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2021

EFFECTS OF FRUIT AND VEGETABLE INTAKE ON DIRECT AND INDIRECT HEALTH OUTCOMES

Background paper for the FAO/WHO international workshop on fruits and vegetables 2020



The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry, no matter how small, should be recorded to ensure the integrity of the financial statements. This includes not only sales and purchases but also expenses, income, and transfers between accounts.

The second part of the document provides a detailed breakdown of the accounting cycle. It outlines the ten steps involved in the process, from identifying the accounting entity to preparing financial statements. Each step is explained in detail, with examples provided to illustrate the concepts.

The third part of the document focuses on the classification of accounts. It discusses the different types of accounts used in accounting, such as assets, liabilities, equity, revenue, and expense accounts. It explains how these accounts are organized into a chart of accounts and how they are used to record transactions.

The fourth part of the document covers the journalizing process. It describes how transactions are recorded in the journal, including the use of debits and credits. It provides examples of journal entries for various types of transactions, such as sales, purchases, and adjustments.

The fifth part of the document discusses the posting process. It explains how the journal entries are transferred to the ledger accounts. It provides examples of ledger entries and shows how the debits and credits are balanced.

The sixth part of the document covers the preparation of financial statements. It discusses the different types of financial statements, such as the balance sheet, income statement, and statement of cash flows. It provides examples of how these statements are prepared and how they are used to analyze the financial performance of a business.

The seventh part of the document discusses the closing process. It explains how the temporary accounts (revenue, expense, and dividend) are closed to the permanent accounts (assets, liabilities, and equity). It provides examples of closing entries and shows how the accounts are balanced.

The eighth part of the document covers the reversing entries. It discusses how these entries are used to reverse the effects of certain adjusting entries. It provides examples of reversing entries and shows how they are recorded.

The ninth part of the document discusses the importance of internal controls. It explains how internal controls are used to prevent and detect errors and fraud. It provides examples of internal controls and shows how they are implemented.

The tenth part of the document covers the final steps of the accounting cycle. It discusses the preparation of the financial statements and the closing of the books. It provides examples of the final entries and shows how the accounts are balanced.

EFFECTS OF FRUIT AND VEGETABLE INTAKE ON DIRECT AND INDIRECT HEALTH OUTCOMES

Background paper for the FAO/WHO international workshop on fruits and vegetables 2020

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ABSTRACT

This background paper summarizes the evidence on the effects of fruits and vegetables intakes on direct and indirect health outcomes. For direct health outcomes, we have primarily considered premature mortality and non-communicable disease occurrence. For indirect health outcomes, we have briefly considered planetary health and reducing inequities. Two existing low-risk-of-bias systematic reviews identified broad and significant benefits from fruits and vegetables intakes on premature mortality, coronary heart disease, and type 2 diabetes incidence. These direct health effects observed due to fruits and vegetables intakes are considerable, and may be due to their constituents, such as dietary fibre and micronutrients, and their low energy density and high satiety relative to other foods that may also contain added sugars, sodium, and saturated fats. Modelling and observational research studies have reported benefits to sustainability outcomes and a reduction of inequities in food systems with the production of fruits and vegetables grown within agroecological systems and distributed through short supply chains. Such systems require protection from large-scale monocropping and industrial methods of food production and supply. Finally, we have considered fruit and vegetable processing and preparation methods given the considerable health consequences of changes to the food supply towards ultra-processed products. This background paper concludes with a summary of findings.



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DECLARATION OF INTERESTS

The authors declare no conflict of interest.

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ABBREVIATIONS AND ACRONYMS

CHD	coronary heart disease
CVD	cardiovascular disease
FAO	Food and Agriculture Organization of the United Nations
GRADE	Grading of Recommendations Assessment, Development and Evaluation framework
NUGAG	WHO Nutrition Guidance Expert Advisory Group subgroup on Diet and Health
F&V	fruits and vegetables
WHO	World Health Organization
GRC	WHO Guideline Review Committee

1. INTRODUCTION

The regular consumption of fruits and vegetables (F&V) is of considerable benefit to human health (Ashfin *et al.*, 2019). Previous expert consultations and workshops convened by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) in the early 2000s resulted in global recommendations for a minimum daily intake of 400 g of fruits and vegetables, excluding starchy tubers (WHO, 2003, 2005). Emerging evidence has accumulated since the 2004 WHO/FAO recommendations, providing greater confidence in the direction and size of health effects from F&V intakes, as well as in the mechanisms behind their action.

The purpose of this paper is to summarize the existing evidence on the effects of F&V intakes on direct and indirect health outcomes. For direct health outcomes, this background paper took advantage of recent work by the WHO Nutrition Guidance Expert Advisory Group (NUGAG) subgroup on Diet and Health. The body of evidence considered by NUGAG included the risk assessment and use of data from a systematic review and meta-analysis on the effects of F&V intakes on premature mortality, cardiovascular disease, and total cancer (Aune *et al.*, 2017), and a series of systematic reviews and meta-analyses on carbohydrate quality and human health that included analyses on F&V fibre (Reynolds *et al.*, 2019). For indirect health outcomes, consequences of F&V consumption and production have

been considered against planetary health outcomes and inequities within the food system. Information on these topics is drawn from existing modelling or observational studies.

This paper serves as one of the background documents for the 2020 FAO/WHO International Workshop on Fruits and Vegetables.

2. METHODS

WHO, through the work of NUGAG, is currently updating the recommendations for carbohydrate intakes, which includes comments on F&V consumption. This work followed the procedures required by the WHO Guideline Review Committee (GRC) to issue recommendations for public health. The GRC was established by the Director General to ensure that WHO guidelines are of a high methodological quality and are developed through a transparent, evidence-based decision-making process. As NUGAG work would not be completed within the timeline for the preparation and convening of the 2020 FAO/WHO International Workshop on Fruits and Vegetables, this background paper summarizes the evidence assessed by NUGAG that is publicly available. This includes: a systematic review and meta-analysis on the effects of F&V intakes on premature mortality, cardiovascular disease, and total cancer (Aune *et al.*, 2017), which was assessed

by NUGAG and rated as a high quality low-risk-of-bias systematic review and meta-analysis, and a series of systematic reviews and meta-analyses on carbohydrate quality and human health that included analyses on F&V fibre (Reynolds *et al.*, 2019), which was commissioned by NUGAG following the WHO Handbook for Guideline Development (WHO, 2014).

Health outcomes regarded as critical and important by the WHO NUGAG subgroup on Diet and Health are: all-cause mortality; incidence and mortality from coronary heart disease (CHD), stroke, and cardiovascular disease (CVD); incidence of type 2 diabetes; and incidence of colorectal, breast, endometrial, esophageal, and prostate cancers. The selection of the critical and important outcomes, as well as the assessment of quality and risk of bias of the body of evidence by NUGAG,

followed the procedures described in the WHO Handbook for Guideline Development. The selection of such outcomes does not mean that other outcomes are not important or critical, but that among the several potentially related outcomes to be assessed, these were considered as of highest priority for public health.

The summary of the published methods and results of the two systematic reviews and meta-analysis prepared for this background paper includes: the number of records identified, included and excluded by each review; summary relative risks (RR) and their respective 95 percent confidence intervals (95%CI) for each outcome; and dose-response findings. The full description of methods of these reviews, and the details of each study included or



excluded, are available in the papers and respective supplementary materials (Aune *et al.*, 2019; Reynolds *et al.*, 2019).

Two potential indirect effects of F&V intakes on health are highlighted as a narrative review. These are the effects of consumption, supply and production of F&V on planetary health and social determinants of health. Existing modelling and observational studies on the impacts of F&V intake on shifts in food production were used to comment on environmental changes clearly linked with human health. Reviews and reports on inequities within the food system and on social determinants of health served the analysis on how F&V consumption, supply and production links to health.

Papers reporting or reviewing mechanistic studies are also included to provide explanations on the plausibility of findings on direct and indirect effects of F&V intakes on health. In addition, studies on other factors that may exacerbate, attenuate, eliminate or reverse the direct and indirect effects of F&V intakes are presented and discussed, including: ways of production, storage and processing, and preparation for consumption.

Finally, a proposal of recommendation on the intake of F&V is presented for consideration of the participants of the 2020 FAO/WHO International Workshop on Fruits and Vegetables.

3. RESULTS

Effects of fruits and vegetables intake on direct health: premature mortality and non-communicable disease occurrence

Aune *et al.* (2017) was identified as a comprehensive and low-risk-of-bias systematic review of prospective observational studies considering F&V intakes on premature mortality, fatal and non-fatal cancer, fatal and non-fatal cardiovascular disease (CVD), fatal and non-fatal coronary heart disease, and fatal and non-fatal stroke. This review used extreme quantile and dose response analysis. Quality of the evidence from this review was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework (Guyatt *et al.*, 2008), and revised if required after discussion with the WHO Nutrition Guidance Expert Advisory Group's subgroup on Diet and Health.

These authors initially considered 49 772 records, out of which 142 publications (featuring the results of 95 cohort studies) were included in the review (Aune *et al.*, 2017). Findings from this review are shown in Table 1.

An inverse dose response gradient was observed between F&V intakes and all outcomes assessed, with death and disease occurrence reducing as F&V intakes increased. When compared with the lowest consumers, reductions in all-cause mortality and all disease outcomes were observed from a 50 g increase per day. When compared with a global average intake value of 210 g/adult/day, risk reduction in all disease outcomes was observed starting with

F&V intakes from 330 g/adult/day. Greater risk reductions were apparent for most outcomes up to 800 g/adult/day, with no detrimental effects identified with intakes above 800 g/adult/day. Although benefits were observed with any increase, results indicate the risk reduction is steepest up to 400 g/adult/day, suggesting a target of at least 400 g/adult/day to achieve relevant health gains.

TABLE 1: Fruits and vegetables intakes and critical or important health outcomes

OUTCOME	N STUDIES	N CASES	N PEOPLE	AVERAGE YEARS FOLLOWED	RELATIVE RISK (95%CI)	ABSOLUTE RISK (95%CI)	DOSE RESPONSE RELATIONSHIP	GRADE CERTAINTY
ALL-CAUSE MORTALITY	22	87 574	1 035 556	11.3	0.82 (0.79 to 0.86)	15 fewer per 1 000 (from 12 fewer to 18 fewer)	Yes	Low
ALL-CANCER (FATAL AND NON FATAL)	13	904 300	904 300	9.5	0.93 (0.87 to 0.98)	4 fewer per 1 000 (from 1 fewer to 8 fewer)	Yes	Moderate
CVD (FATAL AND NON FATAL)	16	27 842	963 240	11.2	0.84 (0.79 to 0.90)	5 fewer per 1 000 (from 3 fewer to 6 fewer)	Yes	Low
CHD (FATAL AND NON FATAL)	16	18 516	792 197	10.7	0.87 (0.83 to 0.91)	3 fewer per 1 000 (from 2 fewer to 4 fewer)	Yes	Moderate
STROKE (FATAL AND NON FATAL)	8	10 560	226 910	10.1	0.79 (0.71 to 0.88)	10 fewer per 1 000 (from 6 fewer to 13 fewer)	Yes	Moderate

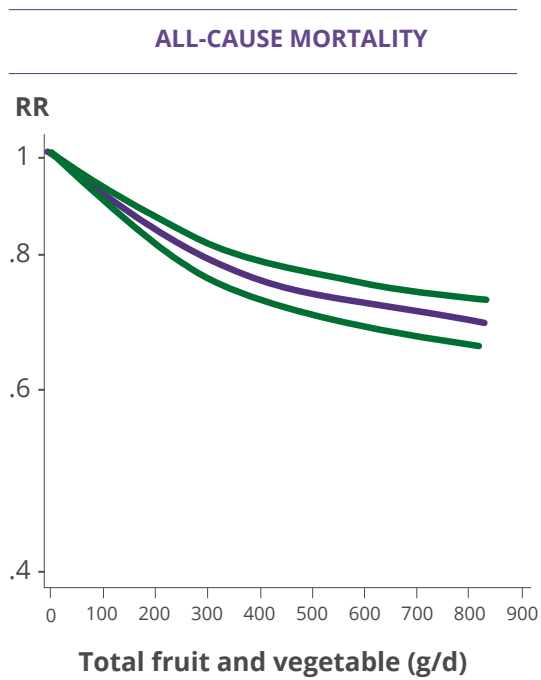
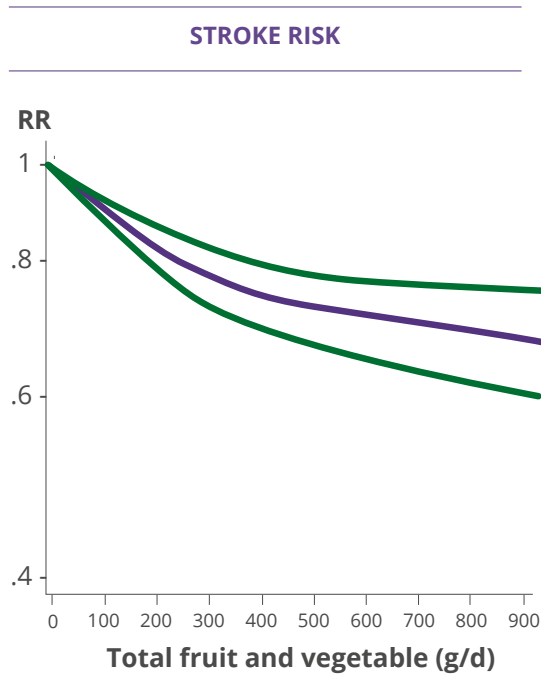
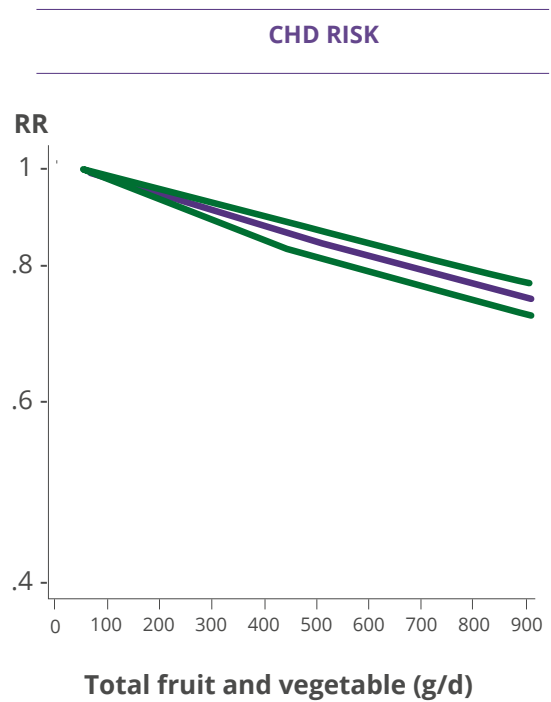


FIGURE 1: Dose response associations for fruits and vegetables intake and all-cause mortality, CHD risk, and stroke risk. Image from Aune *et al.* (2017)



Best fitting cubic spline
95% confidence interval

In a systematic review commissioned by the NUGAG, Reynolds *et al.* (2019) considered vegetable or fruit fibre intakes and all-cause mortality; incidence and mortality of coronary heart disease (CHD), stroke, and cardiovascular disease (CVD); incidence of type 2 diabetes; and incidence of colorectal, breast, endometrial, esophageal, and prostate cancers. This systematic review also used extreme quantile and dose response analyses, and GRADE to assess the quality of evidence.

Reynolds *et al.* (2019) initially considered 22 356 titles of which 243 studies were included in the review. Thirty-nine prospective observational studies reported on either vegetable or fruit fibre intakes. The findings from this review on vegetable fibre are shown in Table 2.



TABLE 2: Vegetable fibre intake and critical or important health outcomes

OUTCOME	N STUDIES	N CASES	N PEOPLE	AVERAGE YEARS FOL-LOWED	RELATIVE RISK (95%CI)	ABSOLUTE RISK (95%CI)	DOSE RESPONSE RELATIONSHIP	GRADE CERTAINTY
ALL-CAUSE MORTALITY	2	32 069	389 731	9.0	0.96 (0.90 to 1.02)	3 fewer per 1 000 (from 2 more to 8 fewer)	No	Very low
ALL-CANCER MORTALITY	1	13 171	388 122	9.0	0.96 (0.90 to 1.01)	1 fewer per 1 000 (from 0 fewer to 3 fewer)	No	Very low
CVD MORTALITY	2	518	33 771	14.2	0.87 (0.68 to 1.11)	2 fewer per 1 000 (from 2 more to 5 fewer)	No	Very low
CVD INCIDENCE	2	1 381	42 068	6.2	0.91 (0.77 to 1.08)	3 fewer per 1 000 (from 3 more to 8 fewer)	No	Very low
CHD MORTALITY	4	3 566	418 022	11.8	0.88 (0.79 to 0.97)	1 fewer per 1 000 (from 0 fewer to 2 fewer)	Yes	Moderate
CHD INCIDENCE	4	2 367	106 426	6.0	0.83 (0.73 to 0.95)	4 fewer per 1 000 (from 1 fewer to 6 fewer)	Yes	Moderate
FATAL STROKE	1	130	31 036	14.3	0.58 (0.30 to 1.11)	2 fewer per 1 000 (from 0 fewer to 3 fewer)	No	Very low
STROKE INCIDENCE	4	8 438	202 385	14.3	0.84 (0.79 to 0.91)	7 fewer per 1 000 (from 4 fewer to 9 fewer)	Yes	Moderate
TYPE 2 DIABETES	9	29 944	350 969	12.2	0.94 (0.86 to 1.03)	5 fewer per 1 000 (from 3 more to 12 fewer)	No	Low
COLORECTAL CANCER	6	7 279	787 246	7.8	1.00 (0.92 to 1.08)	0 fewer per 1 000 (from 1 fewer to 1 more)	No	Low
BREAST CANCER	7	20 880	637 996	11.9	0.92 (0.86 to 1.00)	3 fewer per 1 000 (from 0 fewer to 5 fewer)	No	Low
ENDOMETRIAL CANCER	1	669	68 070	19.0	1.21 (0.94 to 1.55)	2 more per 1 000 (from 1 fewer to 5 more)	No	Very low
OESOPHAGEAL CANCER	1	169	34 351	14.0	0.69 (0.45 to 1.08)	2 fewer per 1 000 (from 0 fewer to 3 fewer)	No	Very low
PROSTATE CANCER	2	2 886	145 903	8.8	1.03 (0.89 to 1.19)	1 more per 1 000 (from 2 fewer to 4 more)	No	Very low

Supporting the findings of Aune *et al.* (2017), Reynolds *et al.* (2019) identified that higher intakes of vegetable fibre reduced the risk of coronary heart disease mortality and incidence, as well as stroke incidence when compared with those

consuming the lowest intakes. Findings from this review on fruit fibre are shown in Table 3.

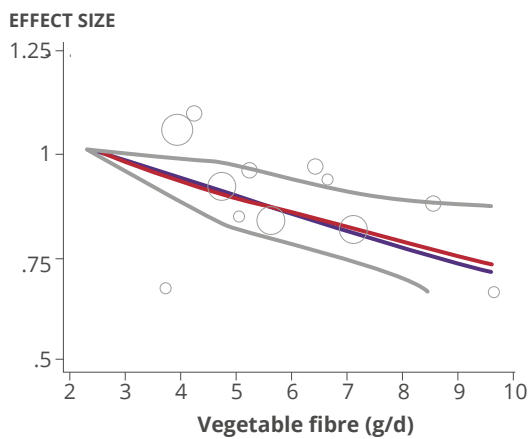
TABLE 3: Fruit fibre intake and critical or important health outcomes

OUTCOME	N STUDIES	N CASES	N PEOPLE	AVERAGE YEARS FOLLOWED	RELATIVE RISK (95%CI)	ABSOLUTE RISK (95%CI)	DOSE RESPONSE RELATIONSHIP	GRADE CERTAINTY
ALL-CAUSE MORTALITY	2	32 069	389 731	9.0	1.03 (0.99 to 1.07)	2 more per 1 000 (from 1 fewer to 6 more)	No	Very low
ALL-CANCER MORTALITY	1	13 171	388 122	9.0	0.98 (0.92 to 1.04)	1 fewer per 1 000 (from 1 more to 3 fewer)	No	Very low
CVD MORTALITY	2	518	33 771	14.2	0.74 (0.56 to 0.97)	4 fewer per 1 000 (from 0 fewer to 7 fewer)	No	Very low
CVD INCIDENCE	2	1 381	42 068	6.2	0.81 (0.68 to 0.97)	6 fewer per 1 000 (from 1 fewer to 11 fewer)	No	Very low
CHD MORTALITY	4	3 566	418 022	11.8	0.73 (0.59 to 0.91)	2 fewer per 1 000 (from 1 fewer to 3 fewer)	Yes	Very low
CHD INCIDENCE	4	2 367	106 426	6.0	0.89 (0.77 to 1.02)	2 fewer per 1 000 (from 0 fewer to 5 fewer)	No	Low
STROKE MORTALITY	1	130	31 036	14.3	0.79 (0.42 to 1.48)	1 fewer per 1 000 (from 2 fewer to 2 more)	No	Very low
STROKE INCIDENCE	4	8 438	202 385	1.3	0.85 (0.79 to 0.91)	6 fewer per 1 000 (from 4 fewer to 9 fewer)	Yes	Moderate
TYPE 2 DIABETES	8	29 782	347 541	12.3	0.89 (0.80 to 0.99)	9 fewer per 1 000 (from 1 fewer to 17 fewer)	No	Very low
COLORECTAL CANCER	6	7 279	787 246	7.8	0.90 (0.79 to 1.04)	1 fewer per 1 000 (from 0 fewer to 2 fewer)	No	Very low
BREAST CANCER	7	20 880	637 996	11.9	0.97 (0.89 to 1.05)	1 fewer per 1 000 (from 2 more to 4 fewer)	No	Low
ENDOMETRIAL CANCER	1	699	68 070	19.0	0.97 (0.76 to 1.25)	0 fewer per 1 000 (from 2 fewer to 3 more)	No	Very low
OESOPHAGEAL CANCER	1	169	34 351	14.0	0.75 (0.51 to 1.09)	1 fewer per 1 000 (from 0 fewer to 2 fewer)	No	Very low
PROSTATE CANCER	2	2 886	145 903	8.8	0.96 (0.84 to 1.09)	1 fewer per 1 000 (from 2 more to 3 fewer)	No	Very low

Higher intakes of fruit fibre reduced the risk of CVD mortality and incidence, CHD mortality, stroke incidence, and type 2 diabetes incidence when compared with the lowest intakes. Dose response relationships were observed for CHD mortality and stroke incidence. Neither vegeta-

ble nor fruit fibre intakes were associated with a reduced risk of the cancers considered (breast, colorectal, endometrial, esophageal, and prostate). Effects for the combined intake of both F&V fibre were not estimated.

VEGETABLE FIBRE AND STROKE INCIDENCE



FRUIT FIBRE AND CHD MORTALITY

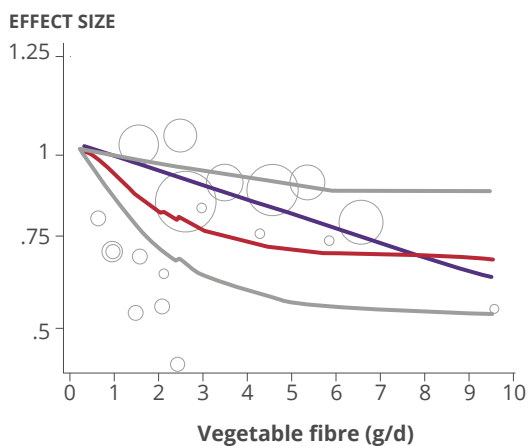
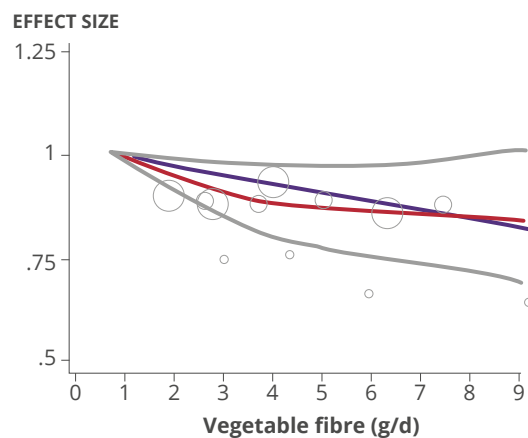


FIGURE 2: Dose response associations for vegetable fibre and stroke incidence, fruit fibre and stroke incidence, fruit fibre and CHD mortality). Image from Reynolds *et al.* (2019)

FRUIT FIBRE AND STROKE INCIDENCE



Linear Model
Spline Model

Effects of fruit and vegetable intake on indirect health: Planetary health and reducing inequities within the food system

Fruit and vegetable consumption and planetary health

The regular consumption of F&V, such as within or when moving towards a plant-based diet, also has benefits on human health in a generational context by protecting planetary health (Horton *et al.*, 2014; WHO, 2019). Current eating patterns and dietary guidelines often do not meet set environmental targets in terms of greenhouse gas emissions, freshwater use, cropland use, and fertilizer application (Springmann *et al.*, 2020). These breaches of environmental targets would be negated or ameliorated with some populations moving away from high intakes of animal source foods towards a greater diversified plant-based intake (WHO, 2019; Springmann *et al.*, 2016). When comparing between food groups, there can be considerable co-benefits to health and the environment when increasing the production and intake of F&V when compared with sugar, and with processed and unprocessed red meat (Springmann *et al.*, 2020; Clark *et al.*, 2019). It is worth noting that such modelling relates to commercial food systems in the developed context, and does not apply to animal source foods that have been hunted or foraged, obtained within indigenous or traditional food systems, or in subsistence farming.

Further in-depth information on this topic is covered by the FAO/WHO background paper on policies and programs promoting sustainable fruit and vegetable value chains, however the topic is mentioned briefly here given its obvious connection with human health.

Fruits and vegetables as promoters of equity

As another essential aspect of health, F&V consumption can also promote equity when it drives a change towards more equitable shaped food systems. Traditional wholesalers and fresh produce markets are an important entry point for many farmers to sell their goods and generate income. However, small-scale operators that produce and/or supply communities with F&V have increasingly been displaced by big operators, resulting in increased inequities and job losses that affect health (Chen, Yijie and Feifei, 2016; Marmot *et al.*, 2008; Hergenrather *et al.*, 2015). Socioeconomic position is inversely associated with health status, and such health inequities are caused by unequal distribution of power, income, goods and services, both globally and nationally according to the WHO Commission on Social Determinants of Health (Marmot *et al.*, 2008).

The transition of food systems from wholesalers and fresh produce markets to large supermarkets has resulted in greater availability and intake of ultra-processed food products (Machado *et al.*,

2018; Costa *et al.*, 2013; Luiten *et al.*, 2016; Jiménez *et al.*, 2014; Marrón-Ponce *et al.*, 2019; Machado *et al.*, 2017; Baker *et al.*, n.d.), impacting dietary intake and health status. Reshaping the food system towards greater F&V intake and protecting the role of small-scale operators could therefore be expected to generate jobs, income, and engagement in more sustainable and equitable practices (Saget, 2020). Structural and legislative change towards protecting and promoting small-scale operations will need to identify the empowerment of women in agricultural practices (Satyavathi, Bharadwaj, and Brahmanand, 2010), given their often under-recognized presence (Dixon, 1982), and the pervasiveness of gender inequities resulting in greater unfair damage to women and girls' health and survival (Marmot *et al.*, 2008).

Dominance of F&V markets by big operators is also linked to monotonization of food systems. The less diverse the foods available in a food system are, the easier it is for big operators to take over the value chain (Mooney, 2017). A potential leverage point for increased consumption of F&V to improve equity is its linkage with the seasonality and diversity of F&V where possible. Increased consumption of diversified and seasonal F&V has the potential to improve equity by increasing the role of small-scale operators to provide greater diversity of F&V beyond "economically valuable" crops.

Policies that can effectively increase the consumption of F&V are addressed by the FAO/WHO background paper on policies and programs promoting sustainable fruits and vegetables value chains, so this section serves to reinforce the need for such policies to be equity promoting, in order to optimize the health benefits that F&V intakes can provide.

4. DISCUSSION

How fruit and vegetable intake benefit human health

Numerous attributes of F&V may explain the observed improvements in critical and important health outcomes with higher intakes.

Dietary fibre

F&V are major sources of fibre in the diet. Their intake is likely to increase satiety and satiation through various mechanisms, and may support weight loss and weight maintenance. Increased dietary fibre intake also significantly reduces low-density lipoprotein (LDL) cholesterol and triglyceride levels, systolic blood pressure and fasting plasma glucose in both the prevention and management of non-communicable diseases (Reynolds *et al.*, 2019; Reynolds, Akerman and Mann, 2020). Food processing methods such as

juicing, pulverizing, mashing, and extruding can reduce the fibre content of F&V by mechanically shearing fibres into less complex structures available for digestion. This may explain in part why some fibres consumed in the form of capsules or pills may not exert beneficial effects.

Many F&V fibres can be digested by the gut microbiota, leading to greater diversity and functional capacity within the microbiome and the release of beneficial metabolites such as short-chain fatty acids (Makki *et al.*, 2018; Desai *et al.*, 2016). Such metabolites go on to affect other systems or mechanisms to reduce the incidence of certain conditions such as colorectal cancer (Reynolds *et al.*, 2019; Makki *et al.*, 2018; Schroeder *et al.*, 2018; Zou *et al.*, 2018). In addition, increased F&V fibre intakes and the production of short-chain fatty acids by the gut bacteria enhance mucus and anti-microbial peptide production, increase expression of tight junction proteins, reduce oxygen levels and promote a functional immune system (Makki *et al.*, 2018; Desai *et al.*, 2016). A healthy gut microbiota can preserve the mucus layer and can enhance protection against infections or the development of chronic inflammatory diseases (Schroeder *et al.*, 2018; Zou *et al.*, 2018; Johansson *et al.*, 2008). The healthy gut microbiota contributes to human health in many ways that are not yet fully understood, however these include: protecting against pathogens; development of the gut immune system; vitamin synthesis; the metabolism of xenobiotics; regulating the production of neurotransmitters and hormones; and

the maturation and development of the immune system (Reynolds *et al.*, 2019; Rescigno, 2014). Given that the microbiome has evolved symbiotically with its human host by utilizing dietary fibres as substrate, maintaining high fibre intakes may be essential to our ongoing development.

One further beneficial aspect of consuming higher intakes of F&V fibres is their effect on transit time through the gastrointestinal track (Kelsay, Behall and Prather, 1978). Carcinogenic compounds can be consumed or occur in the gastrointestinal track as a by-product of microbial biotransformation, such as secondary biliary acids (Ajouz, Mukherji and Shamseddine, 2014). Such compounds in high amounts can lead to oxidative/nitrosative stress and DNA damage, altering cell cycle rate and lead to cancer initiation and promotion. A faster and regular transit time, as well as the capacity of F&V fibre to bind and remove compounds directly, reduces interaction time between cell lines in the colon and potential carcinogens, thereby reducing risk of colorectal cancer (Kelsay, Behall and Prather, 1978; Ajouz, Mukherji and Shamseddine, 2014).

Micronutrients and phytochemicals

F&V are good sources of micronutrients such as vitamins and minerals, which are essential for normal physiological function. F&V also contain phytochemicals such as: carotenoids, phenolic compounds, indoles and terpenoids. Phytochemicals can have various synergetic anti-carcinogenic and

anti-inflammatory effects (Lampe, 1999; Surh, 2003; Liu, 2004; Zhu, Du and Xu, 2018; Zhang, Virgous and Si, 2019). This is a second example of why capsules or supplements of F&V extracts may not exert the expected beneficial effects observed when consumed from whole or minimally processed F&V.

Vitamins, minerals, and phytochemicals provide different protective effects at different stages of the development of diseases and/or at different structures of the cells and organs of the human body. Such effects include: protection against genetic damage, avoiding deregulations to cell cycle that could result in the initiation of a cancer; ceasing the cascade of cell damage caused by oxidative/nitrosative stress, acting as analogous of cell cycle regulators correcting cell cycle deregulation and/or impeding apoptosis suppression; promoting selective apoptosis of damaged cells to impede cancer progression; and suppressing pro-inflammatory factors that may have negative consequences on non-communicable disease occurrence (Surh, 2003; Zhu, Du and Xu, 2018).

Alongside a reduction in the risk of non-communicable diseases, intake of micro-nutrients and phytochemicals from F&V may also reduce the severity of some infectious disease through strengthening the immune system. High intakes of F&V would not protect against a virus such as COVID-19, however those consuming adequate intakes may be better equipped to recover from the illnesses that resulted from the infection when compared with those that have a diet low in F&V (Makki

et al., 2018; Choudhury *et al.*, 2020; Butler and Barrientos, 2020; Maguire, 2020). Finally, given the wide array of micronutrients and phytochemicals found in different F&V, promoting greater dietary diversity through the consumption of an array of F&V may be a means to ensure adequate intakes and access to the myriad of beneficial factors they provide.

Fruits and vegetables within the whole diet

F&V have a relatively low energy density and make a minimal contribution to sodium or saturated fatty acid intake when minimally processed. High intakes of F&V therefore provide bulk within the diet that may otherwise be provided by foods that are less satiating, have a higher energy density, or contain added sodium, sugars, and saturated fats. As an example of this, a successful family-based intervention aimed at increasing F&V intakes also reduced the consumption of foods high in sugars and fat (Epstein *et al.*, 2001). Cross-sectional studies of both children and adults have shown higher F&V intakes are associated with lower intake of saturated fatty-acids and lower energy dense diets (Ledikwe, 2006; Dennison, Rockwell and Baker, 1998; Löwik, Hulshof and Brussaard, 1999).

Emerging factors that may alter the beneficial effects of high fruit and vegetable intake

In line with global population growth, food production and transport systems have become larger and more efficient. Food processing and methods of preparation for consumption are also changing over time. How F&V are produced, processed, and prepared for consumption may augment or attenuate the expected benefits from their intake.

Fruits and vegetables production

Industrial agricultural systems focused on large-scale production of a few highly yielding plant foods, often coupled with intensive use of synthetic fertilizers and pesticides, are major drivers of agrobiodiversity erosion and agricultural monotonization (Boody and DeVore, 2006). Such production methods are systemically and recursively linked to environmental damage, including atmospheric accumulation of greenhouse gases, loss of topsoil, waste and pollution of water, eutrophication of rivers and lakes, reduction of soil fertility, loss of ecosystem pest control, extinction of species and biodiversity erosion (Imhoff *et al.*, 2004), which impact back on human health and future agricultural productivity (Davis, 2009; Benbrook, 2009; Tilman and Clark, 2014; Welch and Graham, 2005). By pursuing high yield and mass production of low-priced commodities, industrial agriculture promotes nutrient and genetic dilu-

tion of food crops and a reduction in the essential amino acids, vitamins, minerals and phytochemicals density of foods (Davis, 2009; Benbrook, 2009; Tilman and Clark, 2014; Simpson, Le Couteur and Raubenheimer, 2015). In addition, such agricultural systems pose an even greater risk to the health of rural workers and those in rural communities who are exposed to direct contact pesticides that exert known carcinogenic, teratogenic, mutagenic and/or endocrine disruption effects (Humans IWGotEoCRt, 2017). Pesticides are also a health hazard that is widespread in food systems, in F&V, other foods and agricultural commodities, ultra-processed products, in natural resources including fluvial and pluvial waters, soil and air, in agents of ecological defence and symbiotic systems such as insects, birds, fishes and other animals, as well as in human fluids including blood and breastmilk (Rojas-Squella *et al.*, 2013; Zhou *et al.*, 2012; Damgaard *et al.*, 2006; Genuis, Lame and Birkjolz, 2016; Risebrough, 1986; Hurlbert, 1975; Hallmann *et al.*, 2014; Sanchez-Bayo and Goka, 2014; Gill, Ramos-Rodriguez and Raine, 2012). Such pervasive contamination of living beings and the environment with pesticides poses considerable risk to human and planetary health.

Conversely, agricultural diversification and biodiversity conservation can contribute to ecological intensification and balance of agricultural systems (Gurr *et al.*, 2016), as well as to more nutritious foods and diets, increasing the potential of F&V to exert their beneficial effects on human health (Imhoff *et al.*, 2004; Welch

and Graham, 2005; Elinder, 2005). Human health depends on a great variety of essential nutrients available in an even greater variety of foods, hence diversified agricultural systems, such as agroecological ones, can contribute better to fulfil human needs by increasing the number of nutrients available as well as their density in plant foods, including F&V (Dainese, 2019; Kremen and Merenlender, 2018; Hunter *et al.*, 2011; Frison and Clément, 2020; Lundgren and Fausti, 2015; Tilman *et al.*, 2011; Alexandratos, 1999).

Fruits and vegetables processing

The way F&V are processed before purchase, from being frozen to ultra-processing, may also alter how their intake interacts with human health.

Storage and minimal processing

Minimally processed F&V are those that have undergone physical processing retaining most of their inherent properties, such as cutting, slicing, chopping, blanching, freezing; without the addition of sugars, fats or sodium (Monteiro *et al.*, 2019; Tomas-Barberan and Gil, 2008).

F&V continue their life cycle after being harvested. They start to lose nutrients through respiration, photo degradation, oxidation and dehydration, and their composition and spoilage may vary depending on how they are handled, stored, processed and prepared (Spikes, 1981). Recommendations to shorten F&V supply systems, besides providing the environmental and socioeconomic benefits, could also improve nutrient content in minimally processed F&V. Refrigeration and freezing can sufficiently retard the respiration and transpiration of F&V to reduce nutrient degradation, particularly hydrophilic nutrients, such as vitamin C. The contrary is



also true for other nutrients that are more thermoresistant, and some that increase in bioavailability when submitted to temperatures around 100 °C.

Salt and sugar preserving processes

F&V preserved in sugars and/or sodium based preservatives can contribute to excessive intake of free sugars and sodium, increasing the risk for the diseases that minimally processed F&V intake is able to reduce (Arcand *et al.*, 2014; Azais-Braesco *et al.*, 2017; Ahuja *et al.*, 2019; Cuadrado-Soto, 2018; Acton *et al.*, 2017; Chatelan *et al.*, 2019). There is evidence to suggest that F&V preserved in sugars (e.g. in syrup) and/or salt (e.g. pickled), do not provide reduction in the risk for critical and important health outcomes, with the consumption of fruit canned in syrup increasing the risk for cardiovascular diseases and all-cause mortality (Aune *et al.*, 2017).

Fruit and vegetable juicing

Although F&V juice may be a source of micronutrients within the diet, juicing is a food processing technique not typically included within definitions of minimally processed foods (Monteiro *et al.*, 2019). Juicing mechanically shears cell walls within F&V, reducing their fibre content (Grigelmo-Miguel and Martín-Belloso; 1998). In order to increase the shelf life or stability of juices within industrial food systems, juices may also undergo further additional processing such as centrifugation, filtra-

tion, heating, concentration, precipitation, or coagulation (Mushtaq, 2018). Each of these food-processing steps may further deplete the nutrient content of the F&V included in juices. F&V consumed in juices may be less satiating than whole fruit (Flood-Obbagy and Rolls; 2009), potentially providing more energy and sugars than when fresh F&V are consumed. This may be of particular concern in childhood, due to children's smaller dietary intakes and higher nutrient demands while growing.

Food Standards Codes of some countries include reconstituted juice, that is water added to a concentrate, within the definition of 100 percent fruit juice (Code of Federal Regulations, 2013), potentially confounding previous attempts to determine the relationship between juice intakes and health outcomes. The WHO Guideline on sugars intake states that "free sugars include monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates" (WHO, 2015). The WHO recommendation is to reduce the intake of such free sugars, including those found in fruit juices, to less than 10 percent of total energy intake (WHO, 2015). The guideline includes a conditional recommendation that a further reduction of free sugars to below 5 percent of total energy intake would provide further benefits (WHO, 2015).

Ultra-processing

Ultra-processed food and drink products are industrial formulations, which, besides salt, sugar, oils, and fats, include substances not used in culinary preparations, in particular additives used to imitate sensorial qualities of minimally processed foods and their culinary preparations (Monteiro *et al.*, 2010). They are typically created by a series of industrial techniques and processes mostly of exclusive industrial use (Monteiro *et al.*, 2019). Such products can contain residual components of F&V however they are unlikely to provide the health benefits associated with the intake of minimally processed F&V.

In many countries, marketing of ultra-processed products with none or residual components of F&V is still allowed to feature text or pictorial references to F&V in ways that are disproportional to the composition of the product (Mikkelsen *et al.*, 2007). This creates a halo effect for ultra-processed products that misleads consumers towards perceiving health benefits of such products (Sütterlin and Siegrist, 2015), when they are actually exposing their diets to a greater harm (Moubarac, 2015). The consumption of ultra-processed food and drink products is consistently associated with poorer dietary quality and increased risk for several critical and important health outcomes (Monteiro *et al.*, 2019). Such labelling and marketing strategies misrepresent the ultra-processed product contents to leverage greater sales while displacing minimally

processed F&V from the diet (Arrúa *et al.*, 2017; Centurión, Machín and Ares, 2019; Nobrega, Ares and Deliza, 2020; Europe, 2017)

Fruit and vegetable preparation and cooking

How F&V are prepared for consumption at the household level can also have important impacts on health. Most obvious is the need for safe and hygienic food storage and preparation practices, as for other foods, so as to reduce foodborne illnesses. This is typically regulated under a food standards or food safety code in developed countries, however foodborne illness remains a considerable health and economic cost for many developing countries. WHO has estimated that the burden for foodborne diseases was 31 million Disability-Adjusted Life Years in 2010, while the World Bank estimated the costs of foodborne illnesses due to lost productivity and medical expenses in low- and middle-income economies to be USD 110 billion each year (WHO, 2015; Jaffee *et al.*, 2018).

The preparation of F&V for consumption may involve separation of inedible parts, fragmentation (e.g. chopping, grating, slicing), heating and cooling. Such physical processes can also alter their nutrients and phytochemicals content. Alterations vary according to the type and combination of F&V, the preparation methods used, the type of nutrient and phytochemical, and the direction (e.g. improvement or reduction in concentration or bioavailability) and extent (e.g. greater or smaller changes in

concentration or bioavailability) of the alteration of nutrients and phytochemicals content. F&V preparation methods can also affect longer-term health outcomes by means of the addition of sugars, sodium, trans fats, or saturated fats. Given the relationship between added sugars and weight gain and dental caries (Te Morenga, Mallard and Mann, 2013; WHO, 2017), added sodium and stroke incidence and mortality (Ashfin *et al.*, 2019), and the contribution of added saturated fats and trans fats to CHD incidence and mortality (WHO, 2018), they should be used sparingly as culinary ingredients within the broader context of the diet.-

FAO/WHO do not currently include starchy roots and tubers within their definition of F&V, potentially due to uncertainty around their health benefits (WHO, 2003). This was a contentious decision given the cultural importance and relevance of starchy roots and tubers within the traditional diet of many cultures. Since that time, further evidence and evidence synthesis has been published on the role of starchy vegetable consumption and human health. Potato consumption has been considered with risk of all-cause mortality, CHD, type 2 diabetes, colorectal cancer, and hypertension (Schwingshackl, 2019). A recent systematic review and dose response meta-analysis did not identify associations between total potato intake and all-cause mortality, CHD, stroke, or colorectal cancer. Instead, the study indicates that health impacts of potato were related to their preparation method, with negative effects on type 2 diabetes and hypertension observed from

fried and salted potato intake, and no adverse effects from boiled and baked potato (Schwingshackl, 2019). The same understanding of food preparation in the home can be applied to F&V in relation to the cooking methods and added ingredients.

Proposed fruit and vegetable intake

Adults and children should be encouraged to consume a diverse range of F&V to enable optimal intakes for human health. Reflecting on how F&V are produced, supplied, processed, and prepared is important given the role of each of these factors in influencing F&V's nutrient density, in contributing to planetary health, and in reducing health inequities. Previous WHO/FAO recommendations of at least 400 g a day of F&V intakes for adults continues to be supported by the recent literature. An update to this recommendation should add that this intake should be from minimally processed F&V.

5. SUMMARY OF FINDINGS

- Higher intakes of F&V reduce risk of premature mortality and incidence of prevalent non-communicable disease when compared with lower or average intakes.
 - Such benefits accrue due to the contents of F&V influencing physiological processes in the body and the microbiota, as well as higher intakes of F&V displacing energy dense or nutrient poor food products.
 - How F&V are produced, processed, and prepared has broad consequences for human health. Recursively, greater consumer demand for minimally processed fruits and vegetables can contribute to reshaping the food system.
 - Where F&V are purchased, who has grown and supplied them, and how they are grown, processed, and prepared for consumption are expected to have direct and indirect impacts on health.
 - The benefits of the consumption of F&V may extend beyond human health to planetary health and reducing inequities. Factors that may improve such a systemic impact on health include:
 - Agroecological production systems;
 - Short and recursive production-supply-consumption circuits;
 - Equitable production and supply systems, led by indigenous peoples, women and small-scale farmers and operators;
 - Consumption of minimally processed F&V in the form of fresh and diversified culinary preparations;
 - Diversified families, genera and species of F&V produced, supplied and consumed.
- Agricultural diversification and biodiversity conservation can contribute to more nutritious foods and diets, increasing the potential of F&V to benefit human health.
 - The consumption of ultra-processed products that may contain remnants of F&V products can result in greater intakes of sodium, free sugars, trans fats and saturated fats that undermine and can reverse health benefits observed with minimally processed F&V intakes. In addition, they also displace F&V intakes.
 - Marketing techniques using images of F&V that misrepresent the true proportion and nature of F&V ingredients contained in products mislead consumers perception and understanding about the identity, quality and healthfulness of the product.





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