appears to be constrained to commonness, as too much yellowness and redness may be associated with illness such as jaundice. The optimal dose of carotenoid supplementation for enhancing

health appearance was observed to be approximately 8.5 mg a day. However, the effects of carotenoids are difficult to perceive in darker skin [49].

5.2. Interventions Studies on Dietary and Physical Activity

In the past decade, there have been few intervention studies in the country which combined both dietary and physical activity interventions. These were carried out among adults and of the working population and targeted to reduce risks for developing non-communicable diseases and obesity. The studies were carried out among overweight women, government workers and security guards [43, 45, 48].

In a randomized controlled trial by Juliana and colleagues [43], 31 obese women aged between 40 and 60 years old in the Klang Valley, with high breast adiposity were studied. "Her Shape Intervention (HSI)", was a home-based, 4-month program for working women with dietary intake and physical activity intervention. The HSI program included group meetings for diet consultation, physical activity training, a home-based health education package, "Daily Success Checklist" booklets and weekly telephone calls to ensure compliance, while controls were only given a brief dietary consultation at the beginning of the study. Diet consultation for the intervention group included encouragement to increase FV intake at every meal. Significant changes in total energy intake, total cholesterol/ high-density lipoprotein (HDL), body mass index (BMI), breast adiposity and matrix metallopeptidase 9 (MMP9) (a protein associated with obesity and breast cancer) were observed in the intervention group. A significant increase was also seen in vitamin C intake and activity scores increased by 11% [43].

In a quasi-experimental study by Sulaiman [48] among 283 overweight and obese workers, a workplace intervention to improve dietary intake and physical activity reported a reduction in the weight and body mass index (BMI) of workers in a 6-month 'Healthy Worker Program'. Based on the Socio-Ecological Model, the intervention was delivered at the

organizational, inter- and intrapersonal levels and used environmental modification. This included poster displays, monthly health information, telephone and co-worker motivation, environmental modification and organizational support for a healthier lifestyle. Health information included recommended intake of FV and healthy recipes. Workers were assessed on their dietary intake, physical activity, weight and quality of working life after the program ended (at 6 months) and again at three months after the program ended (post-program) to determine sustainability of changes. At the end of the program, there were significant differences in weight loss and BMI. A weight loss of at least 5% of initial body weight was observed in 14% of the intervention group and 4% among controls. The intervention group was 1.6 times more likely to lose 5% of their body weight than controls (relative risk (RR) = 1.6; 95% CI: 1.2, 2.2). A significant reduction in BMI by 0.5 kg/m^2 was seen in the intervention group. Mean daily vitamin C intake was found to have increased at post-program, among the intervention group, that is from 58 mg to 69 mg. Other outcomes included an increasing trend in physical activity in the intervention group which continued post-program. Three months after the program ended, the intervention group was significantly more active and was 1.8 times more likely to achieve 10,000 steps/day compared to controls. Post-program, there was also significant improvement in quality of working life; through a reduction of 'Stress at Work' and increase in 'General Well-Being' components in the intervention group [48].

Moy and colleagues [45] conducted a 2-year worksite intervention among 150 security guards, which consisted of a dietary intake and physical activity intervention. Its components were intensive individual and group counseling for a healthy diet and active lifestyle, focus group discussions with role models, use of self-monitoring booklets, tailor-made brochures, modified recipes and quizzes to raise health awareness. The study observed significantly lower blood levels of total cholesterol in the intervention group (mean difference = -0.38 mmol/L, 95% CI: -0.63, -0.14). There was increased FV intake and reduced fat intake within the intervention group as seen from consumption scores [45].

6. NUTRITIONAL STUDIES ON FV AND HEALTH IN MALAYSIA

FV are recommended by nutritionists because of their health benefits as they contain abundant dietary fibers, vitamins, mineral and phytochemicals [51]. FV also contain bioactive compounds such as phenolic compounds, anthocyanins, carotenoids and ascorbic acids. These compounds act by combating reactive oxygen species (ROS) and reactive nitrogen species (RNS), stimulating the immune system, regulating the expression of genes involved in cell proliferation or apoptosis and modulating hormone metabolism. They also have antibacterial and antiviral actions [52]. In the human body, these actions reduce the incidence of cancer, inflammation, cataracts, macular degeneration and cardiovascular disease [52]. For many years FV attracted increasing attention and accumulative research conducted to determine their bioactive effects such as antioxidant, antimicrobial, anti-inflammatory and anticancer effects [51]. In this sub-chapter, nutritional studies of FV and health in Malaysia are presented. For better understanding, the studies have been divided into *in vitro* and *in vivo* models.

6.1. Health Effect Studies on FV Using *In Vitro* Models

6.1.1. Antioxidant Activity Studies

Antioxidant activity is the most studied activity in FV. Assays that were used to measure antioxidant activity are 2,2-diphenyl-1-picrylhydrazyl (DPPH), ferric reducing antioxidant power (FRAP), 2,2'-azino-*bis*(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS), oxygen radical absorbance capacity (ORAC) and β-carotene bleaching assay (53-74). Besides chemical assays, antioxidant activity was also evaluated using cell lines-based antioxidant capacity assays such as a study on the anticarcinogenic effects of vegetable extracts using breast carcinoma cell lines [75] and the antiproliferation effects of fruit extracts on breast cancer cell lines [76].

The types of fruits tested for antioxidant activities included the powder-puff tree *(Barringtonia racemosa)*, roselle *(Hibiscus sabdariffa*) [53], gandaria (*Bouea macrophylla* Griffith) [54], banana *(Musa sapientum*) [55], carambola *(Averrhoa carambola* L.) [58], papaya (*Carica papaya)* [77], pomelo *(Citrus Grandis* L.) [61], passion fruit (*Passiflora edulis*) [63], bambangan (*Mangifera pajang Kort)* [66], nypa palm *(Nypa fruticans* Wurmb.) [60], pink-flesh guava *(Psidium guajava L*) [68], ciku *(Manilkara zapota*), pomegranate *(Punica granatum*), mangosteen *(Garcinia mangostana*), kiwifruit *(Actinidia deliciosa*), apple *(Pyrus malus*), grape *(Vitis vinifera*), lychee *(Litchi chinensis*), mango *(Mangifera indica*), durian *(Durio zibethinus*), avocado *(Persea americana*) [76], dragon fruit *(Hylocereus undatus*) [78], borneo red star fruit *(Baccaurea angulate*) [79] and dabai *(Canarium odontophyllum* Miq.) [80].

Types of vegetables tested for antioxidant activities included oyster mushrooms *(Pleurotus spp*) [56], lalis *(Plectocomiopsis geminiflora*), pantu *(Eugeissona insignis*) [81], cashew *(Anacardium occidentale*) [82], melicope *(Melicope iunuankenda*), pygmy smartweed *(Polygonum minus*), curry leave *(Murraya koenigii*), Indonesian bay leaf *(Eugeniapolyantha*) [57], seaweed (*Eucheuma cottonii*) [59], water spinach *(Ipomoea aquatica* Forsk), Chinese leek *(Allium tuberosum*), Indian spinach *(Basella alba L.*), sweet potato leaves *(Ipomoea batatas L. Lam*), romaine lettuce *(Lactuca sativa var longifolia*) [83], winter melon *(Benincasa Hispida*), squash *(Cucurbita maxima*), bottle gourd *(Lagenaria siceraria*), luffa *(Luffa acutangula*), bitter gourd *(Momordica charantia*), snake gourd *(Trichosanthes cucumerina*) [84], stink bean *(Parkia Speciosa*) [62], ulam raja *(Cosmos caudatus*), selom *(Oenanthe javanica*), pegaga *(Centella asiatica*) [64], garlic *(Allium sativum* L.), red onion (*Allium cepa* L.) [69], four-angled bean *(Psophocarpus tetragonolobus* D.C.), French bean *(Phaseolus vulgaris* L.), long bean *(Vigna sesquipedalis* L.), snow pea (*Pisum sativum* var. *macrocarpon L.*), snap pea *(Pisum sativum*) [71], red cabbage *(Brassica oleracea* var. *capitate rubra*), Chinese cabbage non-heading cabbage *(Brassica rapa pekinensis* var. *cylindrica*), Green cabbage *(Brassica oleracea* var. *capitata*), mustard cabbage *(Brassica juncea* var. *rugosa*) and Chinese white cabbage *(Brassica rapa* var. *chinensis*) [73].

There are many factors that influence the antioxidant capacity in FV such as cultivars, part of FV used, cooking method and extraction variables (solvent-ratio, time, solid particle size, temperature and solvent type) [85]. A study done by Tan and colleagues [65] on three common cultivars of banana in Malaysia (Berangan, Mas and Raja) showed that Raja banana had the best ability in DPPH scavenging assays, followed by Mas and Berangan. The study revealed that the DPPH scavenging percentages for Berangan, Mas and Raja banana were 6.2-36.8%, 4.6-48.9% and 3.2-63.1%. In FRAP assays also showed that Raja banana had highest Trolox equivalent (TE) content, 140.8-1607.2 mg TE/100 g FW, followed by Mas (233.6-485.8 mg TE/100 g FW) and Berangan (39.4-403.7 mg TE/100 g FW). Meanwhile, a study on three cultivars of wax apple (*Syzygium samarangense* L.) (red, pink and green) fruits by Khandaker and colleagues (2015) showed that the highest antioxidant strength was observed in red cultivar followed by pink cultivar and green cultivar. DPPH scavenging percentages for red, pink and green cultivar at concentration of 500 µg/mL, were 73 ± 5.05%, 68 ±3. 49% and 64 ± 2.78%, respectively.

Maisarah and colleagues [77] conducted a study to determine the antioxidant activities of different parts of papaya tree including their ripe and unripe fruit, seeds and the young leaves. The antioxidant activities were measured using DPPH and β-carotene bleaching assay. The results showed that the highest antioxidant activity measured by β-carotene bleaching assay was observed in unripe fruit (90.67 ± 0.29%), followed by young leave, ripe fruit and the seed. In the other hand, young leaves exhibited significantly higher scavenging effect compared to other parts and the dose required to reducing the absorbance of DPPH control solution by 50% effective concentration (EC_{50}) was 1.0 ± 0.08 mg/mL. The EC_{50} values were 4.3 ± 0.01 mg/mL, 6.5 ± 0.01 mg/mL and 7.8 ± 0.06 mg/mL for unripe fruit, ripe fruit, and seeds, respectively.

A study by Tan and colleagues [56] on the effects of three different cooking methods (boiling, microwave and pressure cooking) on the antioxidant activities of six different types of oyster mushrooms (*Pleurotus eryngii, P citrinopileatus, P. Cystidiosus, P. flabellatus, P. floridanus* and *P. pulmonarius*) revealed that pressure cooking improved the scavenging

abilities of *P. floridanus* (>200%), *P. flabellatus* (117.6%) and *P. pulmonarius* (49.1%) compared to uncooked samples. These results suggested that cooking, including pressure cooking, can be used to enhance the nutritional value of mushrooms. Another study conducted by Tan & Chan [82] to determine antioxidant activity of fresh and processed (blanched and microwaved) leaves of *Anacardium occidentale* (cashew) and *Piper betel* (betel) leaves showed that blanching in boiling water for 30 seconds resulted in a significant decrease in the phenolic content and antioxidant activity of *A. occidentale* and *P. betel* compared to fresh samples. Antioxidant properties of microwave-treated leaves of *A. Occidentale* remained unchanged but the leaves of *P. Betel* exhibited significant increase.

Rajan & Bhat [54] conducted a study to determine antioxidant activities from the methanolic, ethanolic and aqueous extracts of ripe and unripe fruits of *Boueamacrophylla* (Gandaria). The study revealed that high contents of phenolics, tannins and ascorbic acid were found in unripe fruits extracted with methanol, whereas flavonoids and flavonols were high in ethanolic extracts. Anthocyanins were the highest in ethanolic extracts of ripe fruits. Meanwhile, methanolic extracts of unripe fruits showed the highest antioxidant capacity (16,290.91 μM Fe (II) 100 g^{-1}), with 77.69% DPPH inhibition and 99.76% ABTS radical scavenging activity. This suggests that methanol and ethanol are the best solvents for extracting antioxidant compounds from *B. macrophylla* fruit. Similarly, a study conducted by Ahmed and colleagues [79] found that methanol extracts had best antiradical activity.

6.1.2. Antidiabetic Studies

Alpha-amylase is an enzyme responsible for hydrolysis of complex starch to oligosaccharides in human and other mammals, whereas α-glucosidase hydrolyses oligosaccharides, trisaccharides and disaccharides into glucose and other monosaccharides. Inhibition of carbohydrate metabolizing enzymes including α-amylase and α-glucosidase can control the sugar level in blood [86]. Ee Shian and colleagues [87] evaluated the α-amylase and α-glucosidase inhibitory activities of two local bitter gourd species namely peria kambas (*Momordica subangulata*) and peria katak

(*Momordica charantia)* with three ripening stages (raw, mature and ripe). The results showed that the mature fruit of peria katakor almost three-fold stronger in α-amylase and α-glucosidase inhibition compared to another bitter gourd cultivar. Mature local bitter gourd species showed the greatest ability in decreasing hyperglycaemia post-ingestion through the inhibition of key enzymes in carbohydrate metabolism and can be served as a potent antidiabetic food. A study by Ahmad Aufa and colleagues [81] on lalis *(Plectocomiopsis geminiflora*) and pantu *(Eugeissona insignis*) vegetables revealed that they contain more than 50% α-amylase inhibitory activity. Meanwhile, a study on grey oyster mushroom *(Pleurotus pulmonarius*) also revealed that it contains *α*-glucosidase and *α*-amylase inhibitory activity [88]. Results showed that 30% $(NH_4)_2SO_4$ precipitated fraction of grey oyster mushroom inhibited *Saccharomyces cerevisiae**α*-glucosidase activity (24.18%) and 100% $(NH_4)_2SO_4$ precipitated fraction inhibited porcine pancreatic *α*-amylase activity (41.80%). In a study by Karim and colleagues [89] on methanolic extract of fresh and cooked okra (*Abelmoschus esculentus*), the highest inhibitory activity against α-amylase was demonstrated by the extract of fresh okra followed by blanched, fast cooked and baked pod.

6.1.3. Antimicrobial Studies

Antimicrobial activity of FV varies depending on the cultivar, extract characteristics, bacterial strains and the methods used for evaluating the antimicrobial activity. In a study of bacterial activity against two Gram-positive (*Bacillus cereus*, *Staphylococcus aureus)* and two Gram-negative bacteria (*Escherichia coli*, *Pseudomonas aeruginosa*), antimicrobial activities of three cultivars of wax apple fruit were compared [90]. In this study, the pink cultivar displayed antimicrobial activities against *B. cereus* and *E. coli*, whereas green cultivar showed only against *B. aureus.* Momand and colleagues [91] conducted a study to determine antimicrobial activities of the methanol, ethanol and aqueous extracts of different parts (whole fruit, fruit skin and berry) of Borneo red starfruit (*Baccaurea angulate)* using agar well diffusion and microdilution method against *S. pneumoniae, S. epidermidis, K. pneumoniae* and *P. aeruginosa.* The highest antimicrobial activity was found in the ethanol extract of the fruit

skin using agar well diffusion against *S. pneumonia*. At a concentration of 15.6 mg/mL, the aqueous extract of the fruit skin showed bactericidal properties against *K. pneumoniae* using micro-dilution method. In the antimicrobial study by Basri and colleagues [92] on the hexane, acetone, methanol and aqueous extracts of *Canarium odontophyllum* pulp, results showed that the acetone extract displayed moderate antimicrobial activity against *C. glabrata* with inhibitory zone of 8.0 ± 0.00 mm at all tested concentrations (25, 50, 75 and 100 mg/mL).

6.1.4. Anti-Inflammatory Studies

Rao and colleagues [93] conducted a study to determine the anti-inflammatory activity of *Musa paradisiaca* extracted with methanol (tepal, flesh and skin), ethanol (tepal) and water (tepal) using cold maceration technique. The anti-inflammatory activity of the extracts was assessed by evaluating the ability of the extract to inhibit RAW 264.7 macrophage cell line from generating harmful nitric oxide (NO) induced by bacterial lipopolysaccharide. The result showed that flesh extract has the highest nitric oxide inhibitory activity, with the maximum inhibition of 52.21% at 250 μg/mL, followed by tepal aqueous extract with maximum inhibition of 48.16% at 62.5 μg/mL. It showed that *Musa paradisiaca* plant parts have potential as an anti-inflammatory agent.

6.1.5. Angiotensin I-converting Enzyme (ACE) Inhibitor Studies

Angiotensin I-converting enzyme (ACE) is a central component of the renin-angiotensin system which controls blood pressure. ACE inhibitors are used for the control of hypertension. In a study by Lau and colleagues [94], identification of the peptide sequences from mushroom *(Agaricus bisporus*) was carried out by liquid chromatography–mass spectrometry (LC–MS/MS). The study revealed that eight highly functional ACE inhibitor peptides from the mushroom were KVAGPK, FALPC, RIGLF, EGEPR, APSAK, C4 AHEPVK, GVQGPM and PSSNK. The most potent ACE inhibitor activity was exhibited by AHEPVK, RIGLF, and PSSNK with 50% inhibitory concentration (IC_{50}) values of 63, 116 and 129 μM, respectively. It showed that these peptides may serve as an ingredient in the production of antihypertensive supplements.

Table 2. Summary of nutritional studies of FV and health in Malaysia: An *in-vitro* studies

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative	*Barringtonia racemosa* (Putat/Powder-puff tree), *Hibiscus sabdariffa* (Rozel/Roselle)	Total antioxidant activities of methanol extracts were measured by DPPH and β-carotene bleaching assay. Content of phytochemicals, total flavonoid content (TFC), and total phenolic content (TPC) were determined.	*B. racemosa* extract exhibited high antioxidant activities compared to *H. sabdariffa* methanol fruit extracts in DPPH radical scavenging assay (inhibitory concentration [IC_{50}] 15.26 ± 1.25 µg/mL) and β-carotene bleaching assay (Inhibition, I% 98.13 ± 1.83%). *B. racemosa* showed higher TPC (14.70 ± 1.05 mg gallic acid equivalents [GAE]/g) and TFC (130 ± 1.18 mg quercetin equivalents [QE]/g) compared to *H. sabdariffa* (3.80 ± 2.13 mg GAE/g and 40.75 ± 1.15 mg QE/g, respectively.	[53]
Antioxidative	*Bouea macrophylla* Griffith (Kundang/ Gandaria)	Methanol, ethanol and distilled water of unripe and ripe *B.macrophylla* fruits were evaluated total phenolics, tannins, flavonoids and flavonols. Antioxidant activities were measured using FRAP, ABTS and DPPH.	High contents of phenolics, tannins and ascorbic acid were found in unripe fruits (extracted with methanol), whereas flavonoids and flavonols were high in ethanolic extracts. Anthocyanins were the highest in ethanolic extracts of ripe fruits. Methanolic extracts of unripe fruits showed the highest antioxidant capacity [16,290.91 µM Fe (II) 100 g−1], with 77.69% DPPH inhibition and 99.76% ABTS.+ radical scavenging activities.	[54]

Table 2. (Continued)

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative	*Musa sapientum* (Pisang/ Banana)	Extracts of banana peels and pulps (n-hexane, ethanol and water, water) were tested for antioxidant properties using DPPH and FRAP assays. Antiangiogenic activity was screened using the rat aorta ring assay and antineoplasic activity using MTT assay.	Peels extracted with ethanol exhibited potent antioxidant activity on DPPH, with the lowest IC_{50} value calculated for the ethanol extract (19.10 μg/mL). The ethanol extract of banana pulp demonstrated remarkable FRAP radical scavenging effect, with IC_{50} values of 46.40 μM of Fe2+/mg. The hexane extract of banana peel had the highest cytotoxic activity and was found to inhibit the growth of colon cancer cell line HCT-116.	[55]
Antioxidative	*Pleurotus spp.* (Cendawan tiram/Oyster mushrooms)	The effects of three different cooking methods (boiling, microwave and pressure cooking) on the antioxidant activities of six different types of oyster mushrooms (*Pleurotus eryngii, P citrinopileatus, P. cystidiosus P. flabellatus, P. floridanus & P. Pulmonarius)* were assessed. Antioxidant activities were measured using DPPH assay and reducing power (TEAC).	Pressure cooking improved the scavenging abilities of *P. floridanus* (>200%), *P. flabellatus* (117.6%) and *P. pulmonarius* (49.1%) compared to the uncooked samples. The microwaved *P. eryngii* showed 17% higher in the TEAC value when compared to the uncooked sample.	[56]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative	*Melicope iunuankenda* (Melicope), *Polygonum minus* (Tenggek burung/Pygmy smartweed), *Murraya koenigii* (Daun kari/ Curry leave), *Eugenia polyantha* (Daun salam/ Indonesian bay leaf)	Antioxidant activities were measured using DPPH and β-carotene bleaching assays (BCB). Total phenolic content (TPC) and total flavonoid content (TFC) were determined in water and ethanolic extracts.	Water extract of *E. polyantha* demonstrated the highest TPC and was significantly different ($p < 0.05$) with all the other herbs. *P. minus* showed the highest TFC while Salam leaves showed the lowest TFC for both water and ethanolic extracts. *M. iunuankenda* had the highest DPPH radical scavenging activity while curry leave showed the lowest activity regardless of the solvents used.	[57]
Antioxidative	*Averrhoa carambola* L. (Belimbing besi/ Carambola)	Antioxidant activity was measured using DPPH and β-carotene/linoleic acid model (BCLAM) assays at different ripening stages. Ascorbic acid (AA), total phenolic content (TPC), total flavonoids content (TFC), total carotenoids content (TCC) and β-carotene, tocopherol homologues (α, β, γ and δ) were analysed.	The results showed that AA and TCC were significantly ($P < 0.05$) increased while TPC, TFC and β-carotene showed reversed trends as ripening process was in progressed. The IC_{50} increased significantly ($P < 0.05$) between week 9 and week 13 meaning a decrease of antioxidant activity as carambola get ripen measured by DPPH assay. The antioxidant activity decreased drastically from 40.5% to 15.3% at week 9 and week 13, respectively measured by BCLAM.	[58]
Antioxidative	*Murraya koenigii* L. (Daun kari/Curry Leaf)	Total flavonoid and total phenolic contents were observed in the extracts from Kelantan, Selangor and Johor. Human breast carcinoma cell lines (	The highest total flavonoid and total phenolic contents were observed in the extracts from Kelantan (3.771 and 14.371 mg/g DW). Curry leaf from Kelantan exhibited the highest radical scavenging activity (DPPH, 66.41%) and ferric	

Table 2. (Continued)

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative		MDA-MB-231) were treated with various curry leaf extracts (20, 40, 80, 160, 320 and 640 μg/mL).	reduction activity potential (FRAP, 644.25 μm of Fe(II)/g). Curry leaf extracts from all the locations exhibited significant anticarcinogenic effects inhibiting the growth of breast cancer cell line (MDA-MB-231).	[75]
Antioxidative	*Eucheuma Cottonii, Padina sp (Rumpai laut*/Seaweed)	Antioxidant activities were measured using DPPH assay, FRAP and β-carotene bleaching assay. Total phenolic content of crude seaweeds extract using conventional and soxhlet extraction were analysed.	The methanolic extract of *Padina sp*. showed better radical scavenging and higher phenolic contents than *Eucheuma cottonii*. The soxhlet extraction showed better radical scavenging activity compared to conventional method.	[59]
Antioxidative	*Carica papaya* (Betik/Papaya)	Antioxidant activities from different parts of papaya tree including their ripe and unripe fruit, seeds and the young leaves were measured using DPPH and β-carotene bleaching assay. Total phenolic content (TPC) and total flavonoid content (TFC) were determined.	The highest antioxidant activity through β-carotene bleaching assay was observed in unripe fruit (90.67 ± 0.29%) followed by young leaf, ripe fruit and the seed. Young leaves exhibited a significant higher scavenging effect compared to others. Both TPC and TFC also showed that young leaves had the highest antioxidant content (424.89 ± 0.22mg GAE/100 g dry weight and 333.14 ± 1.03mg rutin equivalent/100 g dry weight, respectively).	[77]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative	*Parkia Speciosa* (Petai/Stink Bean)	Antioxidant activities aqueous and ethanol extracts of *P. speciosa* were measured using DPPH and ABTS assay.	Ethanol extracts possessed stronger DPPH and ABTS radical scavenging, anti-lipid peroxidation, metal chelating and reducing power activities than aqueous extracts.	[62]
Antioxidative	*Ipomoea aquatica Forsk* (Kangkung/ Water spinach), *Allium tuberosum* (Kucai/ Chinese leek), *Basella alba L.* (Di huang miao/Indian spinach), *Ipomoea batatas L. Lam* (Pucuk ubi keledek/Sweet potato leaves) *Lactuca sativa var longifolia* (Yaw mak choy/Romaine lettuce)	The antioxidant capacity of methanol, acetone, and water extracts was evaluated using FRAP and DPPH assay. Phenolics, total flavonoids, flavonols and tannins were also quantified.	Methanol was the best of the three solvents for extraction of antioxidants. Methanol showed higher levels of phenolics in Ubi Keledek. The methanolic extract of Kucai yielded the highest tannin content (0.50 mg CAE/g extract). High flavonoids content was recorded in Ubi Keledek extracts. Methanol and acetone extracts of Ubi Keledek exhibited the highest FRAP values.	[83]
Antioxidative	*Nypa fruticans* Wurmb. (Buah nipah/ Nypa palm)	Total phenolics, flavonoid content, and antioxidant capacities (DPPH, FRAP, ABTS and beta carotene bleaching assay) from endosperm extracts of *Nypa fruticans* (unripe and ripe fruits) were evaluated.	Endosperm extract of unripe fruits (EEU) exhibited the highest phenolics (135.6 ± 4.5 mg GAE/g), flavonoid content (68.6 ±3.1 RE/g) and antioxidant capacity. Free radical scavenging capacity of EEU as assessed by ABTS and DPPH showed inhibitory activity of 78 ± 1.2% and 85 ± 2.6%, respectively. Beta carotene bleaching coefficient	[60]

Table 2. (Continued)

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
			of EEU was higher (2550 ± 123), when compared to endosperm extract of ripe fruits (1729 ± 172).	
Antioxidative	*Passiflora* (Markisa/ Passion fruit)	Total phenolic content (TPC) and total antioxidant activity (DPPH) were determined in fruit juices from seven passion fruit *(Passiflora spp*.) cultivars: *P. edulis* cultivars Purple, Frederick, Yellow, Pink, *P. edulis f. flavicarpa*, *P. maliformis* and *P. quadrangularis.*	Ascorbic acid, TPC and total antioxidant activity were significantly higher in vine-ripened Purple and Yellow *P. edulis*; ranges were 0.22–0.33 g kg^{-1}, 342.80–382.00 mg gallic acid equivalent L^{-1} and 409.13–586.70 μmol Trolox L^{-1}, respectively.	[63]
Antioxidative	*Citrus Grandis L* (Limau bali/Pomelo)	Antioxidant capacity of pomelo pulp and peel of two varieties of pomelo fruit (Tambun White and Tambun Pink) was measured using ferric reducing antioxidant potential and trolox equivalent antioxidant capacity assays. Total phenolic content, total flavonoid content and ascorbic acid content were determined.	The peels of both pomelo fruits had higher antioxidant content and capacity than their pulps. The white variety of pomelo had higher antioxidant content and capacity compared to the pink counterpart. Both varieties of pomelo peels exhibited almost 5-fold higher in total TPC as compared to the pulps. Highest TFC was found in the peel of Tambun White followed by the peel of Tambun Pink. The results have shown that ascorbic acid content in the pulps of both pomelo varieties were significantly higher ($p < 0.05$) than the peels.	[61]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative	*Cosmos caudatus* (Ulam Raja), *Oenanthe javanica* (Selom), *Murraya koenigii* (Daun kari/Curry leaf), *Centella asiatica* (Pegaga), *Parkia speciosa* (Petai).	The total phenolic contents (TPC) and antioxidant activities were investigated using DPPH and FRAP assays.	Ulam Raja and Selom showed the highest antioxidant activities. Curry leaf, Selom and Ulam Raja ranked as ulam with highest TPC.	[64]
Antioxidative	Three *Musa acuminate* cultivars (Pisang berangan, pisang Mas, pisang Raja/Banana)	Antioxidant activities banana extraction using pure methanol, ethanol, acetone and aqueous solution at 50% and 70% concentrations were determined using DPPH and FRAP assays.	Acetone 70% had the strongest antioxidant compounds extraction power compared to other solvents. All banana samples were found to be low in primary antioxidant but powerful secondary antioxidant source of fruit. The ascending order of banana cultivars in term of their antioxidant activities in all antioxidant assays carried out were Berangan < Mas < Raja.	[65]
Antioxidative	*Mangifera pajang Kort. Peels* (Bambangan)	Phenolic compounds and antioxidant capacity (DPPH and FRAP assay) of acidified methanolic extract were analyzed.	The total phenolic content of bambangan peel powder (BPP) was 98.3 mg GAE/g. BPP showed a strong potency of antioxidant activity. BPP had high DPPH radical-scavenging activity, ranging from 57% to 97%. BPP exhibited a high antioxidant power corresponding to that of vitamin C.	[66]

Table 2. (Continued)

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative	*Psidium guajava L.* (Jambu batu isi merah/ Pink-Flesh Guava)	The antioxidant activity of the fruit was evaluated using FRAP and DPPH to compare the different extraction techniques (homogenization, shaking, sonication, magnetic stirring and maceration for 1, 2, and 3 days) and the solvent systems used (methanol, ethanol, and acetone at three different concentrations (50%, 70%, and 100%) and with 100% distilled).	Ultrasonic and homogenization were the best techniques to extract the antioxidant from guava fruit. The average efficiency of the extraction techniques for DPPH values in pink-flesh guava fruit showed that both ultrasonic and homogenization were significantly higher ($P < 0.05$) than other techniques. For FRAP values, ultrasonic was significantly higher ($P < 0.05$) than other techniques including homogenization. Acetone was the best solvent compared to methanol, ethanol, or water. The addition of water to organic solvent increased the effectiveness of the extraction.	[68]
Antioxidative	*Allium sativum* L. (Bawang putih/Garlic), *Allium cepa* L. (Bawang merah/Red onion)	Antioxidant activities were measured using DPPH and ferrous ion chelating assay. Total phenolic content (TPC) was determined.	Total phenolic content (TPC) assay indicate that TPC is higher in red onion (i.e., 53.43 ± 1.72 mg GAE/100g) compared to garlic (i.e., 37.60 ± 2.31 mg GAE/100g). EC_{50} value of garlic is lower than that of the red onion, showing a higher free radical scavenging activity in garlic than in red onion. FIC assay shows that at the highest sample concentration of 1.0 mg/mL, red onion has higher ferrous ion chelating effect (i.e., 45.00 ± 1.73%) as compared to garlic (i.e., 43.29 ± 3.89%).	[69]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative	*Musa x Paradisiaca* (Jantung pisang/Banana Flower)	Phytochemical constituents and antioxidant activities (DPPH assay) in the flower of *Musa x paradisiaca* extracts were determined. The extracts from various solvents; petroleum ether, chloroform, ethanol and water were investigated.	Phytochemicals studies on banana flower extracts showed the presence of alkaloids, glycosides, steroids, saponins, tannins, flavanoids and terpenoids. The flower also contains 5.83 ± 0.78 g/100g total phenolic, 88.31 ± 4.53 mg/100g tannin and 3.98 ±0.01 mg/100g flavanoid. DPPH assay of ethanol extract demonstrated stronger antioxidant activity than aqueous extract in which the IC_{50} value were 1.01 ± 0.16 mg/ml and 1.52 ± 0.13 mg/ml, respectively.	[70]
Antioxidative	*Manilkara zapota* (Ciku), *Punica granatum* (Delima/Pomegranate), *Garcinia mangostana* (Manggis/ Mangosteen), *Actinidia deliciosa*, (Kiwi fruit) *Carica papaya* (betik/ papaya) *Averrhoa carambola* (belimbing/Starfruit), *Hylocereus undatus*,	The breast cancer cell line, MCF-7 were treated with various fruit extracts (50–600 lg/ml).	Chiku and dragon fruit showed high inhibitory activity when compared to the other fruits tested. At a concentration of 600 µg/ml, chiku and dragon fruit extracts inhibited MCF-7 cell growth by almost 85%. A maximum of 88.4% of nitric oxide was scavenged by the chiku extract.	[76]

Table 2. (Continued)

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
	(Buah naga/Dragon fruit) *Pyrus malus (Epal/Apple), Vitis vinifera* (Anggur/Grape), *Litchi chinensis* (Laici/Lychee), *Mangifera indica* (Mango), *Durio zibethinus* (Durian), *Persea americana* (Avocado)			
Antioxidative	*Eucheuma cottonii, E. spinosum, Halymenia durvillaei), Caulerpa Lentillifera, C. racemose, Dictyota dichotoma, Sargassum polycystum, Padina* (Rumpai laut/Seaweed)	Methanol and diethyl ether were used as extraction solvent. The antioxidant activities were determined by TEAC and FRAP. The total phenolic content of then extract was determined.	The methanolic extracts of green seaweeds, *C. lentillifera* and *C. racemosa*, and the brown seaweed, *S. polycystum* showed better radical-scavenging and reducing power ability, and higher phenolic content than the other seaweeds.	[74]
Antioxidative	*Psophocarpus tetragonolobus* D.C.) (Kacang botol/Four-angled bean), *Phaseolus*	The antioxidant capacity was measured using β-carotene and DPPH assays were determined for the raw and blanched vegetables.	The study revealed that blanching caused a significant increase in β-carotene content [fresh (389–539 μg/100 g), blanched (510–818 μg/100 g)], except in snow pea. There was a significant	[71]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
	vulgaris L. (Kacang buncus/French bean), *Vigna sesquipedalis* L. (Kacang panjang/Long bean) *Pisum sativum var. macrocarpon L.* (kacang pea/Snow pea), *Pisum sativum* (kacang manis/Snap pea)	The contents of total phenolics, ascorbic acid and β-carotene were determined.	decrease in ascorbic acid content [fresh (1.2–7.8 mg/100 g), blanched (0.67–3.8 mg/100 g)]. Results showed that all the raw and blanched vegetables had significant higher antioxidant activities for ethanolic extracts than for water extracts, except blanched four angled bean, blanched long bean, raw and blanched snow pea. In water extract, four-angled bean (+397%) was the only vegetable that showed a significant increase in scavenging activity after blanching. Blanched long bean had an increase of 12% scavenging activity comparing with raw long bean (DPPH).	
Antioxidative	*Mangifera pajang* fruit(Bambangan)	The physiochemical composition and antioxidant activities of underutilized *Mangifera pajang* Kosterm fruit pulp and fruit juice powder were studied.	*M. pajang* juice powder (MPJP) was high in protein, carbohydrate, ascorbic acid, and ash whereas *M. pajang* pulp (MPP) was rich in fiber, gross energy, phenolic and β-carotene content. MPJP extract exhibited the highest using DPPH and FRAP methods.	[108]
Antioxidative and anticholine-sterase activity	*Canarium odontophyllum* Miq. Fruit (Dabai)	Antioxidant activities were analyzed using, ABTS and FRAP assays. Total phenolic, total flavonoid, total anthocyanin, total carotenoid contents and acetylcholinesterase inhibitor potential of extracts of	The total phenolic and flavonoid contents were higher in the flesh of *C. odontophyllum* with the values of 11.96 ± 0.05 mg gallic acid equivalent (GAE)/g and 10.11 ± 1.54 mg rutin equivalent (RU)/g, respectively. Total anthocyanin and carotenoid content were also higher in the flesh of the fruit with the values of 12.75 ± 0.28	[80]

Table 2. (Continued)

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
		the flesh and seed of this fruit. *C. odontophyllum* were evaluated.	mg/100g and 2.84 ± 0.11 mg/100g. The flesh of the fruit also showed higher antioxidant activity as assessed using DPPH, ABTS and FRAP assays. M Anti-cholinesterase activity was higher in the seed of *C. odontophyllum.*	
Antioxidative	*Brassica oleracea* var. *Capitata rubra* (Kobis merah/Red cabbage), *Brassica rapa pekinensis* var *cylindrica*), (Kobis China/Chinese cabbage non-heading cabbage) *Brassica oleracea* var *capitata*, (Kobis hijau/ Green cabbage) *Brassica juncea* var *rugosa*) (Kobis mustard/ Mustard cabbage), *Brassica rapa* var *chinensis* (Kobis putih/ Chinese white cabbage)	The antioxidant activity of the vegetable extracts, standard (α-tocopherol) and control (70% methanol) were determined according to the β-carotene bleaching assay, free radical scavenging activity (DPPH) and phenolic content.	Red cabbage had the highest antioxidant activity and phenolic content compared to the other cruciferous vegetables studied ($p < 0.05$). The contributions of all cruciferous vegetables to the antioxidant activity was >79%. The radical scavenging activity was in the order of Chinese white cabbage > red cabbage > mustard cabbage > Chinese cabbage > green cabbage. Phenolic content was in the order of red cabbage > Chinese white cabbage > green cabbage > Chinese cabbage >mustard cabbage.	[73]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative and antiperoxidation	*Baccaurea angulate* (Belimbing dayak/Borneo red star fruit)	The various crude extracts: skin methanol extract (SKM); pulp methanol extract (PLM); whole fruit methanol extract (WFM); skin phosphate buffered saline (PBS) extract (SKP); pulp PBS extract (PLP); and whole fruit PBS extract (WFP) were examined on total phenolic (TPC), total flavonoids (TFC), total carotene content (TCC) and DPPH assay. The antiperoxidation assays of the various *B. angulate* extracts were evaluated.	The methanol extracts were significantly ($p < 0.01$) found to contain higher TPC, TFC and TCC than PBS extracts for all the fruits parts. The methanol extracts also showed remarkable antiradical activity and significant lipid peroxidation inhibition activities, with their IC_{50} results highly comparable to that of commercial blueberry.	[79]
Antioxidative and antidiabetic	*Benincasa Hispida* (Kundur/Winter melon), *Cucurbita maxima* (Labu/squash), *Lagenaria siceraria* (Labu/Bottle gourd), *Luffa acutangula* (Petola/Luffa), *Momordica charantia* (Peria katak/Bitter gourd), *Trichosanthes*	Antioxidant activities of n-hexane, chloroform, ethyl acetate, and methanol extracts were measured using chelating power, DPPH and Reducing Power Assay. Total phenolic content (TPC) and α-Glucosidase inhibitory assay were determined	The highest TPC and metal chelating activity were obtained from the chloroform extracts of *Luffa acutangula* (28.04 ± 0.37 mg GAE/g extract) and *Benincasa hispida* (EC_{50} = 0.44 ± 0.03 mg/mL), respectively. The ethyl acetate extract of *Sechium edule* showed the highest (DPPH) free radical scavenging activity (951.73 ± 29.14 mM TE/g extract). The highest reducing and anti-α-glucosidase activities were shown by the methanol and ethyl acetate extracts of *Momordica charantia*	[84]

Table 2. (Continued)

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
	cucumerina (Labu ular/ Snake gourd)		(692.56 ± 43.38 mM AscAE/g extract; 66.64 ± 2.94%, respectively).	
Antidiabetic	*Pleurotus pulmonarius* (Cendawan tiram/Grey Oyster Mushroom)	*α*-glucosidase inhibitory activity and *α*-amylase inhibition assay were measured.	30%$(NH_4)_2SO_4$ precipitated fraction (F30) inhibited *Saccharomyces cerevisiae*α-glucosidase activity (24.18%) and 100% $(NH_4)_2SO_4$ precipitated fraction (F100) inhibited porcine pancreatic *α*-amylase activity (41.80%).	[88]
Antioxidative and antidiabetic	*Ipomoea aquatic* Forssk (kangkung/Water spinach)	Antioxidant activity in aqueous and methanol extract of three different *I. aquatica* cultivars: upland type with narrow leaves (K-11), the low land and aquatic type with broader arrow-shaped leaves (K-25), and bamboo shaped leaves (K-88) were measured by DPPH assay. Total phenolic acid and α-glucosidase inhibitory activity were determined.	70% methanol extract of upland type with narrow leaves *I. aquatica* (K-11) showed higher total phenolic content, α-glucosidase inhibitory and antioxidant activities than the other two cultivars.	[115]
Antioxidative and antidiabetic	*Momordica charantia* (Peria kambas, Peria katak/Bitter gourd)	Antioxidant properties of two local bitter gourd species namely *peria kambas* and *peria katak* with three ripening stages: raw, mature and ripewere screened with DPPH, FRAP	Mature peria katak appeared as stronger antioxidant vegetables in three antioxidant assays (51.1% in DPPH inhibition, 0.63 g gallic acid equivalent and 2.29 g Trolox equivalent/100 g dried weight of peria	[87]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
		assay and total phenolic content (TPC). α-amylase and α-glucosidase inhibitory activities were evaluated.	katak) than peria kambas. Mature peria katak reported to be 21% and almost three-fold stronger in inhibiting the activity of enzymes α-amylase and α-glucosidase as compared to another bitter gourd cultivar.	
Antioxidative and antidiabetic	*Plectocomiopsis geminiflora* (Wi lalis) and *Eugeissona insignis* (Pantu ketajau)	Total phenolic, flavonoid contents and antioxidant properties (FRAP and ORAC assay) of *P.geminiflora* and *E.insignis* were determined. α-Amylase inhibititory activity and effects on insulin secretion using BRIN BD11 pancreatic cell lines were determined.	*P.geminiflora* had significantly higher phenolic content (2505 mg GAE/100 g dw). *E.insignis* exhibited a significantly higher TFC value (11 mg RE/100 g dw). Significant FRAP(226.8−396.8 μmol Fe2+/100 g) values of *P.geminiflora and E.insignis* were observed. High inhibition of α-amylase activity (>50%) was found from the extracts of *P.geminiflora* and *E.insignis.*	[81]
Antimicrobial	*Canarium odontophyllum* Miq. Fruit (Dabai)	The hexane, acetone, methanol and aqueous extracts of *C. odontophyllum* pulp at 25, 50, 75 and 100 mg/ml were screened for antimicrobial activity using agar well diffusion method.	The crude extracts of *C.odontophyllum* were not active against any of the bacteria tested. *C.glabrata* was susceptible towards the *C. odontophyllum* pulp extract. The acetone extract displayed moderate antimicrobial activity against *C. glabrata* with inhibitory zone of 8.0 ± 0.00 mm at all tested concentrations.	[92]

Table 2. (Continued)

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative and antidiabetic	40 tropical fruit juices (Jus buah-buahan tropika)	Antioxidant activities were measured using DPPH and FRAP assays. Vitamin C, total phenolic contents, α-glucosidase inhibitory activities were determined.	The juice of *Psidium guajava* gave the highest total phenolic (857.24 ± 12.65 µg GAE/g sample) and vitamin C contents (590.31 ± 7.44 µg AAE/g sample). The juice of *Phyllanthus acidus* with moderate contents of total phenolics and vitamin C was found to exhibit the greatest scavenging (613.71 ± 2.59 µg VCEAC/g sample), reducing (2784.89 ± 3.93 µg TEAC/g sample) and α-glucosidase inhibitory activities (95.37 ± 0.15%).	[116]
Antioxidative and antimicrobial	Three cultivars of *Syzygium samarangense* L. (Jambu air/Wax apple) (Red, pink and green fleshy fruits)	Total phenolic contents and total flavonoid content (TFC) of various extracts of red, pink and green fleshy fruits and leaf, bark and fruit extracts were determined. Antioxidant activities of ethanolic fruits extracts of three cultivars were examined by using DPPH assay. The antibacterial activity of wax apple crude extracts was evaluated against four laboratory strains of bacteria including two Gram positive (*Bacillus cereus*, *Staphylococcus aureus)* and two	The highest amounts of total phenols and flavonoids were in methanol extracts compared to ethanol fruit extracts. The highest antioxidant strength was observed in red cultivar followed by pink cultivar while the lowest antioxidant strength was recorded in the green cultivar. Ethanolic bark extracts of red cultivar showed positive antimicrobial activities against four bacteria and the highest percentage reduction (90%) against *S. aureus*. Pink cultivar showed antimicrobial activities against *B. cereus*	[90]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
		Gram negative bacteria (*Escherichia coli*, *Pseudomonas aeruginosa*).	and *E. coli*, whereas green cultivar showed only against *B. aureus.*	
Antidiabetic	*Hibiscus esculentus* L. (Kacang bendi/Okra)	Methanolic extract of fresh and cooked okra was assayed for α-amylase and α-glucosidase inhibitory activity.	Blanched okra pod extract has the highest inhibitory action against mammalian pancreatic α-glucosidase followed by fresh, fast cooked and baked pod extract. The highest inhibitory activity against α-amylase was demonstrated by the fresh okra extract followed by blanched, fast cooked and baked pod extract.	[89]
Antimicrobial	*Baccaurea angulate* (Belimbing dayak/ Borneo red star fruit)	Methanol, ethanol and aqueous extracts from three parts (whole fruit, fruit skin, and berry) were determined (using agar well diffusion and microdilution method) against *S. pneumoniae, S.epidermidis, K. pneumoniae* and *P. aeruginosa.*	The highest antimicrobial activity was in ethanol extract of fruit skin using agar well diffusion against *S. pneumonia*. Aqueous extract of skin at the concentration of 15.6 mg/ mL acted as a bactericidal agent against *K. pneumoniae* using microdilution method.	[91]
Antioxidative, antityrosinase and antimicrobial	*Anacardium occidentale* (Daun gajus/ Cashew), *Piper betle* (Daun sireh/betel) leaves	Antioxidant activity of fresh and processed (blanched, microwaved) leaves were measured using the DPPH, potassium ferricyanide and ferrozine assays. Total phenolic content, total flavonoid content, caffeoylquinic acid content and tyrosinase inhibition was determined. Antibacterial activity was assessed (using the disc-diffusion)	Tyrosinase inhibition of fresh *A. occidentale* was high while *P. betle* leaves exhibited an enhancement of tyrosinase activities. Blanching did not affect the tyrosinase inhibition of cashew leaves but microwave treatment resulted insignificant increase. Antioxidant properties based on phenolic content and antioxidant activity of fresh leaves of *A. occidentale* far exceeded those of	[82]

Table 2. (Continued)

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
		against Gram-positive bacteria of *Brevibacillus brevis*, *Micrococcus luteus* and *Staphylococcus cohnii* and Gram-negative bacteria of *Escherichia coli*, *Pseudomonas aeruginosa* and *Salmonella enterica*.	*P. betel*. Blanching in boiling water for 30 seconds resulted in a significant decrease in the phenolic content and antioxidant activity of *A.occidentale* and *P.betle* compared to fresh samples. Fresh *A.occidentale* and *P. betel* inhibited both Gram-positive and Gram-negative bacteria tested. Blanched and microwave-treated cashew leaves exhibited strong antibacterial properties.	
Angiotensin 1-converting enzyme (ACE) inhibitor	*Agaricus bisporus* (Cendawan butang/ Mushroom)	Identification of the peptide sequences present was carried out by liquid chromatography–mass spectrometry (LC–MS/MS). ACE inhibitory activity was determined using an ACE inhibitory assay kit.	Eight highly functional ACE inhibitory peptides from the mushroom were KVAGPK, FALPC, RIGLF, EGEPR, APSAK, C4 AHEPVK, GVQGPM and PSSNK. The most potent ACE inhibitory activity was exhibited by AHEPVK, RIGLF and PSSNK with IC_{50} values of 63, 116 and 129 µM, respectively.	[94]
Antimicrobial	*Hylocereus polyrhizus* (Buah naga isi merah/ Red flesh pitaya), *Hylocereus undatus* (Buah naga isi putih/ white flesh pitaya) peels	The antibacterial activity of ethanol, chloroform and hexane extracts peels against nine pathogens (*Bacillus cereus* (ATCC 14579), *Staphylococcus aureus* (ATCC 25923), *Listeria monocytogenes* (ATCC 19115), *Enterococcus faecalis* (ATCC 14506), *Salmonella*	Result from disc diffusion method showed that chloroform extracts from *H. polyrhizus* and *H. undatus* peel were found to exhibit good antibacterial activity. Result of the minimum inhibitory concentration (MIC) showed that all extracts inhibit the growth of bacteria in the range of 1.25-10.00 mg/mL for	[78]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
		typhimurium (ATCC 13311), *Escherichia coli* (ATCC 25922), *Klebsiella pneumoniae* (ATCC 13883), *Yersinia enterocolitica* (ATCC 23715) and *Campylobacter jejuni* (ATCC 29428) was evaluated using disc diffusion method and broth micro-dilution method.	all bacteria while their minimum bacteriacidal concentrations (MBC) indicated double of the MICs concentration except for *B. cereus*, *L. monocytogenes* and *C. jejuni.* Chloroform extract of both *H. polyrhizus* and *H. undatus* peel showed the most potent antibacterial activity.	
Anti-inflammatory	*Musa paradisiaca* (Pisang/Banana)	*Musa paradisiaca* were extracted with methanol (tepal, flesh and skin), ethanol (tepal) and water (tepal) using cold maceration technique. The anti-inflammatory activity of the extracts was assessed by evaluating the ability of the extract to inhibit RAW 264.7 macrophage cell line from generating harmful nitric oxide (NO) induced by bacterial lipopolysaccharide (LPS).	Flesh extract has the highest NO (generated by LP) inhibitory activity, with a maximum inhibition of 52.21% at 250 µg/mL, followed by tepal aqueous extract with a maximum inhibition of 48.16% at 62.5 µg/mL.	[93]

Table 3. Summary of nutritional studies of vegetables and fruits and health in Malaysia: An *in vivo* studies

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative	*Nephelium lappaceum* peel, (Rambutan) *Garcinia mangostana* (Manggis/Mangosteen) peel, *Lansium domesticum* (Langsat) peel	Rats (Sprague-Dawley) were fed orally with Rambutan peel extract (100mg/kg/day), Mangosteen peel extracts (100 mg/kg/day) and Langsat peel extract (100 mg/kg/day) for 14 and 30 days.	Fruit peel extracts significantly decreased ($p < 0.05$) the marker enzyme of serum glutamic oxaloacetic transaminase, serum glutamic pyruvic transaminase activities, the alkaline phosphatase level, total protein and total bilirubin level. Oral administration of peel extracts for 14 and 30 days resulted in a significant increase ($p < 0.05$) in superoxide dismutase, glutathione reductase, catalase and lipid peroxidation levels, compared with a control group. Rambutan peel extracts exhibited higher antioxidant potency than mangosteen and langsat.	[96]
Hepatopro-tective and antioxidative	*Psidium guajava* (Jambu batu/Guava) Fruit	Rats (male Sprague-Dawley) were fed orally with (200, 400 mg/kg BW of freeze-dried polysaccharide *P. Guajava* for fourteen days. At day 15, the rats orally received paracetamol (PCM) (2 g/kg).	Polysaccharide *P. Guajava* supplementation significantly decreased aspartate transaminase, alanine transaminase and level of TNF-α following PCM induction ($p < 0.05$). Polysaccharide *P. Guajava* supplementation also showed increased level of glutathione and superoxide dismutase activity, mild histological changes and increased glycogen storage. Polysaccharide *P. Guajava* supplementation attenuates the PCM-induced liver injury by enhancing the endogenous antioxidant activity.	[97]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antidiabetic and antioxidative	*Passiflora edulis* (Markisa/Passion fruit) peel and seed	Diabetic rats were fed orally with (250, 500 mg/kg, *Passiflora edulis* extracts*)* at 72 hours after Streptozotocin injection for 15 days.	*P.edulis* extracts significantly ($P < 0.001$) decreased the blood glucose level in the diabetic rats. *P. edulis* extract protected the end organs by restoring the antioxidants enzyme, significantly increasing superoxide dismutase level and decreasing catalase and thiobarbituric acid reactive substance level in visceral organs (liver and kidneys).	[98]
Antioxidative	*Canarium odontophyllum Miq.* (Dabai) Fruit pulp oil	Rabbits (male New Zealand white) were supplemented with NP (normal diet daily + 2% pulp oil) followed by NK (normal diet + 2% kernel oil) for 4 weeks. Supplementation of oil was by force feeding. There was a two-week wash-out period between NP and NK supplementation.	Supplementation of *C.odontophyllum Miq.* pulp oil increased high-density lipoprotein (HDL-C), significant decrease of low-density lipoprotein (LDL-C), triglyceride (TG) and thiobarbiturate reactive substances (TBARS) levels. Supplementation with pulp oil resulted in significant increase ($P < 0.05$) of superoxide dismutase (SOD), glutathione peroxidase (GPx) activities and total antioxidant status (TAS) levels as compared to rabbits fed on normal diet. Supplementation of kernel oil caused significant decrease of total cholesterol (TC) level and moderate decrease of low-density lipoprotein (LDL-C). Supplementation with kernel oil resulted in significant increase ($P < 0.05$) in superoxide dismutase (SOD) activity and total antioxidant status (TAS) levels.	[117]

Table 3. (Continued)

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antioxidative	*Hylocereus undatus* (Buah naga isi putih/ White Pitaya)	Streptozotocin-induced diabetes rats were fed with aqueous extracts of *H.undatus* (250, 500 mg/kg) for 5 weeks.	*H.undatus* extract significantly decreased ($P < 0.05$) the fasting blood glucose levels in diabetic rats. in comparison with control group. *H.undatus* extract treatment significantly decreased ($P < 0.05$) the elevations of systolic blood pressure, pulse pressure and pulse wave velocity in diabetic rats at the end of 5 weeks. *H.undatus* extract significantly decreased ($P < 0.05$) the plasma malondialdehyde levels while superoxide dismutase and total antioxidant capacity significantly increased ($P < 0.05$).	[107]
Hypolipidemic effect	*Parkia speciose* Hassk (Petai/Stink Bean)	Rats (Sprague-Dawley) were fed with aqueous seed extract of *P.speciose* (50, 100, 200, 400 mg/kg BW).	The highest aqueous extract dose of 400 mg/kg body weight has significant effect in reducing blood glucose levels in rats.	[106]
Antidiabetic	*Hylocereus polyrhizus* (Buah naga isi merah/ Red Pitaya) fruit	Insulin resistant rats were fed with high-fat diet with red pitaya (10% daily energy intake fresh pitaya, 10% daily energy intake thermally-treated pitaya at 95°C for 30 min, 10% daily energy intake thermally-treated pitaya at 105°C for 60 min for 11 weeks).	Fresh pitaya significantly ($p < 0.05$) attenuated the insulin resistance, hypertriglyceridemia and atherosclerotic changes induced by fructose supplement in rats. Thermally-treated pitaya at 95°C for 30 min (containing low antioxidant content) significantly ($p < 0.05$) improved hyperinsulinemia. Thermally-treated pitaya at 105°C for 60 min (contained low antioxidant	[101]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
			and soluble dietary fiber content) feed to rats had no significant effect on insulin resistance, dyslipidemia and atherogenesis.	
Antidiabetic	*Theobroma cacao L.* (Buah koko/Cocoa)	Streptozotocin-diabetic rats were fed with cocoa autolysates (dissolved in carboxymethyl cellulose) were gavaged to the animals and blood glucose levels were measured at 2 and 4 hours after autolysates administration.	Cocoa autolysates significantly decreased blood glucose at 4 hours.	[102]
Antihyper-glycemic	*Canarium odontophyllum* (Dabai) fruit	Obese-diabetic rats were fed with dabai fruit extracts (300, 600 mg/kg BW) from weeks 13 to 17.	The supplementations of 600 mg dabai extracts/kg BW manage to reduce the plasma glucose at week 17 by 30%. Dabai extracts also significantly reduced the plasma cholesterol level by 19.1% and low-density lipoprotein (LDL-c) levels by 42% and 57%, and increased high-density lipoprotein (HDL-c) by 47%. Dabai extracts also reduced insulin resistance.	[100]
Antihyper-glycemic	*Momordica charantia* (Peria katak/Bitter gourd)	The diabetic rats were fed with aqueous extract from *M.charantia* at a dosage of 20 mg/kg body weight twice daily for a period of 4 weeks.	Administration of *M.charantia* extracts significantly reduced the levels of blood glucose in the second, third and fourth weeks post-treatment as compared to the control group ($p < 0.05$). Administration of *M.charantia* extracts reduced the malondialdehyde (MDA) concentration in plasma and in the pancreas of the *M.charantia* treated diabetic group.	[104]

Table 3. (Continued)

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antihyper-glycemic	*Alpinia galanga* (Lengkuas/Galangal) *Momordica charantia* (Peria katak. Bitter gourd) *Portulsca Olerangiotensia* (Gelang pasir/Purslane)	Rats (Sprague-Dawley) were fed with aqueous extract of *A.galanga, M.charantia* and *P.Oleracea* (2.5, 25, 250, 500 and 2500 mg/kg BW). The aqueous extracts were given once at the beginning of the experiment at time -30 minutes.	*A.galanga, M.charantia* and *P.Oleracea* (500mg/kg BW) significantly lowered the blood sugar level ($p < 0.05$).	[105]
Antihyper-glycemic	*Theobroma cacao* (Buah koko/Cocoa)	Three different dosages of cocoa polyphenols-rich extract (10, 20 and 30mg per 100 g BW) were administered orally once a day for 1 week before STZ injection and for 3 weeks thereafter.	Cocoa polyphenols-rich extract (20 mg)-pretreated group showed a 143% increase in plasma glucose levels, compared with a 226% increase in diabetic control rats. Cocoa polyphenols-rich extract could also normalise total cholesterol, triglycerides and high-density lipoprotein cholesterol at the end of the experiment compared with the baseline.	[109]
Antiobesity	*Morinda citrifolia L.* leaf (Mengkudu/Noni)	Rats (male Sprague-Dawley) were fed high-fat (36% kcal fat) diet with M.citrifolia leaf extracts (150, 350 mg/kg BW) for 12 weeks.	*M.citrifolia* leaf extracts reduced body weight.*M. citrifolia* leaf extracts had significantly ($p < 0.05$) reduced percentage of visceral fat (3.45–4.04%) as compared to rats on the high fat diet (6.08%). *M.citrifolia* leaf extracts improved the plasma lipid profiles with a marked decrease in plasma triglyceride and low-density lipoprotein levels. *M.citrifolia* leaf extracts also significantly improved other pro-obesity related factors such as plasma insulin and leptin.	[111]

Bioactivities	FV studied/local name	Experimental design	Major findings	Ref
Antihyperchol-esterolaemia	*Tamarindus indica* (Asam gelugur/ Tamarind)	Syrian hamsters fed with high-cholesterol diet with *T. indica* fruit pulp extract (500 mg/kg BW) for 10 weeks.	Administration of *T. indica* fruit pulp to hypercholesterolaemic hamsters significantly lowered serum triglyceride, total cholesterol and LDL-C levels but had no effect on the HDL-C level.	[99]
Antiinflammatory	*Eucheuma cottonii* (Rumpai laut/Seaweed)	Rats (female Sprague-Dawley) were fed with (150, 300 mg/kg BW) of seaweed *E. cottonii* extracts. The *E. cottonii* extracts paste was dissolved in distilled water and delivered to the rats by oral gavage once a day starting week 6 until week 10.	Seaweed *E. cottonii* extracts significantly ameliorated nasal itching, sneezing, lung histopathology, immunohistochemistry and related genes changes. Seaweed *E. cottonii* extracts decreased mucin synthesis and downregulated the tumour necrosis factor-alpha (*TNF-α*), interleukin (IL)-4, nuclear factor kappa beta (*NF-κB*), epidermal growth factor receptor (*EGFR*) and matrix metalloproteinase (*MMP*)-9 expressions but increased the interferon-gamma (*IFN-γ*) expression.	[103]
Hypolipidemic effect	*Morinda citrifolia* L. (Mengkudu/Noni) fruit	Streptozotocin-induced diabetic rats were fed orally with aqueous extract of *M. citrifolia* (0.25, 0.50, 1.00 g/kg) for 6 weeks.	Administration of 0.50 and 1.00 g/kg of *M. citrifolia* extracts significantly reduced the plasma triglyceride level ($p < 0.05$). Administration of 1.00 g/kg of *M. citrifolia* extracts significantly decreased the concentration of triglyceride and total lipid in the liver in the diabetic rats.	[95]
Antioxidant status	*Mangifera pajang* (Bambangan)	32 non-smoking (12 male and 20 female) volunteers daily consumed a 250 ml of study drink either mango juice (placebo group) or bambangan juice powder.	Significant increase in concentration of plasma β-carotene, ascorbic acid and total antioxidant.	[108]

6.2. Health Effect Studies on FV Using In Vivo Models

The health effects of FV have been studied in animal and in pre-clinical in vivo models (Table 2; Table 3). The bioactive compound of FV possess various beneficial properties such as antioxidant, antidiabetic, antihyperglycemics, antiobesity, antihypercholesterol-aemia, anti-inflammatory and hypolipidemics. Fruits that have been tested include noni (Morinda citrifolia L.) [95], rambutan (Nephelium lappaceum), mangosteen (Garcinia mangostana), langsat (Lansium domesticum) [96], guava (Psidium guajava) [97], passion fruit (Passiflora edulis) [98], tamarind (Tamarindus indica) [99], dabai (Canarium odontophyllum) [100], red pitaya (Hylocereus polyrhizus) [101], cocoa (Theobroma cacao L.) [102]. Types of vegetables that have been tested include seaweed (Eucheuma cottonii) [103], bitter gourd (Momordica charantia) [104], galangal (Alpinia galangal) [105] and stink bean (Parkia speciose Hassk) [106].

6.2.1. Antioxidative Studies

Few studies have used Sprague-Dawley rat models to provide certain mechanistic information related to anti-oxidative property of FV. In one study, Sprague-Dawley rats were fed orally with rambutan (*Nephelium lappaceum)* peel extract (100 mg/kg/day), mangosteen (*Garcinia mangostana***)** peel extracts (100 mg/kg/day) and langsat (*Lansium domesticum)* peel extract (100 mg/kg/day) for 14 and 30 days [96]. The study showed that the fruit peel extracts significantly decreased the marker enzyme of serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT) activities, the alkaline phosphatase level, total protein and total bilirubin level. Oral administration of peel extracts for 14 and 30 days resulted in a significant increase ($p < 0.05$) in superoxide dismutase (SOD), glutathione reductase (GR), catalase and lipid peroxidation levels, compared with a control group. Rambutan peel extracts exhibited higher antioxidant potency than mangosteen and langsat.

In a study by Aspalilah and colleagues [97], male Sprague-Dawley rats were fed orally with (200, 400 mg/kg BW of freeze-dried polysaccharide *Psidium guajava* for fourteen days. On day 15, the rats were administered paracetamol (PCM) orally (2 g/kg). The polysaccharide *P. guajava* supplementation significantly decreased aspartate transaminase (AST), alanine transaminase (ALT) and level of tumor necrosis factor-α (TNF-α) following paracetamol (PCM) induction ($p < 0.05$) and attenuates the PCM-induced liver injury by enhancing the endogenous antioxidant activity.

In another study by Kolla and colleagues [107], streptozotocin-induced diabetic rats were fed aqueous extracts of dragon fruit *(Hylocereus undatus)* (250, 500 mg/kg) for 5 weeks. The study revealed that *H. undatus* extract significantly decreased ($p < 0.05$) fasting blood glucose levels in diabetic rats in comparison with a control group. *H. undatus* extract treatment significantly decreased ($p < 0.05$) the elevations of systolic blood pressure, pulse pressure and pulse wave velocity in diabetic rats at the end of 5 weeks. *H. undatus* extract significantly decreased ($p < 0.05$) plasma malondialdehyde levels while superoxide dismutase (SOD) and total antioxidant capacities significantly increased ($p < 0.05$). Muhammad Ibrahim and colleagues [108] conducted a single-blinded, crossover supplementation trial to determine the effects of a bambangan *(Mangifera pajang)* juice powder drink on plasma vitamin and antioxidant enzyme levels and liver and kidney functions revealed significant increase in concentrations of plasma β-carotene, ascorbic acid and total antioxidant. The study showed that liver and kidney functions were unaffected after consumption of bambangan juice powder.

6.2.2. Antidiabetic Studies

Diabetes mellitus has been classified as a major concern among developed and developing countries worldwide. In Malaysia, 3.5 million people were diagnosed with diabetes mellitus in 2015. In a study by Kandandapani and colleagues [98], diabetic rats were fed orally with 250 and 500 mg/kg passion fruit (*Passiflora edulis)* extracts at 72 hours after streptozotocin injection for 15 days. The study observed significantly

decreased blood glucose level in the diabetic rats. In another study by Omidizadeh and colleagues [101], insulin resistant rats were fed with high-fat diet with red pitaya *(Hylocereus undatus)* (10% daily energy intake fresh pitaya, 10% daily energy intake thermally-treated pitaya at 95◦C for 30 min, 10% daily energy intake thermally-treated pitaya at 105◦C for 60 min for 11 weeks). There was a significant attenuation of insulin resistance, hypertriglyceridemia and atherosclerotic changes induced by fructose supplement in rats. Thermally-treated pitaya at 95°C for 30 minutes significantly improved hyperinsulinemia. In a study by Sarmadi and colleagues [102], streptozotocin-diabetic rats were fed with cocoa *(Theobroma cacao)* autolysates (dissolved in carboxymethyl cellulose) were gavaged to the animals and blood glucose levels were measured at 2 and 4 hours after autolysates administration. The study showed that cocoa autolysates significantly decreased blood glucose at 4 hr.

6.2.3. Antihyperglycemic Effect Studies

Hyperglycaemia is a condition which an excessive amount of glucose circulates in the blood plasma and it is one of typical diabetic complications. In a study by Mokiran and colleagues [100], obese-diabetic rats were fed with dabai *(Canarium odontophyllum)* fruit extracts (300 and 600 mg/kg body weight (BW) from weeks 13 to 17. The supplementations of 600 mg dabai extracts/kg BW managed to reduce the plasma glucose at week 17 by 30%. Dabai extracts also significantly reduced the plasma cholesterol level by 19.1% and low-density lipoprotein (LDL-c) levels by 42% and 57%, while increasing high-density lipoprotein (HDL-c) by 47%. Dabai extracts also reduced insulin resistance. In a study by Rezaeizadeh and colleagues [104], the diabetic rats were fed with aqueous extract from bitter gourd *(Momordica charantia*) at a dosage of 20 mg/kg body weight twice daily for a period of 4 weeks. Study showed that administration of *M. charantia* extracts significantly reduced the levels of blood glucose in the second, third and fourth weeks post-treatment as compared to the control group ($p < 0.05$). In a study by Ruzaidi and colleagues [109], three different dosages of cocoa *(Theobroma cacao)* polyphenols-rich extract (10, 20 and 30 mg per 100 g BW) were administered orally once a day for

1 week before streptozotocin (STZ) injection and for 3 weeks thereafter. The study revealed that cocoa polyphenols-rich extract (20 mg)-pretreated group showed a 143% increase in plasma glucose levels, compared with a 226% increase in diabetic control rats. Cocoa polyphenol-rich extract could also normalise total cholesterol, triglycerides and high-density lipoprotein (HDL) cholesterol at the end of the experiment compared with the baseline.

6.2.4. Anti-obesity Studies

Obesity is one of the risks factors associated with hypertension and non-insulin-dependent diabetes mellitus [110]. In a study by Jambocus and colleagues [111], Sprague-Dawley rats were fed high-fat (36% kcal fat) diet with noni *(Morinda citrifolia*) leaf extracts (150, 350 mg/kg BW) for 12 weeks. The study revealed that *M. citrifolia* leaf extracts reduced body weight. *M. citrifolia* leaf extracts had significantly reduced percentage of visceral fat (3.45–4.04%) as compared to rats on the high fat diet (6.08%). *M. citrifolia* leaf extracts improved the plasma lipid profiles with a marked decrease in plasma triglyceride and low-density lipoprotein (LDL) levels. *M. citrifolia* leaf extracts also significantly improved other pro-obesity related factors such as plasma insulin and leptin. *M. citrifolia* leaf extracts show promise as natural and safe anti-obesity agents.

6.2.5. Antihypercholesterolaemia Studies

Hypercholesterolemia occurs when there is excessive cholesterol in the body. High cholesterol raises the risk for cardiovascular disease [112]. In a study by Lim and colleagues [99], Syrian hamsters fed with high-cholesterol diet with tamarind *(Tamarindus indica*) fruit pulp extract (500 mg/kg BW) for 10 weeks. The study showed that administration of *T. indica* fruit pulp to hypercholesterolemic hamsters significantly lowered serum triglyceride, total cholesterol and low-density lipoprotein (LDL-C) levels but had no effect on the high-density lipoprotein (HDL-C) level. These finding showed that tamarind fruit pulp exerts its hypocholesterolemic effect by increasing cholesterol efflux, enhancing

LDL-C uptake and clearance, suppressing triglyceride accumulation and inhibiting cholesterol biosynthesis.

6.2.6. Anti-Inflammatory Studies

In a study by Abu Bakar and colleagues [103], female Sprague-Dawley rats were fed with (150, 300 mg/kg BW) seaweed *Eucheuma cottonii* extracts. The *E. cottonii* extracts paste was dissolved in distilled water and delivered to the rats by oral gavage once a day starting week 6 until week 10. The study revealed that seaweed *E. cottonii* extracts significantly ameliorated nasal itching, sneezing, lung histopathology, immunohistochemistry and related gene changes. Seaweed *E. cottonii* extracts also decreased mucin synthesis and down regulated the tumour necrosis factor-alpha (TNF-α), interleukin (IL)-4, nuclear factor kappa beta (NF-κB), epidermal growth factor receptor (EGFR) and matrix metalloproteinase (MMP)-9 expressions but increased the interferon-gamma (IFN-γ) expression. These findings indicated that seaweed consumption may be beneficial for asthma treatment. The mechanisms involve include reducing inflammation, mucin synthesis, eosinophil infiltration and MMP-9-related tissue remodelling.

6.2.7. Studies on Hypolipidemic Effects

Hyperlipidaemia refers to increased levels of lipids in the blood and it is one of the significant risk factors involved in the development of cardiovascular disease [113]. In a study by Hadijah and colleagues [95], streptozotocin-induced diabetic rats were fed orally with aqueous extract of noni *(Morinda citrifolia*) (0.25, 0.50, 1.00 g/kg) for 6 weeks. The study showed that administration of 0.50 and 1.00 g/kg of *M. citrifolia* extracts significantly reduced the plasma triglyceride level ($p < 0.05$). Administration of 1.00 g/kg of *M. citrifolia* extracts also significantly decreased the concentration of triglyceride and total lipid in the liver of the diabetic rats. In a study by Chee Beng Jin and Hamdan [106], Sprague-Dawley rats were fed with aqueous seed extract of stink bean *(Parkia speciose*) (50, 100, 200, 400 mg/kg BW). The study showed that the

highest aqueous extract dose of 400 mg/kg body weight has a significant effect in reducing blood glucose levels in rats.

7. RECOMMENDATIONS

The Malaysia School-Based Nutrition Survey 2012 and Malaysian Adult Nutrition Survey (MANS) 2014 reported a very poor intake of FV, milk and dairy products [16]. One of the strategies to strengthen food and nutrition research and development in the latest National Plan of Action for Nutrition of Malaysia (NPANM III, 2016-2025) is the establishment of Nutrition Research Priorities (NRP) in Malaysia [114]. NRP in Malaysia for the 11th Malaysia Plan (2016-2020) was developed to continue addressing important research gaps of evidence and identifying issues in nutrition that warrant further research in the country. It is in accordance with the national priorities and current needs. There are seven NRP areas whch have been identified. These are 1) Maternal, infant and young child nutrition; 2) Monitoring and evaluation of National Food and Nutrition Security, Nutritional Status and Programs; 3) Life Course Food Intake and Dietary Practices; 4) Macro- and Micronutrient Excesses and Deficiencies; 5) Overweight and Obesity; 6) Diet-Related Non-Communicable Diseases (Cancer, Diabetes and Cardiovascular Disease) and 7) Food Composition Database [114].

Changes in lifestyles and dietary habits of Malaysians over the last decade may be attributed to the socioeconomic developments in the country. These changes affect the nutritional status of all age groups in the population. There is convincing evidence that unhealthy dietary lifestyle and excessive consumption of high-energy foods, such as processed foods that are high in fats and sugars, promotes overweight and obesity compared to low-energy foods such as FV. Several nutrition surveys at the national level have been conducted since 1986. However, gaps remain in the availability of data on FV intake/pattern among adolescents, toddlers, pregnant women, the elderly and indigenous population groups. Dietary adequacy is important for better growth and development.

Determination of factors influencing food and nutrition security in the food systems is a demanding issue. FV prices and government policies for food production and trade should be studied for its effects on the nation's nutrition security. This will provide baseline data, important for needs assessment and the decision-making process (policies and programs). There is also a lack of national data on bioavailability of micronutrients in local foods and diets. This has to be addressed to determine micronutrients, such as vitamins and minerals, in FV available in the market. A national assessment of the prevalence of micronutrient deficiencies is also recommended. This can be conducted by assessing dietary intake or biological samples (eg. blood) from the population of all age groups. The rational is to develop a database for micronutrient status and to establish its association with health outcomes.

One of the main focuses is understanding food intake and dietary practices. Assessment of the impact of nutrition on growth and development is required. More research is needed on nutrition-related behavior among all age groups and the variability in individuals in response to diet and food intakes. There is a need to evaluate the effectiveness of interventions to promote healthy dietary practices. More information is required to determine factors affecting FV intakes among Malaysians. There are also limited studies in Malaysia on the effects of unhealthy dietary practices in the later stages of life. Concerns in this respect are focused on low intake of FV and excess intake of sugar, salt and fats in the population. For any nutrition research and programs being implemented, a comprehensive and updated Malaysian Food Composition Database must be available and accessible for health professionals, researchers and those involved in food production and preparation.

There appears to be a lack of FV intake interventions in Malaysia. Health education and counseling were mostly used in studies which showed favorable health outcomes. FV interventions appear to bring about positive physical, biochemical, psychological, behavioral and aesthetic outcomes. More interventions are recommended to promote intake of FV, especially among groups of the community with poor consumption. Intervention programs should be of wider scope, including both children

and adults. Adults play a vital role for household purchasing decisions. Continuous intervention to nurture healthy eating habits among children may have a positive impact until adulthood.

Many nutritional studies on different types of FV and its effects on health have been conducted in Malaysia. Various FV have shown numerous bioactive properties such as antioxidant, anti-diabetic, antimicrobial and anti-inflammatory effects. In future, more FV should be evaluated for bioactivity. Bioactive components can be isolated, identified and further explored for mechanism of action. In addition, the toxicological evaluation of FV is also necessary for safe human consumption, especially for those rarely consumed in the population.

CONCLUSION

In conclusion, more research is required to address gaps in answering issues related to the consumption of FV in Malaysia. Funding for research is available locally and internationally. However, more large-scale research among the population are required to answer questions on how to improve FV consumption further. Nationwide studies are demanding for the Ministry of Health (MOH) of Malaysia but useful for decision-making on nutrition-related health policies.

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AUTHOR'S CONTRIBUTION

Dr. Nurul Izzah Ahmad drafted the introduction, FV consumption in Malaysia and its sociodemographic determinants. Wan Nurul Farah Wan Azmi drafted the MANS study in Malaysia. Dr. Nur Suffia Sulaiman and Dr. Nur Hayati Azizul drafted topics on intervention studies conducted in Malaysia. Norhayati Mustafa Khalid drafted the content on nutrition-related FV studies. Dr. Mohd Fairulnizal Md Noh contributed content on recommendations for future FV studies in the country. All authors critically reviewed and approved the final version of the manuscript for publication.

Conflicts of Interest

The authors declare no conflict of interests.

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