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Avocado Consumption and Immune Response: A Review on Ethiopian Context

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Abstract

This article is going to discuss about avocado (*Persea americana*) in terms of varieties, nutritional fact, scientific evidences of immune response of avocado and its nutrients with special emphasis on Ethiopian situation. According to the United States Department of Agriculture(USDA) National Nutrient Database; avocados contain carbohydrate, protein, mono-unsaturated fatty acids, dietary fiber, minerals including calcium, iron, magnesium, potassium, sodium, copper, manganese, phosphorus, zinc and selenium and vitamins like vitamin A, K, C, E, B6, thiamine, riboflavin, niacin, pantothenic acid and folate. Early published literature showed that avocado can boost up immune systems, having antioxidant and anti-inflammatory potency. Avocados are available throughout the year in Ethiopia, but price, quality and accessibility may vary from region to region. But Ethiopians are fond of eating avocados in form of juice, salad, and sandwich as well as in raw form irrespective of age, sex and social class. On the other hand, Institute for Health Metrics and Evaluation (USA) enlisted the top five leading causes of death in Ethiopia (2017), they are Neonatal disorders; Diarrhoeal diseases; Lower respiratory infection; Tuberculosis; Ischaemic heart disease. Among the identified mortality related behavioural risk, malnutrition and dietary practice are within top five lists. Based on this information, Ethiopia has to search any low cost food based dietary approach, which can support to handle immunity mediated disease burden with the limited resources and health service implementation challenges. In this respect, avocado can be considered for its nutritional value and It's availability, accessibility and affordability issue. Unfortunately, there is no published research article and/ review and/ case study available related to avocado consumption and health benefits specially immune response in Ethiopian context. Along with in depth research on nutritional characteristics of avocado; exploration and attention are required in field of the avocado farming, food processing technology, awareness creation on "what-when-how" to consume food and multi-sectoral coordination between Government, Non-Governmental organisation and other stakeholders.

Keywords: Avocado; Immune Response; Ethiopia

Introduction

The avocado (*Persea americana*) is a tree, are cultivated in tropical and Mediterranean climates throughout the world, but long thought to have originated in South Central Mexico. The tree is producing a nutrient-dense fruit with different varieties. The fruit is often called "alligator pear," as it tends to be pear-shaped and has green, bumpy skin like an alligator. Based on Food and Agriculture Organization of United Nations Database of avocado production in 2016 and 2017, top five producers are Mexico, Dominican Republic, Peru, Indonesia and Colombia. Ethiopia stands at 20th position in terms of production, total share just above one present of the world market [1]. According to United States Department of Agriculture (USDA) nutrient database, a typical serving of avocado (100 g) is moderate to rich in mono-unsaturated fatty acids, several B vitamins and vitamin K, with good content of vitamin C, vitamin E, vitamin A, magnesium, potassium, dietary fiber, phytochemicals (carotenoids, phytosterols etc) [2]. It is well documented by the researchers that incorporating avocado into daily diet can strengthen immune system, lower cholesterol, reduce risk of heart disease and help to manage weight, skin health, cancer, eye health, osteoarthritis [3].

According to Institute for Health Metrics and Evaluation(USA), the top five leading causes of death in Ethiopia (2017) are Neonatal disorders; Diarrhoeal diseases; Lower respiratory infection ; Tuberculosis; Ischaemic heart disease; mostly body immunity response related diseases. Based on Global Burden of Disease (GBD) 2017, Ethiopia in the phase of epidemiological transition; facing a double disease burden. Among the identified mortality related behavioural risk, malnutrition and dietary practice are within top five lists [4]. Considering this information, Ethiopia has to think about any low cost food based dietary approach, which can support this double burden of disease in long run. In this regard, avocado is a unique in terms of nutritional value and already been accepted in Ethiopian diet. Moreover; it is available, accessible and affordable almost all over the country throughout the year except some regional variations. Unfortunately, there is no published research article and/, review and/, case study available related to avocado consumption and health benefits specially immune response in Ethiopian context. Along with researchers, policy makers also did not pay more attention on organized and improved avocado farming, processing and marketing in the country.

This article is going to highlight on avocado varieties, nutritional fact, scientific evidences of immune response of avocado and its nutrients with special emphasis on Ethiopian situation. The information and analysis of this review may guide the country to combat disease burden even with the limited resources and health service implementation challenges.

Cultivation of Different Varieties of Avocado in Ethiopia

Avocado was first introduced to Ethiopia in 1938 by private orchardists in Hirna and Wondo-genet and production gradually spread into the countryside where the crop was adapted to different agro-ecologies [5]. Ethiopian soil and ideal altitude, combined with thirteen months of sunshine, lead to produce avocados with robust flavours and rich, creamy flesh for local and export market. The first governmental orchards were formed at Tepi and Gera, the bypass of the Great Rift Valley by the year 1979. To date, the avocado commands 75 percent of the total fruit acreage in these areas. Principally Hass (clean texture, and deep purple skin upon ripening), the most important fruit variety in the southwest part of Ethiopia. The season for Hass variety is the Ethiopian rainy season (May to October). It is characterized by a darkish purple hue and has a sumptuous flavour that belies its smooth external skin. Next is Fuerte (nutty flavour, notably creamy texture, and maintains green colour while ripening), which is also available between May and October. The other variety is Ettinger (green smooth-skinned), which looks exactly like Fuerte, only that it is available for a short duration of between April and August. Nabal (exceptionally creamy flesh and a gentle coconut flavour), is not easy to spot in many orchards, is notable for its yellowish green hue and delicious flesh. It is accessible between May and October. The only variety that is outside the prime season is Pinkerton, visually closest to Hass. It bears a simple fruit with plenty of pulp and tiny stone. It is available between December to April. So in Ethiopia, avocados are available throughout the year ignoring the varieties. Avocado farming till not yet fully organised in most part of Ethiopia, mostly small-scale production, somewhere as a house-plant, some where it is cultivated alongside other crops, including tea or coffee [6].

Nutritional Facts of Avocado

Nutrient	Value (USDA Database)[2]	Value (Ethiopian Food Composition Table) [7]
Water [g]	73.23	83.3
Energy [kcal]	160	110.1
Protein [g]	2	1.6
Carbohydrate(by difference)[g]	8.53	5
Fiber, total dietary [g]	6.7	3.1
Sugars, total [g]	0.66	NDA
Fat[g]	14.66	9.3
Fatty acids, total saturated [g]	2.13	NDA
Fatty acids, total Monounsaturated [g]	9.8	NDA
Fatty acids, total Polyunsaturated [g]	1.82	NDA
Minerals		
Calcium, Ca [mg]	12	13
Iron, Fe [mg]	0.55	1.7
Magnesium, Mg [mg]	29	NDA
Phosphorus, P [mg]	52	40
Potassium, K [mg]	485	NDA
Sodium, Na [mg]	7	NDA
Zinc, Zn [mg]	0.64	NDA
Manganese, Mn[mg]	0.142	NDA
Copper, Cu[mg]	0.19	NDA
Selenium, Se [µg]	0.4	NDA
Fluoride, F[µg]	7	NDA
Vitamins		
Vitamin C, total ascorbic acid [mg]	10	13
Thiamine [mg]	0.07	0.06
Riboflavin [mg]	0.13	0.11
Niacin [mg]	1.74	0.8
Pantothenic acid[mg]	1.389	NDA
Vitamin B-6 [mg]	0.26	NDA
Folate, total[µg]	81	NDA
Vitamin A equiv[µg]	7	NDA
Beta Carotene [µg]	62	0
Vitamin E (alpha-tocopherol) [mg]	2.07	NDA
Vitamin K (phylloquinone) [µg]	21	NDA

NDA= No Data Available

Table 1: Nutrition Facts: Avocados, raw, all commercial varieties (per 100gm).

Table 1 showing amount of nutrients present in 100gm of raw avocado from two sources: one from USDA Database and another from Ethiopian Food Composition Table. It is visible that in case of Ethiopian Data, most of the micro-nutrient values are not available. Nutrients like protein, carbohydrate, dietary fibre, fat, energy, calcium, iron, phosphorus, Vitamin C, thiamine, riboflavin, and niacin values are available in both the cases with small difference. These differences may be due to techniques used for analysis; irrigation and soil type, time of harvest, degree of ripening, lack of access to improved varieties those are prone to attacked by pests and diseases; poor post-harvesting techniques etc.

Immune Response of Avocado in terms of Nutrient Content

Immune System: An Overview

The immune system protects the body against infections and other external and internal threats by utilizing three distinct layers, depending on the nature of the threat: physical (e.g., skin, epithelial lining of the gastrointestinal and respiratory tracts) and biochemical barriers (e.g., secretions, mucus, and gastric acid), numerous different immune cells (e.g., granulocytes, CD4 or CDS T and B cells), and antibodies (i.e., immunoglobulins).

The first line of defence is innate immunity, which combines physical and biochemical barriers with a non-specific, leukocyte-mediated cellular response to defend against pathogens. If the pathogen manages to avoid these innate defences, a more complex, adaptive, antigen-specific response is triggered, mediated by T and B lymphocytes, which produces antibodies to target and destroys the pathogen. The adaptive immune system involves an antigen-specific response mediated by T and B lymphocytes that is activated by exposure to pathogens; this works with the innate immune system to reduce the severity of infection. The complement system can work with both the innate and adaptive immune systems; i.e., immunity from serum antibodies produced by plasma cells; i.e., an immune response that does not involve antibodies, but responds to any cells that display aberrant the major histocompatibility complex (MHC) markers, such as cells invaded by pathogens (Figure 1) [8].

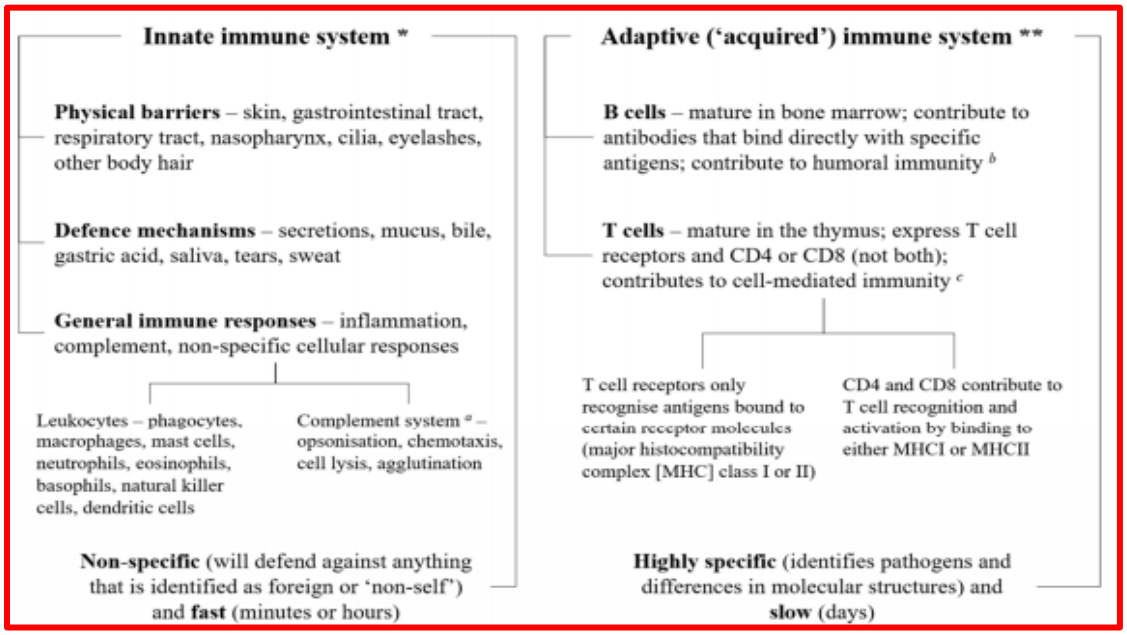

Figure 1: Simple overview of the immune system [8].

Life-style factors affecting immune function: An overview

Immunological maturity is achieved by adolescence, and young adults should be well fortified against attack by pathogens [9]. Nevertheless, several lifestyle-related factors affect immune competence in healthy adults and increase their risk of infection (Figure 2). In particular, energy-dense, micronutrient-poor convenience foods combined with a sedentary lifestyle, leading to obesity, make less bioavailable the immune-competent nutrients, suboptimal immune response, and increased risk of infection [10]. However, prolonged and excessive exercise, over-training is also thought to impair immune function [11-13]. Pollution and cigarette smoking compromise immune function, particularly when combined with poor nutrition [14]. Chronic, psychological stress is another

factor that can impact immune function, suppressing cellular and humoral responses [15]. Alcohol consumption has variable effects on immunity; moderate amounts of polyphenol-rich alcoholic beverages potentially provide some immune protection, but excessive consumption can suppress many aspects of immune function and consequently increase the risk of infection [16]. Sleep is an important homeostatic regulator of immune function and plays a specific role in immunological memory [17].

There is a bidirectional interaction among nutrition, infection and immunity: the immune response is compromised when nutrition is poor, predisposing individuals to infections, and a poor nutritional state may be exacerbated by the immune response itself to an infection [18]. It is clear that optimal immuno-competence depends upon nutritional status [19]. The risk of infection is also influenced by gender, age, genetics, early programming, vaccination history, pathogen exposure, specific health conditions, and diseases.

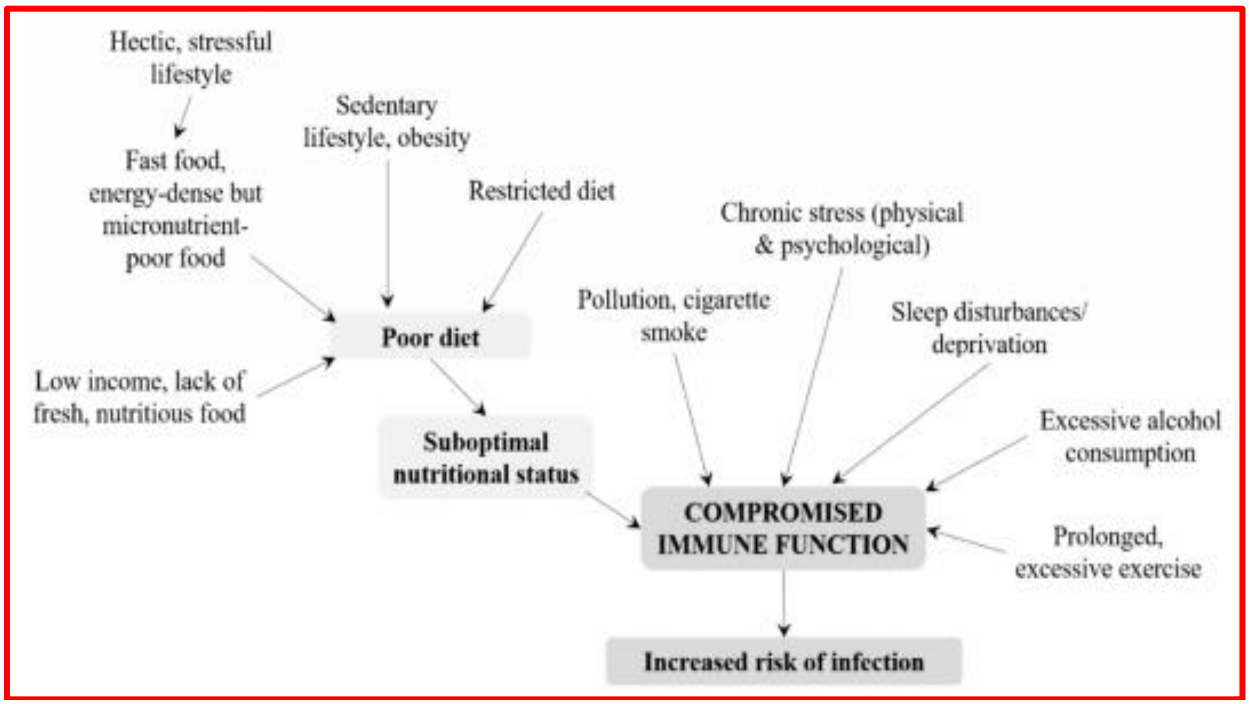

Figure 2: Life-style factors affecting immune function [20].

Nutrients have vital roles throughout the immune system that are independent of life stage. The nutrients are essential to sustain as immune-competent include protein, fat, vitamins A, C, D, E, B6 and B12, folic acid, iron, selenium, copper and zinc [21].

Immune-competent Nutrients present in Avocado and their role in Immune Response: An overview

The nutrients which support and stimulate the immune system are called "Immuno nutritional elements". Adequate nutrition (macronutrients and micronutrients) is crucial not only to ensure a good supply of the energy sources, but also for the development, maintenance and expression of the immune response [22].

Proteins: Proteins make up frame work for cells. Many immune mechanisms rely on production of active protein compounds or cell replication. In protein deficiency, functions of immune system decrease. It is thought that the negative effect of protein deficiency on immunity is connected with the effect of immune system regulator for some amino acids [23].

Fats: It is required for absorption of antioxidant fat-soluble vitamins, permeability and stability for cell membranes [24].

Vitamin C: Role of Vitamin C in innate Immunity:
(i) as an effective antioxidant that protects against ROS(reactive oxygen species) and RNS(reactive nitrogen species) produced when pathogens are killed by immune cells [25,26].
(ii) To regenerate other important antioxidants such as glutathione and vitamin E to their active state? [25]. (iii) To promote collagen synthesis, thereby supporting the integrity of epithelial barriers [14].
(iv) To stimulate production, function and movement of leukocytes (e.g., neutrophils, lymphocytes, phagocytes) [25,26].
(v) To increase serum levels of complement proteins [26].
(vi)In antimicrobial and Natural Killer (NK) cell activities and chemotaxis [14].
(vii) To involve in apoptosis and clearance of spent neutrophils from sites of infection by macrophages [27]. Role of Vitamin C in adaptive Immunity: (i) to increase serum levels of antibodies [26,27]. (ii) Lymphocyte differentiation and proliferation [14,27].

Vitamin A: Role of Vitamin A in innate Immunity:
(i) To maintain structural and functional integrity of mucosal cells in innate barriers (e.g., skin, respiratory tract, etc.) [26].
(ii) For normal functioning of innate immune cells (e.g., NIC cells, macrophages, neutrophils) [26]. Role of Vitamin A in adaptive Immunity: (i) for proper functioning of T and B lymphocytes, and to generate of antibody responses to antigen [26]. (ii) To involve in development and differentiation of Helper T cell-1(Th1) and Helper T cell-2 (Th2) cells and supports Th2 anti-inflammatory response [14].

Vitamin E: Role of Vitamin E in innate Immunity: (i) act as fat-soluble antioxidant [14]. (ii) To protect the integrity of cell membranes from damage caused by free radicals [26]. (iii) To enhance Interleukin- 2(IL-2) production and NK cell cytotoxic activity [10]. Role of Vitamin E in adaptive Immunity: (i) To enhance T cell-mediated functions and lymphocyte proliferation [14]. (ii) To optimize and enhance Th1 and suppresses Th2 response [14].

Vitamin B6: Role of VitaminB6 in innate Immunity: (i) to regulate inflammation [28]. (ii) cytokine production and NK cell activity [28]. Role of Vitamin B6 in adaptive Immunity: (i) for endogenous synthesis and metabolism of amino acids, the building blocks of cytokines and antibodies [26]. (ii) Lymphocyte proliferation, differentiation and maturation [26]. (iii) to maintain Th1 immune response [14]. (iv) antibody production[28].

Folate: Role of Folate in innate Immunity: (i) to maintain innate immunity (NK cells) [14]. Role of Folate in adaptive Immunity: (i) involved in cell-mediated immunity [28]. (ii) Important for sufficient antibody response to antigens [28] (iii) to support Th-1 mediated immune response [28].

Zinc: Role of Zinc in innate Immunity: (i) as an antioxidant to protect against ROS and RNS [25]. (ii) To modulate cytokine release and induces proliferation of CD8+ T cells [14]. (iii) To maintain skin and mucosal membrane integrity [14]. Role of Zinc in adaptive Immunity: (i) cellular growth and differentiation of immune cells that have a rapid differentiation and turnover [29]. (ii) Essential for intracellular binding of tyrosine kinase to T cell receptors, required for T lymphocyte development and activation [25]. (iii) To support Th1 response [14].

Iron: Role of Iron in innate Immunity: (i) to involve in regulation of cytokine production and action [14]. (ii) To form highly-toxic hydroxyl radicals, thus involved in the process of killing bacteria by neutrophils [14]. (iii) To generate of ROS that kill pathogens [26]. Role of Iron in adaptive Immunity: (i) important in the differentiation and proliferation of T lymphocytes [26]. (ii) Essential for cell differentiation and growth, component of enzymes critical for functioning of immune cells (e.g., ribonucleotide reductase involved in DNA synthesis) [14].

Copper: Role of Copper in innate Immunity: (i) act as a free-radical scavenger [21]. (ii) Having antimicrobial properties [26]. (iii) Accumulates at sites of inflammation, important for IL-2 production and response [28,26]. (iv) Innate immune response to bacterial infections [26]. Role of Copper in adaptive Immunity: (i) support in T cell proliferation [28]. (ii) Antibody production and cellular immunity [30].

Selenium: Role of Selenium in innate Immunity: (i) essential for the function of selenium-dependent enzymes (selenoproteins) that can act as redox regulators and cellular antioxidants, potentially counteracting ROS [14,26]. (ii) selenoproteins are important for the antioxidant host defence system affecting leukocyte and NK cell function [28]. Role of Selenium in adaptive Immunity: (i) involved in T lymphocyte proliferation

[21,28], (ii) participating in the humoral system (e.g., immunoglobulin production) [28].

Avocado and Immune Response: Scientific Evidences

Avocado contains substantial amounts of bioactive compounds such as phytosterols, β-sitosterol. The β-sitosterol in avocado also has a special effect on immunity, contributing to the treatment of diseases such as cancer, HIV and infections. In relation to cancer, it works by suppressing carcinogenesis and in HIV by strengthening the immune system [31]. This compound enhances lymphocytes proliferation and natural killer cell activity, which inactivates invading microorganisms [32].

Avocado can help in absorption antioxidants. Most carotenoid-rich fruits and vegetables are low in lipids. It has been documented that eating carotenoids (antioxidants including lycopene and beta-carotene) with avocado or avocado oil increased their absorption, which is attributed primarily to the lipids present in avocado [33].

Oxidative stress can induce neuronal damages and modulate intracellular signalling, ultimately leading to neuronal death by apoptosis or necrosis. There is evidence for increased oxidative damage to macromolecules in amyotrophic lateral sclerosis, Huntington's disease, Parkinson's disease, and Alzheimer's disease. The critical review results indicated that compounds in avocado are unique antioxidants, by suppressing radical generation, acting as effective neuropreventive agents [34].

Jaquelina and his colleagues (2013) reported that antimicrobial activity of avocado with the help of antimicrobial peptides (AMP) to control of pathogens [35]. Basic scientific research studies a systematic review and meta-analysis of the available high-quality randomized clinical trials indicated that 300 mg of avocado and soybean unsaponifiables (ASU; an extract prepared from avocado and soybean oil) per day (with or without glucosamine and chondroitin sulfate) appears to be beneficial for patients with hip or knee Osteoarthritis. This is indicating anti-inflammatory function of avocado [36].

According to Andriamanalijaona, et al. (2006), avocado and soybean unsaponifiables (ASU) exert a preventive action on the deleterious effects exerted by IL-1beta in periodontal diseases [37]. California Hass avocados have the highest content of lutein among commonly eaten fruits, lipophilic extract of avocado can inhibit the growth of both androgen-dependent (LNCaP) and androgen-independent (PC-3) human prostate cancer cell lines in vitro. Incubation of PC-3 prostate cancer cells with the avocado extract led to G2/M cell cycle arrest accompanied by an increase in p27 protein expression [38].

Avocado extract selectively induced apoptosis in human oral cancer cell lines by modulation of reactive oxygen species [39]. In the same year, Castillo-Juarez et al. concluded that antibacterial activity of a methanolic avocado extract against Helicobacter pylori, a cause of gastritis implicated in the etiology of gastric cancer [40]. The facial skin is frequently subjected to ongoing oxidative and inflammatory damage by exposure to ultraviolet rays and visible radiation, which can be controlled by carotenoids. Avocado's highly bioavailable lutein and zeaxanthin (type of carotenoids) may help to protect the skin from damage from both UV and visible radiation [41].

Ethiopian Context

In Ethiopia, avocados are very popular to everybody irrespective of age, sex, socio-economic class. Ethiopians are preparing juice by mixing avocado with sugar and milk or water, usually served with “Vimto”(locally called, brand name may be different, made up of grapes juice mostly) and a slice of lemon. Beside this, multiple layered fruit juices (locally called Spris) made of avocados, mangoes, bananas, guavas, and papayas is one of the favourite for Ethiopians. Avocados are also used to make salads and with bread as sandwiches as well as consumed raw. But avocado farming and marketing is not that much organised throughout the country. Even, there is no specific database available related to avocado consumption in any part of Ethiopia. According to Ethiopia National Food Consumption Survey (2013), the proportion of diet contributed by Vitamin A rich fruits and vegetables among women of Gambella region and Southern region relatively higher than other part of the country; Amhara region is comparatively better position in children Vitamin A rich fruits and vegetables consumption. Not only regional, difference is there between urban and rural population consumption also. But overall Vitamin A rich fruits and vegetables consumption is very low throughout the country [42]. The researchers have already documented that tobacco use,

physical inactivity, unhealthy diet (low dietary diversity and faulty dietary practices), excessive alcohol use, as well as "Khat" consumption are widely prevalent in Ethiopia, those behaviours are antagonist for bioavailability of immune-competent nutrients (those life-style factors related to immune system have been already mentioned in this article) [43].

Conclusion

Based on the above discussions, it can be concluded that Ethiopia is lacking in Immune-competent individuals and malnutrition-dietary practice has been identified under the top five mortality related behavioural risk list. This is the prime time, when nutritionist and food scientist of this country have to consider any low cost, culturally accepted food based dietary approach to handle the immunity related disease burden from infant to adult. Another interesting point to be noted that researchers have suggested avocado as a complementary and transitional food for infants and toddlers in terms of its taste, consistency and nutritional value to ensure their optimal health [44]. Considering nutritional potential and existing scientific evidences, avocado can be warranted for further exploration in terms of immune response and related health benefits over the life course in Ethiopians. A number of actions need to be undertaken in order to promote the health benefits of avocado with special emphasis on immune response. These includes:

- Capacity building, plant breeding and protection activities, implementing improved varieties, post-harvest technology, standardized packaging, organised marketing etc.
- Establishment of local processing industry, especially for avocado pulp processing or oil extraction, considering its composition and the health benefits, which can be used for manufacturing new food products/supplements.
- There is a need to revise the food composition tables for Ethiopia by using the more sensitive technology, because existing one is very old.
- Development of dietary awareness program based not only what to be consumed, how and when to be consumed. Faulty dietary practices making nutrients not bioavailable for physiological and biochemical functions in the body, so deficiency symptoms will come up even after adequate consumption of nutrients.
- Finally, suggested collaboration from Government sectors like health, agriculture, trade and industry, education, urban planning, and transportation along with Non-government organizations and other stakeholders.

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