EFFECTS OF THREE SELECTED FRUITS ON METABOLIC SYNDROME: A SYSTEMATIC REVIEW

Thin Zar Wai [1], Thein Hlaing [2], and Pa Pa Soe [3]

[1]Faculty of Health and Social Sciences, University of Bedfordshire, Luton, UK
[2]District Public Health Department (Ministry of Health), Pyay District, Bago Region, Myanmar
[3]Department of Preventive and Social Medicine, University of Medicine (2), Yangon, Myanmar

ABSTRACT

The increasing prevalence of metabolic syndrome, which includes central obesity, hypertension, diabetes mellitus, and dyslipidemia, has become a global concern. Changes in dietary patterns can affect the metabolic syndrome. This study reviews the effects of passion fruit, Indian gooseberry, and mango on metabolic syndrome and evaluates their effectiveness in controlling its components through dietary intervention. The studies were carefully selected using a PRISMA flow chart, with inclusion and exclusion criteria. Of 6 studies on passion fruit, 3 showed beneficial effects on reducing blood glucose and HbA1C levels, while 2 reported effects on lipid profiles. Passion fruit consumption reduces systolic blood pressure levels. Mango consumption had beneficial effects on blood glucose levels, lipids, systolic blood pressure, and body weight. Amla fruit also showed beneficial effects on blood sugar and lipid levels. The three selected fruits demonstrated favourable effects on various components of metabolic syndrome. The least adequate amount and duration can be implied when selecting fruits for the diet.

KEYWORDS

Metabolic syndrome, Passion fruit, Mango, Amla fruit

1. INTRODUCTION

Metabolic syndrome is an umbrella term encompassing central obesity, increased blood pressure (hypertension), increased blood glucose (diabetes mellitus), and an impaired lipid profile (elevated triglycerides and reduced HDL cholesterol) [1]. Metabolic syndrome is also known as MetS, syndrome X, and insulin resistance syndrome [2]. Central obesity is defined as a waist circumference greater than 40 inches in men and greater than 35 inches in women. Blood pressure greater than 130/85 mmHg and fasting blood glucose greater than 100 mg/dL are included in this definition. Regarding the lipid profile, blood triglyceride levels greater than 150 mg/dL and HDL cholesterol levels less than 40 mg/dL are associated with metabolic syndrome. The presence of any three of these conditions confirms the diagnosis of metabolic syndrome [3].

The prevalence of metabolic syndrome around the world is said to be 20 – 25%, while Asians were found to have a higher rate than Europeans, with 12 – 37% and 12 – 26%, respectively [4]. According to the US National Health and Nutrition Examination Survey (NHANES), the prevalence of metabolic syndrome increased from 36.2% in 2011 to 38.3% in 2018. Aged more than 60 years could be more affected by metabolic syndrome. Even though Non-Hispanic Asians suffered less from metabolic syndrome than other populations, the increasing rate of metabolic syndrome prevalence was significant in the Asian group. Males were more likely to develop

metabolic syndrome than females [5].

Metabolic syndrome can also affect children, with a global prevalence of 3% in children and 5% in adolescents in 2020 [6]. According to Kim, Kim and Cho (2013), the lower socioeconomic status of women was associated with an increased risk of metabolic syndrome [7]. An educated person who can access the necessary information on diet and exercise is unlikely to develop metabolic syndrome [8]. The dietary pattern has a more significant impact on metabolic syndrome. High intake of sweetened beverages, carbohydrate-dense foods, and saturated fats is a risk factor for metabolic syndrome [9]. In a study by Lorzadeh et al. (2020), skipping breakfast is associated with metabolic syndrome [10]. Higher consumption of barbecue has been associated with metabolic syndrome [11]. People with a family history of diabetes mellitus are more likely to suffer from metabolic syndrome. Metabolic syndrome can also affect fast eaters, overeaters, and high seaweed eaters [12].

Fruit consumption is increasing worldwide, particularly in Europe, owing to perceived health benefits. They are often referred to as exotic fruits or superfruits due to their higher nutritional content, including vitamins, minerals, antioxidants, and fibre [13]. Fruit consumption is positively associated with reduced blood cholesterol and blood pressure [14]. Vitamin C, K, and E-enriched fruits can reduce oxidative stress and insulin resistance, which are the causes of metabolic syndrome. Other components of fruits that can reduce metabolic risk include phytochemicals, anti-inflammatory compounds, and antioxidants [15]. Many fruits contain numerous bioactive compounds with health benefits. Among them, this systematic review discussed 3 selected fruits, passion fruit, mango, and gooseberry, that have multiple effects on metabolic syndrome.

2. MATERIAL AND METHODS

A systematic review was conducted to summarise the effects of three selected fruits on metabolic syndrome, based on individual-level studies. There were numerous studies regarding the consumption of the selected fruits and metabolic syndromes. Discrepancies among studies necessitated a systematic, qualitative synthesis of similarities and differences in the evidence. As this systematic review aimed to assess changes in metabolic substances after consuming mango, passion fruit, and gooseberry, it primarily included randomised controlled trials. Besides, this review wanted to verify the possible findings about the effectiveness of three selected fruits on the physiology and mechanism of metabolic syndromes, so clinical or controlled studies with human subjects were selected among different RCTs with human or animal subjects. A retrospective survey of human subjects was also conducted to assess the effectiveness of selected fruit consumption. The reported outcomes were the validated measurements of blood glucose, blood lipid, and blood pressure levels, and body weight, and their associations with the effects of eating mango, passion fruit, and gooseberry. Furthermore, the types of English-language and full text publications were selected without date restrictions, as there was no comparable review approach to date. Peer-reviewed articles were selected, and non-peer-reviewed literature and other technical reports that lacked specific research methodologies were excluded because intervention based evidence was essential to address this review question.

The databases Google Scholar, PubMed, WHO HINARI, Elsevier, ScienceDirect, and Embase were used as sufficient sources for a comprehensive search. The keywords used for the search were human, fruits, mango, passion fruit, gooseberry, and metabolic syndrome. The search sub terms included Mangifera Magnifica, Mangifera Indica, Mangiferin, Passiflora edulis, Amla, Emblica Officinalis, Phyllanthus Emblica, blood glucose, sugar level, diabetes mellitus, blood pressure, hypertension, blood triglyceride, HDL level, lipid level, hypertriglyceridemia, hyperlipidemia, dyslipidemia, overweight and obesity. The use of databases and search exercises was performed by two independent reviewers, who selected key and sub-search terms, searched

using predetermined keywords and exact phrases, applied Boolean logic, and checked text citations and reference lists. The literature that appeared from the search results was filtered through the three processes of the PRISMA flow: identifying the papers according to the selected databases and removing the papers with duplications and exclusion reasons, screening the papers with the predetermined inclusion/exclusion criteria, and selecting the most eligible papers for the review analysis.

Descriptive statistics were performed to quantitatively summarise the background and methodological features of the selected studies and to determine the distributions of these features. The summarised information was presented as frequencies and percentages, and as words and tables. Furthermore, the researcher conducted a thematic analysis, coding the reported findings by theme, segment, and line-by-line. As per the research objectives, the researcher organized the particular coded information to fit under the relevant themes; effects of mango, passion fruit, and gooseberry on blood glucose levels, effects of mango, passion fruit, and gooseberry on blood lipid levels, effects of mango, passion fruit, and gooseberry on blood pressure and effects of mango, passion fruit and gooseberry on body weight. All procedures in the thematic analysis were manual.

3. RESULTS

After receiving approval to proceed with this review from the University of Bedfordshire on 28.1.2023, data extraction of searched works of literature was done. The quality appraisal and data analysis process ran from March 28 to May 14, during which the results and findings were written. Before submitting on July 15, this review was discussed and concluded. The PRISMA flowchart was systematically applied throughout the study selection process.

3.1. Paper selection process summary

After assessing the potential relevance, a total of 10713 titles and abstracts were provided. 8566 titles and abstracts were removed due to duplicate references across the six databases. 1738 titles and abstracts in the peer-review process that could not be accessed in full-text form were also removed. Of the remaining 409 titles and abstracts, 215 were not retrieved because the keywords in their titles, abstracts and study objectives were unrelated to the current review field and objectives. Accordingly, 194 titles and abstracts were left.

After downloading and printing out the 194 studies, 1926 citations were checked in the texts of individual full-text papers. Of these citations, 1,875 had already been screened in the databases and were therefore removed due to duplication. Here, 51 papers were available for further screening.

All downloaded and printed papers (n=194) included the total references (n=5729) in their reference lists. In this screening, 4163 references were duplicated between the databases, 464 references came from Websites, 659 references were cited from unpublished evidence, and 307 were not available for full-text forms. This screening process yielded 136 full-text papers.

Two independent reviewers screened a total of full-text papers (n=381) from the database screening (n=194) and other screenings (n=187). After conventional double-screening processes of full-text papers, 9 full-text papers from the databases screening and 4 full-text papers from citation and reference screenings were successfully selected for further systematic review processes.
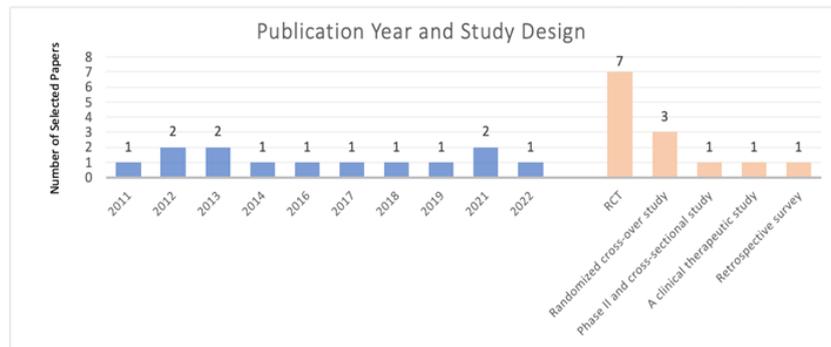
Figure 1. Selection processes of the eligible studies according to the PRISMA flowchart

3.2. Background information of selected studies

Of the 13 included studies, 12 (92.3%) were randomised controlled trials, and 1 (7.7%) was a retrospective survey. The study populations of this review were composed of diabetes subjects (n = 250), healthy adult subjects (n = 17649), obese individuals (n = 41), patients with essential hypertension (n = 150), patients with HIV (n = 36), and healthy children subjects (n = 11974) and therefore the total sample size was 30100. Tables 1, 2 and 3 describe the PICO characteristics and the interventions monitored in the included studies.

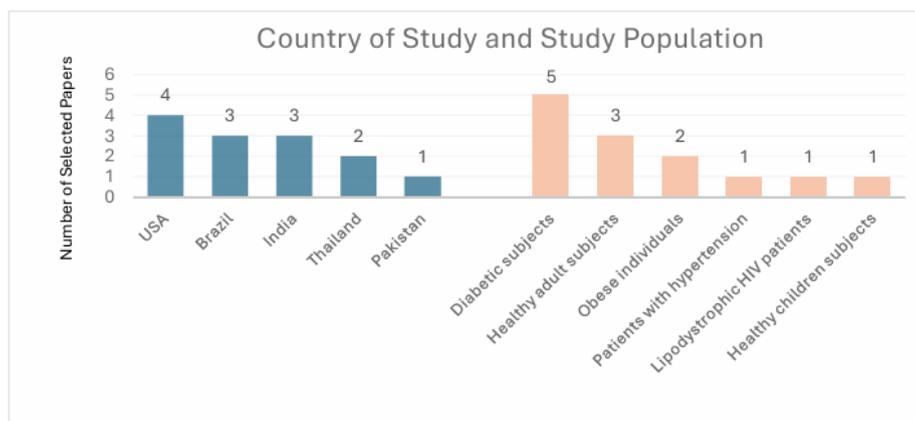Figure 2.Number of Selected Papers with Publication Year and Study Design

Figure 3. Number of Selected Papers with Country of Study and Study Population

Table1.PICO Characteristics and Monitoring the Interventions of Passion Fruit Studies

Reference	Population	Intervention	Comparison	Outcome	Monitoring the intervention
(Prasertsri et al., 2019) [16]	The study involved 14 healthy men and women from Burapha University, Thailand, from January to February 2018. They were 20-30 years old with normal BMI (18.5 - 23 kg/m2), and healthy physical and mental well-being. Regular drinkers and smokers were excluded.	Half of both men and women received 50% passion fruit juice while the other half received the placebo solutions which contained glucose and fructose at 3.5 ml/kg randomly at T0, T30, T60, T90, T120 (mins).	Researchers compared the systolic and diastolic blood pressure, and blood glucose levels between the two groups.	The study tracked how passion fruit juices affected blood pressure and blood glucose compared to a controlled group.	The participants were monitored 5 minutes before the intervention, 25-30 minutes, 55-60 minutes, 85-90 minutes, and 115-120 minutes after taking supplements.
(Khongrum et al., 2022) [18]	This study included 40 Thai adults aged 35-60 years from the community around Chiang Mai University. They had dyslipidemia but were not on lipid-lowering agents and vegetarian diets. Researchers excluded smokers, athletes, obese adults, those with underling medical conditions like diabetes and cancer, and those who took herbal medicines and dietary supplements affecting the lipid metabolism in the previous 14 days.	Twenty adults drank 100 kcal per 300 ml of RP jelly drink per day for 8 weeks, while the others received 100 kcal per 300 ml of placebo jelly drink per day for 8 weeks.	Data were compared between groups and within each group. Measurements were taken at the start, at 4 weeks and at 8 weeks.	This study showed the effects of RP jelly drink on FBS, blood pressure, and BMI compared to the placebo jelly drink.	A questionnaire regarding diet and physical activity was taken up to 7 days before monitoring at 4 and 8 weeks. Body weight and blood pressure were measured individually, while blood test monitoring was done at Chiang Mai Medical Lab, Chiang Mai, Thailand.
(de Queiroz et al., 2012) [20]	Sixty diabetic participants (36 females and 24 males) who attended the Pharmaceutical Care Program (PROA- TENFAR) from the Paraiba State University (UEPB) aged of 57-73 years were included at the start of this study. Later 43 participants remained. Out of them, only one had not taken any hypoglycemic agents (oral or insulin) due to being newly diagnosed.	28 diabetic females and 15 diabetic males took 30 g of yellow passion peel flour daily for 2 months.	Data were determined at day 30 and 60 compared to those levels before intervention.	Yellow passion peel flour's effects on blood glucose, HbA1C, insulin levels, body weight and BMI, were studied in this study.	The Filizola metal rod scale measured body weight, and BMI was calculated. Blood test monitoring was done in the UEPB clinical analysis laboratory at T0, T30, and T60.
(Raju et al., 2013) [23]	Forty-nine people aged 30-70 years of both sexes with type 2 DM (FBS > 140 mg%) and hypertension (BP > 140/90 mmHg) participated in this study.	They were randomly divided into two groups which had gotten 220 mg purple passion fruit capsule for the one and a placebo capsule for the other. The study period was 16 weeks.	Data were compared before and after intervention in both groups.	This study showed the effects of PFP on lipid profile, blood pressure, FBS, 2HPP, and HbA1C levels.	Blood tests were recorded monthly for four months at 4, 8, 12, and 16 weeks. Three days of diet recalls were recorded before and after the intervention.
(Marques et al., 2016) [24]	36 (24 men and 12 women) HIV patients with undetectable viral load and CD4 count > 300 cells/mm3 who had lipodystrophy syndrome secondary to HAART, and dyslipidemia from the Lipodystrophy Ambulatory Center in the João de Barros Barreto University Hospital (HUJBB) were selected for this study.	Group 1 with systematically assigned 18 people received 30 g PFPF daily and diet counseling, while the other Group 2 received diet counseling for 90 days.	The comparison was made before and at 30, 60, and 90 days of the intervention within the group.	TC, TG, HDL-C, and LDL-C were measured at To, T30, T60, and T90 upon the effects of passion fruit peel flour.	Monthly lipid levels monitoring was done at the HUJBB's laboratory in the morning after fasting for 12 hours.
(de Araújo et al., 2017) [28]	Fifty-four diabetic patients, aged 18-65 years of both genders with type 2 diabetes mellitus without hepatic and renal dysfunction from primary care in Redenção, Ceará, Brazil, were recruited to participate in this study. Smokers, alcoholics, those with mental problems or taking insulin were excluded.	Twenty-seven individuals received 12 g of flour (sachets) produced from the rind of the yellow passion fruits three times per day before meals, while the others received treatment from the health service of the study.	The comparison was made between the inter-, intra-case, and control groups.	Capillary and fasting blood glucose and HbA1C levels were monitored to show the effects of yellow passion fruit.	The nurses who took training for 12 hours performed blood tests according to the Guidelines of the Brazilian Society of Diabetes. Monitoring was done at the start of the intervention for 8 weeks. The sachets were delivered with home visits.

Table 2. PICO Characteristics and Monitoring the Interventions of Indian Gooseberry Studies

Reference	Population	Intervention	Comparison	Outcome	Monitoring the intervention
(Akhtar *et al.*, 2011) [17]	32 individuals – 16 with diabetes from the outdoor clinics of the University of Agriculture Faisalabad and Khadija Memorial Trust Hospital Faisalabad, Pakistan, and 16 age and gender-matched individuals from the same family with similar socio-economic and cultural backgrounds were selected. The diabetic participants who did not take insulin within 5 years but took various oral hypoglycemic agents, dietary treatments, or herbal medications.	There were 8 groups. Each group, A, B, C, and D, consisted of 4 healthy people. The other E, F, G, and H groups comprised 4 diabetic patients equally. Carboxymethyl cellulose fiber was given to group A, and oral glibenclamide (Daonil) 5 mg two times per day was given to group E. Groups B and F received 1 g, groups C and G received 2 g, and groups D and H received 3 g of oral E. officinalis fruit mixed with 30 ml of water, after breakfast.	Outcome data were compared within each group before the intervention, at 8, 15, and 21 days after.	The study produced the relationship between the changes of FBS, 2HPP, total cholesterol, total lipids, triglycerides, HDL-C, and LDL-C upon the dosage of E. officinalis.	Blood glucose and lipid profile monitoring was done at the follow-up on 8, 15, and 21 days.
(Shanmugarajan *et al.*, 2021) [19]	18 years or older essential hypertensive patients taking amlodipine 5 mg or enalapril 5 mg who were newly diagnosed or who did not achieve target blood pressure, however, not require additional medications according to the registered physician were included. Patients with secondary hypertension with blood pressure of160/100 mmHg, diabetic patients who are not on control, pregnant, and lactating women, those not taking any contraception, patients with liver, kidney, and heart problems, and who were taking any herbal treatment were excluded from the study.	Seventy-five participants received Phyllanthus emblica extract capsules 500 mg two times per day, while the other 75 took maize starch placebo capsules. The time to take the capsules was 12 weeks for both groups.	Systolic and diastolic blood pressure, HbA1C, and lipid profiles (total cholesterol, LDL, HDL, VLDL, and triglyceride) were compared between and within the groups before and after the intervention.	Data were measured according to the effects of Phyllanthus emblica compared to the placebo group.	Firstly, the patients were monitored for blood pressure 2 weekly for one month and then once per month for 3 months. HbA1C and lipid profiles were measured 2 times at the start and the end of the intervention.
(Usharani, Fatima and Muralidhar, 2013) [22]	The study included 80 individuals aged 30-68 years with type 2 DM on metformin 1500-3000 mg for 8 weeks and endothelial function of less than or equal 6% change in reflection index (RI) on salbutamol challenge. Patients with uncontrolled DM and hypertension or underlying other medical diseases, pregnant and lactating women, chronic alcoholics, and who were taking herbal treatments were excluded.	Eighty males and females were divided randomly into 4 groups (20 in each). The first group received E. officinalis 250 mg BD, the second group received E. officinalis 500 mg BD, the third group received a placebo in the morning while atorvastatin had to be taken at night, and the fourth group received a placebo BD. The total duration of the study was 12 weeks.	Lipid profiles and HbA1C were compared within the group before and after the intervention.	Lipid profile (TC, TG, HDL-C, LDL-C, and VLDL-C) and HbA1C had been affected by the dosage changes in the consumption of E. officinalis.	Outcome measures were taken before and at the end of the intervention in the laboratory with safety measures. Any adverse reaction was monitored with the case report form.

Table 3. PICO Characteristics and Monitoring the Interventions of Mango Studies

Reference	Population	Intervention	Comparison	Outcome	Monitoring the intervention
(Rosas et al., 2022) [21]	27 healthy participants with 18-50 years old aged and BMI of more than or equal to 26 kg/m2 from the San Deigo community were included in the study. Any participants with underlying medical conditions, pregnancy, lactating children, smoking history, taking dietary supplements, gluten and mango allergy, and irregular menstrual cycle were excluded.	16 male and 11 female participants were assigned with 5 blocks method randomly. The first five had to drink 166 g of fresh mango, which contained 100 kcal, and the next five received low-fat cookies, which alternately extended to reach their destination. The duration of the intervention was 12 weeks.	The measurements were monitored by comparing before to 4 and 12 weeks during the intervention period in the mango consumption and low-fat cookies consumption groups.	The effects of fresh mangoes on body weight, body fat, serum glucose, insulin level, HbA1C, blood lipids (TG, TC, HDL-C, LDL-C), and blood pressure were determined in this study.	Monitoring was done at baseline, 4 and 12 weeks during the intervention period after the laboratory's overnight fast of at least 10 hours. Dietary recalls were done by trained staff for 2 days before the monitoring times, and physical activity was checked 7 days before the monitoring days.
(Evans et al., 2014) [25]	20 obese individuals aged 20-50 years with a BMI 30-45 kg/m2 from Stillwater, Oklahoma were included in this study. Individuals with underlying medical diseases, who took supplements, pregnant and lactating mothers, smokers or alcoholics, and people with mango allergies were excluded.	Twenty-two obese individuals were given 10 g of ground freeze-dried mango powder daily for 12 weeks.	Data were compared before and after the intervention. Men and women are also separately determined in the outcomes of the effects.	The effects of mangoes on body weight, height, waist and hip circumferences, body composition by DXA, blood pressure, lipid profile, blood glucose, HbA1C, and plasma insulin concentration were examined in this study.	The participants had to visit for screening, baseline tests, and tests at 6 and 12 weeks. Any problem regarding the intervention was informed. Three days dietary recalls were taken at baseline, 6, and 12 weeks to ensure the intake of mangoes. Trained staff took the physical activity record by physical activity scale 2 at baseline, 6, and 12 weeks.
(Neil, Nicklas and Fulgoni, 2013) [26]	Children 2-18 (n=11,974) and adults older than or equal to 19 years who were not pregnant or lactated (n=17,568) participating in the NHANES 2001-2008 were recruited for this study.	NHANES 2001-2008 participants' data were recruited to identify the mango consumers' conditions.	The outcome results of mango consumers were compared to that of non-mango consumers.	Weight, waist circumference, blood pressure, blood lipids, blood glucose, and insulin levels were determined in this study.	One day dietary recall was used in 2001-2002, and 2 days recall was used starting in 2003-2004, even though the first day of the record was used in this survey. The NHANES protocol was used to measure.
(Fang et al., 2018) [27]	Twelve healthy lean individuals with a BMI of 18 – 26.2 kg/m2 and 9 obese individuals with a BMI > 28.9 kg/m2 aged 18-65 years from the Vegetable and Fruit Improvement Center at Texas A&M University were included. People with underlying diseases and taking any medical treatment, pregnancy or lactation, heavy smokers or drinkers, and mango allergies were excluded from this study.	12 lean and 9 obese participants had to take 400 g of mango supplementation for 6 weeks.	The data were measured before and after intervention in both lean and obese individuals.	Weight, BMI, blood pressure, blood lipids, blood glucose, HbA1C, and insulin levels were measured to know the effects of mango.	Three days dietary recall was done three times before checking outcome measures at week 0 and week 6. Weight, BMI, blood pressure, lipids, blood glucose, HbA1C, and insulin levels were monitored according to the proper tests and machines.

3.3. Risks of bias within studies

After assessing the risks of bias in each included study, all studies (n = 13, 100%) were remarked

as having a low risk in randomization, outcome measurements, and the selection of the reported results, eight studies (61.5%) were remarked as having some deviations from the intended interventions, and two studies (15.4%) were remarked as having some missed outcome data. Overall, seven studies (53.8%) had some concerns about bias, and six studies (46.2%) had low risk across five types of bias (randomisation, performance, participation, outcome measurement, and reporting) (Table 4).

References	D1	D2	D3	D4	D5	Overall
(Prasertsri et al., 2019) [16]	Low	Some concerns	Low	Low	Low	Some concerns
(Akhtar et al., 2011) [17]	Low	Some concerns	Low	Low	Low	Some concerns
(Khongrum et al., 2022) [18]	Low	Some concerns	Low	Low	Low	Some concerns
(Shanmugarajan et al., 2021) [19]	Low	Low	Low	Low	Low	Low
(de Queiroz et al., 2012) [20]	Low	Some concerns	Some concerns	Low	Low	Some concerns
(Rosas et al., 2022) [21]	Low	Low	Some concerns	Low	Low	Low
(Usharani, Fatima and Muralidhar, 2013) [22]	Low	Low	Low	Low	Low	Low
(Raju et al., 2013) [23]	Low	Some concerns	Low	Low	Low	Some concerns
(Marques et al., 2016) [24]	Low	Some concerns	Low	Low	Low	Some concerns
(Evans et al., 2014) [25]	Low	Low	Low	Low	Low	Low
(Fang et al., 2018) [27]	Low	Some concerns	Low	Low	Low	Low
(de Araújo et al., 2017) [28]	Low	Some concerns	Low	Low	Low	Some concerns

3.4. Effects of selected fruits on metabolic syndromes

3.4.1. Passion fruit and metabolic syndrome

Before the intervention, blood glucose levels were 88 mg/dL in the study group and 91 mg/dL in the control group. After the intervention with passion fruit juice, the study group showed that blood glucose level had increased to 116 mg/dL in 30 minutes, and then it decreased gradually to 105 mg/dL in 60 minutes, 92 mg/dL in 90 minutes, and 88 mg/dL in 120 minutes. A significant association ($p < 0.05$) was observed in the study group from before intervention to 30, 60, and 120 minutes, after 30 minutes from intervention to 60, 90, and 120 minutes, and from 60 minutes after the intervention to 90 and 120 minutes. As for the control group, a significant association of p 0.05). de Queiroz et al. (2012) showed that blood glucose levels significantly decreased at day 30 (p=0.000) and at day 60 (p=0.001) [20]. From baseline to day 60, blood glucose levels were significantly reduced ($p < 0.0001$). HbA1C level also significantly reduced from before to after intervention with p=0.032. Insulin levels remained constant in females on day 30; however, differences were observed in males (p=0.006). That held for day 60, showing significant male changes (p=0.047). From day 30 to day 60, a significant change in insulin level was seen in males with p=0.047, while no change was seen in females. Another study by Raju et al. (2013) showed that fasting blood glucose significantly reduced in the purple passion fruit consumption group after 16 weeks (p=0.04) while post-prandial blood glucose increased in the placebo group (p=0.02) [23]. No significant change in HbA1C level was seen in both groups, with a p-value of more than 0.05, which similarly occurred in a study by de Araújo et al. (2017) [28].

Concerning the effects of passion fruit juice on blood pressure, the study by Prasertsri et al. (2019) described that systolic blood pressure changes were not significant throughout the intervention in comparing two groups with p level of 0.42 in 0 minutes, 0.97 in 30 minutes, 0.74 in 60 minutes, 0.11 in 90 minutes, and 0.43 in 120 minutes [16]. When the diastolic blood pressure of the study group was compared with that of the control group, no significant differences were observed at 0 minutes ($p = 0.62$), 30 minutes ($p = 0.42$), 60 minutes ($p = 0.11$), 90 minutes ($p = 0.13$), or 120 minutes ($p = 0.95$). Similarly, other studies reported that systolic and diastolic blood pressure did not differ between groups before and after the intervention [18, 23].

Regarding the lipid levels, a study showed that for the RP jelly drinks group, there was a significant decrease in LDL-C ($p<0.05$) and an increase in HDL-C ($p<0.05$) at 4 weeks after consumption [18]. After 8 weeks, LDL-C and TG were marked as reduced in the RP jelly drinks group (16% and 17%). No difference in TC levels is observed between the two groups. There were no significant changes in lipid profiles in the placebo group ($p>0.05$). The study's outcome measures [23] indicated that lipid profiles showed no significant changes in either the study or control groups after 16 weeks of intervention, with all p-values> 0.05. Among HIV patients, passion fruit juice intervention was associated with a significant reduction in total group cholesterol levels on day 30 ($p=0.007$), day 60 ($p<0.0001$), and day 90 ($p=0.001$). At the same time, no change was seen in the other group. LDL-C level was reduced in the intervention group on day 90 ($p=0.0082$), while no change was seen in the other group. A decrease in HDL-C level was observed only in the intervention group at day 90 ($p=0.0294$). Triglyceride reduction was observed only in the intervention group at days 30 ($p=0.034$), 60 ($p=0.0078$), and 90 ($p=0.0140$) [24].

Concerning the relationship between passion fruit juice and body weight, BMI showed no significant changes throughout the intervention in both groups with a p-value of >0.05 [18]. Body weight increased significantly on day 60 ($p=0.000$) compared to baseline and day 30, and BMI also rose significantly on day 60.

3.4.2. Indian gooseberry and metabolic syndrome

Concerning the effects on blood glucose levels, Akhtar et al. (2011) reported that the fibre receiving group A showed no significant changes in FBS and 2HPP throughout the intervention period [17]. Healthy individuals in the group who received 1g of E. officinalis showed significantly lower fasting blood glucose levels on day 21 and 2HPP levels on days 15 and 21 ($p < 0.05$). Both the regular and diabetic groups receiving 2 g of E. officinalis showed decreased fasting blood glucose levels at 15 and 21 days after the intervention, and 2-hour glucose levels at 8, 15, and 21 days, with p-values <0.05. Groups D and H individuals who took 3 g of E. officinalis were found to have decreased fasting and 2 hours post-prandial blood glucose levels throughout the three monitoring days (8, 15, and 21) with $p <0.05$. In the OHA taking group, a significant p value (0.05) was observed for both FBS and 2HPP on all monitoring days. Similar findings were reported in the study [22], which showed the significantly reduced HbA1C in groups 1 and 2 ($p< 0.01$) when comparing pre- and post-intervention values. For group 3, it decreased significantly ($p<0.001$). When the intervention result of the HbA1C of group 2 was compared to that of group 4, it showed a significantly decreased level of HbA1C in group 2 with $p<0.05$.

3.4.3. Mango and metabolic syndrome

Blood glucose levels were significantly decreased in the mango consumption group ($p=0.004$).

Insulin levels remained constant throughout the mango consumption period (p=0.041) and HbA1C level change was insignificant [21]. Similar outcome measures were reported in a study [25] that blood glucose levels decreased in both males and females after 12 weeks (p<0.001) overall [males (p=0.018) and females (p=0.003) respectively]. Insulin level was increased in only male subjects (p=0.032). HbA1c levels showed no change after the intervention. Fang et al. (2018) reported that blood glucose, insulin, and HbA1c levels showed no significant difference between pre- and post-intervention values in both groups (p> 0.05) [27].

and LDL-C levels decreased significantly in the study group in 4 and 12 weeks from baseline (p<0.05), while those increased in the control group [21, 27]. TC and HDL-C showed no change in either group throughout the intervention [21]. Evans et al. (2014) reported that HDL and triglycerides did not change in any individuals after 12 weeks of intervention. (p>0.05) [25]. The outcome is measured by Neil, Nicklas, and Fulgoni (2013), who found that, when calculating OR, the risk of reducing HDL-C (p=0.0066) and raising triglycerides (p=0.0161) was associated with mango consumption.

Noo significant changes in systolic or diastolic blood pressure were observed in either group on any intervention day [21, 26, 27].

When looking the body weight and BMI, they were increased in all measurement weeks in both study and control groups (p<0.05) [21, 26, 27]. However, Evans et al. (2014) reported that, in both sexes, weight, BMI, waist and hip circumferences, waist-to-hip ratio, fat mass, and lean mass showed no significant changes (p > 0.05) after the intervention [25]. After 12 weeks of mango consumption, hip circumference significantly reduced in males (p=0.048), while female subjects showed no difference.

4. DISCUSSION

This systematic review studied the effects of passion fruit, Indian gooseberry, and mango on metabolic syndrome. Although some studies reviewed the effects of one of the fruits on one of the features of metabolic syndrome, no study has comprehensively reviewed the effects on all components of metabolic syndrome. Furthermore, no prior study has examined the effects of these three fruits on metabolic syndrome, despite my search. Therefore, this review was expected to provide reliable information on the interactions between these three fruits and metabolic syndrome features.

4.1. The difference between the previous systematic reviews and this current review

Although many systematic reviews have examined the effects of the three fruits on metabolic syndrome features, some studies will be reviewed in comparison with this review. In a study of the effect of passion fruit peel flour on glycemic control [29], a total of 11 studies of any language were reviewed, and the effects of passion fruit on HbA1C level were found with a CI of 0.32 and a p-value of <0.05. Even though the above study mentioned passion fruit's beneficial effect on HbA1C, that study described the comparison between passion fruit and turmeric. In this current review, all metabolic features due to the effects of passion fruit were discussed.

In Setayesh et al. (2023), there were five randomised controlled trials about Amla fruit in adults with an average BMI of 25.5 [30]. That review showed that consumption of E. officinalis had beneficial effects on blood glucose and lipid profiles. This review included three studies on the amla fruit in individuals with diabetes and hypertension. It examined the effects of E. officinalis on blood glucose and lipid profiles, as well as on hypertension. The subsequent study by T.

Acampado et al. (2023) comprised four randomised trials, and the results showed that Emblica reduced total cholesterol and LDL-C levels and increased HDL-C levels over 12 weeks [31].

Wu et al. (2021) reviewed the effects of Mangiferin in diabetic animal models in 2020, which contained 19 articles [32]. The review showed reduced levels of blood glucose, total cholesterol, and triglycerides in diabetic animals due to the effects of Mangiferin. In that review, Mangiferin was identified to have biphasic effects on body weight, reducing body weight in obese animals and increasing it in lean animals. In this review, 4 human studies that included both diabetic and healthy individuals were examined and showed more realistic effects of mango on all features of metabolic syndrome.

4.2. Effect of passion fruit on blood glucose

Among 6 studies regarding the effects of passion fruit, 5 studies discussed the effect on blood glucose levels. The amount, preparation, and types of passion fruit differed from one study to another, which contained 50% juice, 100 kcal in a 300 ml jelly drink, 2 yellow passion fruit rind flour with different amounts (30 g and 12 g), and 220 mg of purple passion fruit. The duration of the studies ranged from a minimum of 120 minutes to a maximum of 16 weeks. The study population included both sexes in all studies, diabetic individuals in three studies, individuals with dyslipidemia in one study, and healthy individuals in one study. 2 studies reported no changes in blood glucose levels. In comparison, 3 studies reported significant reductions in blood glucose levels. One study reported a reduction in HbA1c and a beneficial effect on insulin levels, whereas the other reported no change in HbA1c. An article about consuming 15% yellow passion fruit rind flour for 16 weeks by De Faveri et al. (2020) showed increased glucose tolerance and insulin sensitivity in mice with cafeteria-induced metabolic disorders [32]. A study that gave passion fruit peel flour 30% for 8 weeks showed that consumption could prevent insulin resistance and decrease glucose levels in a low fructose diet in young rats [33].

4.3. Effect of passion fruit on lipid profile

Among 6 articles about passion fruit's effects, three showed the effects on lipid profiles. The first article examined the effect of a 100 kcal/300 ml jelly drink on dyslipidemia; the second described the effects of 220 mg of purple passion fruit in diabetic patients; and the last examined the effects of passion fruit peel flour in HIV patients on ART. The study durations ranged from 8 to 16 weeks. Although one study showed no significant beneficial changes, the other two reported significant reductions in total cholesterol, triglycerides, and LDL-C, with rising HDL-C levels. An article that studied the effect of Passiflora edulis rind powder in Wistar rats for 30 days showed a reduction in total cholesterol and triglycerides [34]. Another study examined the effects of Passiflora edulis in diabetic rats and reported a pronounced favourable change in lipid profiles [35].

4.4. Effect of passion fruit on blood pressure

In this review, three articles on passion fruit studied the effect on blood pressure. Patients with dyslipidemia, diabetes mellitus, and good health of both genders were included in each article. Only one of them, who took 220 mg of purple passion capsule for 16 weeks, showed a beneficial effect on systolic blood pressure. Diastolic blood pressure showed no significant change in all three articles. Konta et al. (2014) demonstrated that a maximum 8g/kg dose of yellow passion fruit pulp for 5 days significantly reduced systolic blood pressure in spontaneously hypertensive rats [36]. Zibadi et al. (2007) reported significant decreases in both systolic and diastolic blood pressure in humans and a significant decrease in systolic blood pressure in rats [37]. Another study also demonstrated that passion fruit peel extract can benefit systolic and diastolic blood

pressure, even at a minimal effective dose of 2.5 mg/kg, in spontaneously hypertensive rats [38].

4.5. Effect of passion fruit on body weight

Out of all the 6 studies regarding passion fruit, two studies described the effect of passion fruit on body mass index. The first study was conducted on patients with dyslipidemia who received 300 mL of RP jelly for 8 weeks and found no significant change in BMI between groups or within groups. By contrast, another study in this review reported weight gain and changes in BMI after consuming 30g of yellow passion peel flour for 2 months in individuals with diabetes mellitus. In a study of mice with metabolic disorders, passion fruit peel flour reduced body weight gain compared with the control group [32].

4.6. Effect of Indian gooseberry on blood glucose

There were 3 studies: one investigated the effect on fasting blood glucose and 2HPP, while the others examined the effect on HbA1c levels. One study examined 150 hypertensive adults with or without type 2 DM; the other two identified the effects on diabetic individuals. The first study described the effects of E. officinalis at doses of 1, 2, and 3 grams for 21 weeks, while the second and third studies examined 500 mg of Phyllanthus emblica capsule twice daily and 250 or 500 mg twice daily for 12 weeks. The first article demonstrated significant effects on fasting and postprandial glucose levels. Regarding the second and third articles, the second showed no effect on HbA1C; however, the third demonstrated a beneficial effect on HbA1C levels. Elobeid and Ahmed (2015) reported that 200–400 mg/kg of amla in diabetic rats significantly reduced blood glucose, with effects more pronounced than those of metformin [39]. After 6 weeks of taking 5ml/kg of Indian gooseberry fruit juice, blood glucose levels reduced significantly in high-fat diet-induced obesity [40].

4.7. Effect of Indian gooseberry on lipid profile

All 3 articles from this review demonstrated the effect of Indian gooseberry on blood lipid levels. In the study of normal and diabetic adults, total cholesterol, triglycerides, lipids, and LDL-C decreased significantly, and HDL-C levels increased significantly. In a study of the effect of amla on 80 diabetic patients, total cholesterol, triglycerides, LDL-C, and VLDL-C showed significant decreases, whereas HDL-C showed a significant increase when comparing the inter- and intra group comparisons. The last study showed no change in lipid profiles. Elobeid et al. (2013) and Elobeid and Ahmed (2015) demonstrated the decreasing action of amla on total cholesterol and triglycerides in diabetic rats [39, 41]. In a study, when comparing two doses of amla fruit (10 and 20 mg/kg), the 20 mg/kg dose showed a significant reduction in total cholesterol level, while the 10 mg/kg dose showed no significant change [42]. S. Patil, D. Desai, and R. M. (2015) described the effects of amla on hyperlipidemic rats for 21 days, showing adverse effects on HDL and LDL levels and beneficial effects on triglycerides and VLDL levels [43].

4.8. Effect of Indian gooseberry on blood pressure

Only one out of three articles mentioned the effect of amla on blood pressure. The study population had hypertension, and the participants who had diabetes mellitus were mentioned to be under control with treatment. After comparing case and control groups, both systolic and diastolic blood pressures showed no significant changes. Even though systolic blood pressure significantly increased in high fructose-fed rats in the study (Kim et al., 2010), it also described that the effect of amla extract controlled the high blood pressure well [42].

4.9. Effect of Indian gooseberry on body weight

None of the three articles included in this review reported the effect of amla fruit on body weight. Elobeid et al. (2013); Elobeid and Ahmed (2015) mentioned that consuming 200 – 400 mg/kg of E. officinalis in diabetic rats significantly increased body weight [39, 41]. When the ethanolic extract of E. officinalis was given to hyperlipidemic rats, the weight gain percentage was significantly lower in the study [43].

4.10. Effect of mango on blood glucose

A total of 4 articles regarding the effect of mango were contained in this review. The minimal duration of the study was 6 weeks, and the maximal duration was included in the retrospective survey, from 2001 to 2008. Three articles studied overweight and obese individuals, while the retrospective survey presented the data according to the NHANES survey. The amount of mango consumption differed from one study to another. The first study mentioned that the amount of fresh mango was 100 kcal/166 grams, the second was 10 grams of ground freeze-dried mango powder one time per day, and the last one described the amount as 400 grams of mango. Among them, two papers demonstrated that mango consumption was related to reducing blood glucose levels and significantly affecting insulin levels. In comparison, the results of two other papers disagreed with the fact of reducing blood glucose by mango intake. HbA1C level was shown as no change in all papers. Apontes et al. (2014) mentioned that Mangiferin decreased the fasting plasma glucose and insulin resistance in high-fat diet mice [44]. In a study of the effect of freeze dried mango, blood glucose levels decreased significantly in high-fat diet-induced mice, even though insulin level was not changed significantly [45].

4.11. Effect of mango on lipid profile

Only one of the mango studies from this review mentioned that triglycerides and LDL-C levels were significantly reduced because of mango. In the retrospective survey, it was found that mango consumers had associated with increased triglycerides and decreased HDL-C levels, which are the risks for metabolic syndrome. The other two studies described that mango consumption did not affect lipid profile. Lucas et al. (2011) demonstrated that mango significantly decreased total cholesterol after 8 weeks of intervention [45]. A 12-week study of 31 overweight female volunteers found favourable lipid profile results that significantly reduced total cholesterol, triglycerides, and LDL-C and increased HDL-C [46].

4.12. Effect of mango on blood pressure

Of four studies, three showed that mango consumption had no significant effect on blood pressure. In a study of 12 lean and 9 obese individuals, systolic blood pressure was reduced significantly in lean individuals, while no effect on obese individuals could be seen. In the other study of 8 males and 19 females, overweight and obese individuals, after consumption of mango pulp for 8 weeks, systolic blood pressure was also found to be reduced [47].

4.13. Effect of mango on body weight

The first study in this review showed that mango consumption was associated with increased body weight and BMI. The second study mentioned that although mango consumption did not affect body weight, BMI, and fat mass, hip circumference was significantly reduced in males. In the retrospective survey, mango consumers were associated with reduced body weight. The last

study described that a mango diet did not affect body weight and BMI. In a study about Mangiferin, high-fat diet-induced body weight gain was reduced depending on the amount given [44]. Even though BMI was reduced during the intervention, a significant change was not found in the mango study on obese female individuals [46].

5. CONCLUSION

Yellow and purple passion fruits influence blood glucose levels in a dose- and duration-dependent manner. The fast action of passion fruit juice on blood glucose levels was seen in 30 minutes, while a long-term effective decrease in blood glucose levels was seen in the consumption of 30 grams of passion fruit peel flour in 30 days. 220 mg of purple passion fruit capsule had a beneficial effect on systolic blood pressure in 16 weeks. Favourable results of lipid profiles could be seen in 1 month after taking 300 ml of juice or 30 grams of peel flour. Consumption of passion fruit did not affect body weight. At least 500 mg of E. officinalis showed an influence on blood glucose levels in 12 weeks, while 1 gram of E. officinalis affected blood glucose levels in 21 days. Blood lipid profile levels were also reduced at 500 mg for 12 weeks and 1 gram for 21 days. E. officinalis showed no effect on blood pressure level and body weight. Blood glucose level was decreased by 100 kcal (166 grams) of fresh mango or 10 grams of freeze-dried mango powder in 12 weeks. Triglycerides and LDL-C could be reduced by eating 100 kcal of fresh mango. Consumption of 400 grams of mango for 6 weeks had a systolic blood pressure-reducing effect. Body weight could be increased by the consumption of 100 kcal of fresh mango for 12 weeks. Consumption of these fruits, depending on regional availability, is encouraged as part of dietary management in patients with metabolic syndrome. Although those three fruits showed less effectiveness for central obesity, their use for the other three metabolic syndrome factors may have beneficial effects by reducing elevated laboratory parameters. Even in areas without access to passion fruit peel flour or capsules, people can consume fresh passion fruit or juice to reduce the risk of metabolic syndrome and use it as a dietary intervention, which is also important in a multidisciplinary approach to treatment. In Asian countries, where amla and mango are widely available, eating them can benefit many. Although those fruits can be effective in patients with metabolic syndrome, overeating is not recommended because a healthy and balanced diet is needed for our body's metabolism.

6. LIMITATIONS AND IMPLICATIONS

All the papers from this review were downloaded from free sites. Therefore, this review will not cover many influential and precise papers from different regions. Only English-language papers were used because of the language translation difficulty. Amounts of fruits and durations of interventions also differed from one to another, and the underlying medical conditions and ages of participants were not the same. Therefore, comparing the data might be different depending on the amount of fruit and participants, as well as the duration of the study.

Although there were many systematic reviews regarding the intervention on animals, there were limited reviews regarding the intervention on humans. The effects of three fruits on the features of metabolic syndrome were discussed in this review, so searching for the three fruits on every one of the features of metabolic syndrome will be more accessible by reading this review. Amounts and durations of fruit consumption that give benefits were reviewed; therefore, it will be helpful for those people with metabolic syndrome to know the right amount to consume fruit. This review will also give more benefits in producing the proper dosage medications that can demonstrate the effectiveness of these fruits on the features of metabolic syndrome.

REFERENCES

[1] NHLBI (2022) What Is Metabolic Syndrome. Available at: https://www.nhlbi.nih.gov/health/metabolic-syndrome(Accessed:23November2022).

[2] Saklayen, M.G. (2018) 'The Global Epidemic of the Metabolic Syndrome', *Current HypertensionReports*,20(12).Availableat:https://doi.org/10.1007/s11906-018-0812-z.

[3] JOHNSHOPKINS(2022)*MetabolicSyndrome.* Availableat:https://www.hopkinsmedicine.org/health/conditions-and-diseases/metabolic-syndrome(Accessed: 23 November 2022).

[4] Manaf,M.R.A.*etal.*(2021)'Prevalenceofmetabolicsyndromeanditsassociatedrisk factors among staffs in a Malaysian public university', *Scientific Reports*, 11(1). Available at: https://doi.org/10.1038/s41598-021-87248-1.

[5] Liang, X.P. *et al.* (2021) 'Prevalence of metabolic syndrome in the United States National Health and Nutrition ExaminationSurvey (nhanes) 2011–2018', *European Heart Journal*, 42. Available at: https://academic.oup.com/eurheartj/article/42/Supplement_1/ehab724.2420/6394450

[6] Noubiap, J.J. *et al.* (2022) 'Global, regional, and country estimates of metabolic syndrome burdeninchildrenandadolescentsin2020:a systematic reviewandmodelling analysis'. *The Lancet Child and Adolescent Health,* 6(3), pp. 158-170. Available at: https://doi.org/10.1016/s2352-4642(21)00374-6.

[7] Kim, J.Y., Kim, S.H. and Cho, Y.J. (2013) 'Socioeconomic status in association with metabolic syndrome and coronary heart disease risk', *Korean Journal of Family Medicine*,34(2),pp.131–138.Availableat:https://doi.org/10.4082/kjfm.2013.34.2.131.

[8] Stephens,C.R.*etal.*(2020)'TheImpactofEducationandAgeonMetabolicDisorders', *Frontiers in Public Health*, 8(180). Available at: https://doi.org/10.3389/fpubh.2020.00180.

[9] Lorzadeh, E. *et al.* (2020) 'Dietary Habits and their Association with Metabolic SyndromeinasampleofIranianadults:Apopulation-basedstudy',*FoodScienceand Nutrition*, 8(11), pp. 6217–6225. Available at: https://doi.org/10.1002/fsn3.1918.

[10] Atasi,M.*etal.*(2022)'DietaryPatternsandTheirAssociationwithMetabolic Syndrome andTheirComponentsinMiddle-ClassAdultsfromDamascus,Syria:ACross-Sectional Study', *Hindawi - Journal of Nutrition and Metabolism*, 2022. Available at: https://doi.org/10.1155/2022/5621701.

[11] Fallah,Z.*etal.*(2022)'Theassociationbetweendietaryhabitsandmetabolicsyndrome: findings from the Shahedieh-cohort study', *BMC Nutrition*, 8(117). Available at: https://doi.org/10.1186/s40795-022-00609-5.

[12] Shin,M.-H.*etal.*(2009)'Dietaryintake,eatinghabits,andmetabolic syndrome in Korean men', *Journal of the American Dietetic Association*, 109(4), pp. 633–40. Available at: https://doi.org/10.1016/j.jada.2008.12.015.

[13] Cornara,L.*etal.*(2020)'EmergingExoticFruits:NewFunctionalFoodsinthe European Market', *eFood*, 1(2), pp. 126–139. Available at: https://doi.org/10.2991/efood.k.200406.001.

[14] Zheng, J. *et al.* (2017) 'Effects and mechanisms of fruit and vegetable juices on cardiovasculardiseases',*InternationalJournalofMolecularSciences*,18(3).Available at: https://doi.org/10.3390/ijms18030555.

[15] Tian, Y. *et al.* (2017) 'Fruit and vegetable consumption and risk of the metabolic syndrome:Ameta-analysis',*PublicHealthNutrition*,21(4),pp.756–765.Availableat: https://doi.org/10.1017/S136898001700310X.[15].

[16] Prasertsri, P. *et al.* (2019) 'Acute effects of passion fruit juice supplementation on cardiacautonomicfunctionandbloodglucoseinhealthysubjects',*PreventiveNutrition and Food Science*, 24(3), pp. 245–253. Available at: https://doi.org/10.3746/pnf.2019.24.3.245.

[17] Akhtar, M.S. *et al.* (2011) 'Effect of amla fruit (Emblica officinalis Gaertn.) on blood glucoseandlipidprofileofnormalsubjectsandtype2diabeticpatients',*International Journal of Food Sciences and Nutrition*, 62(6), pp. 609–616. Available at: https://doi.org/10.3109/09637486.2011.560565.

[18] Khongrum, J. *et al.* (2022) 'Antidyslipidemic, Antioxidant, and Anti-inflammatory EffectsofJellyDrinkContainingPolyphenol-RichRoselleCalycesExtractandPassion Fruit Juice with Pulp in Adults with Dyslipidemia: A Randomized, Double-Blind, Placebo-Controlled Trial', *Oxidative Medicine and Cellular Longevity* [Preprint]. Available at: https://doi.org/10.1155/2022/4631983.

[19] Shanmugarajan,D.*etal.*(2021)'AntihypertensiveandpleiotropiceffectsofPhyllanthus emblica extract as

an add-on therapy in patients with essential hypertension—A randomized double-blind placebo-controlled trial', *Phytotherapy Research*, 35(6), pp. 3275–3285. Available at: https://doi.org/10.1002/ptr.7043.

[20] de Queiroz, M. do S.R. *et al.* (2012) 'Effect of the yellow passion fruit peel flour (Passiflora edulis f. flavicarpa deg.) in insulin sensitivity in type 2 diabetes mellitus patients.',*Nutritionjournal*,11.Availableat:https://doi.org/10.1186/1475-2891-11-89.[

[21] Rosas,M.*etal.*(2022)'Effectsoffreshmangoconsumptiononcardiometabolicrisk factors in overweight and obese adults', *Nutrition, Metabolism and Cardiovascular Diseases*, 32(2), pp. 494–503. Available at: https://doi.org/10.1016/j.numecd.2021.11.001.

[22] Usharani, P., Fatima, N. and Muralidhar, N. (2013) 'Effects of Phyllanthus emblica extractonendothelialdysfunctionandbiomarkersofoxidativestressinpatientswith type 2 diabetes mellitus: A randomized, double-blind, controlled study', *Diabetes, Metabolic Syndrome andObesity:TargetsandTherapy*,6,pp.275–284.Available at: https://doi.org/10.2147/DMSO.S46341.

[23] Raju, N.N. *et al.* (2013) 'Efficacy of Purple Passion Fruit Peel Extract in Lowering CardiovascularRiskFactorsinType2DiabeticSubjects', *JournalofEvidence-Based Complementary and Alternative Medicine*, 18(3), pp. 183–190. Available at: https://doi.org/10.1177/2156587213475627.

[24] Marques, S. do S.F. *et al.* (2016) 'Evaluation of the effects of passion fruit peel flour (Passifloraedulisfo.flavicarpa)onmetabolicchangesinHIVpatientswithlipodystrophy syndrome secondary to antiretroviral therapy', *Revista Brasileira de Farmacognosia*, 26(4), pp. 420–426. Available at: https://doi.org/10.1016/j.bjp.2016.03.002.

[25] Evans,S.F.*etal.*(2014)'Mangosupplementationimprovesbloodglucoseinobese individuals', *Nutrition and Metabolic Insights*, 7, pp. 77–84. Available at: https://doi.org/10.4137/NMi.s17028.

[26] Neil, O., Nicklas, C.E. and Fulgoni, T.A. (2013) 'Mangoes are Associated with Better NutrientIntake,DietQuality,andLevelsofSomeCardiovascularRiskFactors:National Health and Nutrition Examination Survey', *Journal of Nutrition and Food Sciences*, 3(2), p. 185. Available at: https://doi.org/10.4172/2155.

[27] Fang, C. *et al.* (2018) 'Obesity-Associated Diseases Biomarkers Are Differently Modulated in Lean and Obese Individuals and Inversely Correlated to Plasma PolyphenolicMetabolitesAfter6WeeksofMango(MangiferaindicaL.)Consumption', *Molecular Nutrition and Food Research*, 62(14). Available at: https://doi.org/10.1002/mnfr.201800129.

[28] de Araújo, M.F.M. *etal.* (2017) 'Theeffectofflour fromthe rind of the yellow passion fruitonglycemic controlofpeoplewithdiabetesmellitustype 2:Arandomizedclinical trial', *Journal of Diabetes and Metabolic Disorders*, 16(18). Available at: https://doi.org/10.1186/s40200-017-0300-z.

[29] Sousa, D.F. *et al.* (2020) 'Effectiveness of Passion Fruit Peel Flour (Passiflora edulis L.) versusTurmericFlour(CurcumalongaL.)onGlycemicControl:SystematicReviewand Meta-Analysis', *Current Diabetes Reviews,* 16(5), pp. 450-456. Available at: https://doi.org/10.2174/1573399815666191026125941.

[30] Setayesh, L. *et al.* (2023) 'The impact of Emblica Officinalis (Amla) on lipid profile, glucose, and C-reactive protein: A systematic review and meta-analysis of randomized controlledtrials',*Diabetes&MetabolicSyndrome:ClinicalResearch&Reviews*,17(3). Available at: https://doi.org/10.1016/j.dsx.2023.102729.

[31] T. Acampado, L.R. *et al.* (2023) 'The Efficacy and Safety of Emblica officinalis AqueousFruitExtractamongAdultPatientswithDyslipidemia:ASystematicReview and Meta-analysis', *Acta Medica Philippina*, 57(5), pp. 90–95. Available at: https://doi.org/10.47895/amp.vi0.5047.

[32] De Faveri, A. *et al.* (2020) 'Effects of passion fruit peel flour (Passiflora edulis f. flavicarpa O. Deg.) in cafeteria diet-induced metabolic disorders', *Journal of Ethnopharmacology*,250.Availableat:https://doi.org/10.1016/j.jep.2019.112482.

[33] Goss,M.J.*etal.*(2018)'PeelflourofPassifloraedulisVar.Flavicarpasupplementation prevents the insulin resistance and hepatic steatosis induced by low-fructose-diet in young rats', *Biomedicine and Pharmacotherapy*, 102, pp. 848–854. Available at: https://doi.org/10.1016/j.biopha.2018.03.137.

[34] Barbalho,S.M.*etal.*(2012)'Yellowpassionfruitrind(Passiflora edulis):anindustrial waste oranadjuvantinthe maintenance of glycemia andpreventionof dyslipidemia?', *Journal of Diabetes Research and Clinical Metabolism* [Preprint]. Available at: https://doi.org/10.7243/2050-0866-1-5.

[35] Barbalho,S.M.*etal.*(2011)'Effectsofpassifloraedulisonthemetabolicprofileof diabetic wistar rat offspring', *Journal of Medicinal Food*, 14(12), pp. 1490–1495. Available at: https://doi.org/10.1089/jmf.2010.0318.

[36] Konta,E.M.*etal.*(2014)'Evaluationoftheantihypertensivepropertiesofyellowpassion fruit pulp (passiflora edulis sims f. flavicarpa deg.) in spontaneously hypertensive rats',

[37] *PhytotherapyResearch*,28(1),pp.28–32.Available at:https://doi.org/10.1002/ptr.4949

[38] Zibadi, S. *etal.*(2007) 'Oraladministration of purple passion fruitpeelextractattenuates blood pressure in female spontaneously hypertensive rats and humans', *Nutrition Research*,27(7),pp.408–416.Available at:https://doi.org/10.1016/j.nutres.2007.05.004.

[39] Lewis,B.J.*etal.*(2013)'Antihypertensiveeffectofpassionfruitpeelextractanditsmajor bioactive components following acute supplementation in spontaneously hypertensive rats', *Journal of Nutritional Biochemistry*, 24(7), pp. 1359–1366. Available at: https://doi.org/10.1016/j.jnutbio.2012.11.003.

[40] Elobeid, M.A. and Ahmed, E.A. (2015) 'Antidiabetic efficacy of aqueous fruit extract of amla(Emblicaofficinalis,gaertn)instreptozotocin-induceddiabetesmellitusinmalerats', *Tropical Journal of Pharmaceutical Research*, 14(5), pp. 801–806. Available at: https://doi.org/10.4314/tjpr.v14i5.9.

[41] Juntapremjit,S.andJanthakhin,Y.(2021)'EffectsofIndianGooseberryFruitonAnxiety- Related Behaviors and Memory Performance in High-fat Diet-induced Obese Mice', *Chiang Mai University Journal of Natural Sciences*, 20(4), pp. 1–11. Available at: https://doi.org/10.12982/CMUJNS.2021.094.

[42] Elobeid, M.A. *et al.* (2013) 'Antihyperglycemic Activity and Body weight effects of Extracts of Emblica officianalis, Tamarix nilotica and Cinnamon Plant in Diabetic Male Rats', *office@multidisciplinarywulfenia.org*, 20(11), pp. 18–31.

[43] Kim,H.Y. *etal.*(2010) 'The protectiverole of amla(Emblica officinalisGaertn.) against

[44] fructose-inducedmetabolicsyndromeinaratmodel',*BritishJournalofNutrition*,103(4),

[45] pp.502–512. Availableat:https://doi.org/10.1017/S0007114509991978.

[46] S. Patil, B., D. Desai, S. and R M, P. (2015) 'Effect of ethanolic extract of Emblica officinalis (Amla) on pathophysiology of liver in hyperlipidemic albino Wister rats', *International Journal of Pharma and Bio Sciences*, 6(3), p. B 362-B 372. Available at: www.ijpbs.net.

[47] Apontes, P. *et al.* (2014) 'Mangiferin stimulates carbohydrate oxidation and protects against metabolic disorders induced by high-fat diets', *Diabetes*, 63(11), pp. 3626–3636. Available at: https://doi.org/10.2337/db14-0006.

[48] Lucas, E.A. *et al.* (2011) 'Mango modulates body fat and plasma glucose and lipids in mice feda high-fatdiet',*BritishJournalof Nutrition*,106(10),pp.1495–1505.Available at: https://doi.org/10.1017/S0007114511002066.

[49] Arshad,F.*etal.*(2021)'TherapeuticRoleofMangoPeelsinManagementofDyslipidemia andOxidativeStressinObeseFemales',*BioMedResearchInternational*,2021.Available at: https://doi.org/10.1155/2021/3094571.

[50] Keathley, J. *et al.* (2022) 'Changes in systolic blood pressure, postprandial glucose, and gut microbial composition following mango consumption in individuals with overweight and obesity', *Applied Physiology, Nutrition and Metabolism*, 47(5), pp. 565–574. Available at: https://doi.org/10.1139/apnm-2021-0637.

AUTHOR

The author is a medical doctor with a degree of M.B:B.S and holds the master degree in Nutrition and Dietetics.