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Plant-based diet, its health benefits in human nutrition and advantages in agricultural sustainability

Master thesis

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HONORARY DECLARATION

I am declaring, that I wrote the Master thesis “Plant-based diet, its health benefits in human nutrition and advantages in agricultural sustainability” on my own, and I was using highly professional, and scholarly literature and all information sources are included in references.

In Vienna, 05.04.2016

Signature: Katerina Schreiberová

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SUMMARY

The knowledge that nutrition influences our health, well-being, and quality of life is old as human history. Therefore, the aim of this thesis is to highlight the significance of plant-based diets (PBD) and its impact on the health condition of humans. The thesis also seeks to highlight the health benefits that are associated with consuming a whole food plant-based diet, offering a more profound and encompassing view on nutrition. The work deals with the relationship between food and serious diseases, which are highly related. It identifies main noncommunicable diseases, especially obesity, cardiovascular disease, and cancer. In these cases, including plant-based foods in people´s diets is a preventive solution for such civilization disease. Also, there is a positive aspect of the PBD for the environment when plant-based and animal-based diets were compared.

KEY WORDS: Plant-based diet, obesity, cardiovascular diseases, nutrition, sustainability

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1 INTRODUCTION

Not all eating habits meet daily nutritional requirements because certain foods, especially more attractive ones, may have little nutritional value. Hence, it may not always be a valuable content of minerals, vitamins, and enzymes. Some food choices are made with little consideration of health impact. The question arises, is one willing to change their lifestyle to reduce their risk of chronic civilization disease? What is known, is that food has a 40% impact on human health.

Fortunately, the human body has regenerative abilities. The degree of this ability depends on the body itself, on the environment in which the individual lives and what foods are eaten. Over recent decades, there has been a proliferation of research into the association between diet and health. Obesity has been accused of causing heart disease, diabetes, elevated blood pressure, and other medical problems that may contribute to today´s elevated mortality. Obesity and the overweight increase in population, eating disorders are becoming more common. Most cancer experts claim that eating a variety of colorful fruit and vegetables, grains, and legumes aid in the fight against cancer. Campbell (2006) explains, that cardiovascular diseases (CVD) are merely a result of diet and0lifestyle, and0can rarely0be found apart0from one0another.

What is healthy eating? The sense of a diet has changed dramatically over the years and decades. The diet of the 21st century has been saturated with convenience foods, easily accessed foods in grocery stores, and excessive food advertising strategies by the food industry. All these influences lead to the foundation of the modern diet consisting of predominantly prepackaged foods that rely heavily on corn, soy, and meat processing.

A plant-based diet emphasizes vegetables, fruits, legumes, and whole grains in its whole form. Colorful plant foods are also good sources of phytochemicals. Their main aspect is a protection of our body´s cells from damage-causing agents. They also benefit us in overall health. According to Tonstad et al. (2013), there is no doubt that improved nutrition conditions and intake has contributed to improved health. What humans put into their bodies directly correlates with their health.

Many people don't realize that food production places an enormous demand on natural resources. Agriculture itself is responsible for up to 30 percent (Tilman et al. 2002) of global greenhouse gas emissions – with almost half caused by livestock production alone. Sustainability is a topic of increasing importance as consumers become more interested in learning where does the food come from, how was it grown and where was it produced. Sustainability is a multi-faceted issue, in which the food production system and sustainable diets play a crucial role.

2 SCIENTIFIC HYPOTHESES

The aim of this work is to highlight the significance of plant-based diets (PBD) and its positive impact on human health. In addition, the positive effects of PBD are not only health related, but also support environmental sustainability. Both aspects are addressed and discussed in literature review. Furthermore, health impact was statistically investigated with hypotheses listed below.

HYPOTHESES

$H1_0$: BMI does not depend on the diet type.
$H1_A$: BMI depends on the diet type.

$H2_0$: The CVD occurrence does not depend on BMI, diet and gender.
$H2_A$: The CVD is effected by at least one of BMI, diet and gender.

$H3_0$: Plant-based diet reduces an occurrence of CVD.
$H3_A$: Plant-based diet doesn´t reduce an occurrence of CVD.

$H3^*_0$: Health status does not depend on the diet type and BMI.
$H3^*_A$:Health status does depend on the diet type and BMI.

3 BACKGROUND

Plant-based diet by definition of Tuso et al. (2013); Dunn et al. (2001) includes lots of plant food sin their whole, unprocessed forms such as vegetables, fruits, beans, lentils, nuts, seeds, whole grains, and small amounts of healthy fats. In opposite, it excludes all animal products. Plant-based foods are good sources of all macro and micro nutrients and additionally also naturally lower in calories. A very common misunderstanding with PBD are questions regarding presence and absorption of plant protein. These sensitive and controversial topics will be discussed in detail in *Chapter 3.3.3.*

Human nutrition describes the processes whereby cellular organelles, cells, organs, systems, and the body as whole obtains and uses necessary substances (nutrients) obtained from food to maintain structural and functional functions. Therefore, it is a diet rich in nutrients, boosting enzyme production and providing defense for our bodies.

3.1 Phytochemicals of plants

By definition of Craig (1996), phytochemicals are nonnutritive substances in plants that possess health-protective benefits. In detail explained plants include other compounds such as dietary fiber, carotenoids, phytochemicals, phenolics, flavonoids, phytosterols, and saponins. The main phytochemicals in plants are called flavonoides, and they have extensive biological properties that promote human health and inhibit the risk of disease. Phytochemicals also contain anti-inflammatory and antitumor properties. Therefore, Tonstad et al. (2013) claim that phytochemicals reduce the risk of cardiac disease by lowering production of cholesterol. Most of these flavonoids are found in the color pigmented part of the plant; therefore, different colored plants will provide protection in different ways. The other powerfully colored plants are yellow and this color contains carotenoids. Carotenoids act by fighting against free radicals in the body. According to Harland and Morris (1995), these phytochemicals also provides protection against oxidative damage and stimulates immune function. Oxidative damage is what we know as the aging process of our body.

3.2 Importance of nutrition and nutrition dense food

According to Gibney (2009), there are more than 50 known nutrients (including amino acids and fatty acids) and much more chemicals in food thought to influence human function and health statuses. Nutrients as a whole can be divided into two sub-groups on the necessary quantities: macronutrients and micronutrients. Minerals and vitamins are micronutrients, whereas macronutrients consist of fats, carbohydrates, and proteins, further discussed in *Chapter 3.3 and 3.4*

Functioning of human body requires a supply of necessary nutrients. Smil (2000) indicates general view, that human beings can extract energy from external and internal sources. However, when external nutrient income is insufficient, body uses inner sources for maintaining body functions. Their security is possible especially from received proper food and beverages. Hence, nutrient supply is needed to be regularly provided and delivered by food income. Especially those essential nutrients can´t be synthesized by the body and thus must be derived from the diet.

3.3 Macronutrients

Nutrients are substances needed for growth, energy provision, and other body functions. There are three macronutrients required by the body in relatively large amounts. Although each of these macronutrients supplies the energy needed to run body functions, the amount of energy that each provides varies. According to Drewnowski and Popkin (1997) carbohydrates and proteins each provide 17 kJ/g whereas fats provide 37 kJ/g.

3.3.1 Carbohydrates

Carbohydrates are the single most abundant sources of food energy in the human diet, constituting 40-80% of total energy intake in different populations and are classified according to their degree of polymerization into sugars, oligosaccharides, and polysaccharides and dietary fibers or nonstarch polysaccharides. Carbohydrates are formed in green plants by photosynthesis for a participation of chlorophyll, air carbon dioxide, water, and sunlight. Gibney (2009) explains digestion of glycemic carbohydrates in the small bowel, also as absorbtion and metabolization. On the other hand nonglycemic carbohydrates are fermented in varying degrees to short-chain fatty acids (SCFAs), carbon dioxide, hydrogen, and methane in the large bowel according to Sabate (2003). For an optimum function of the nervous system and other cells, blood glucose

concentrations are tightly controlled by hormones like insulin and glucagon utilizing several possible metabolic pathways for glucose anabolism and catabolism.

Excess glucose uptake also results in an excess of carbon molecules in the body. These molecules in the body are further converted to carbon dioxide and carbonic acid and thereby acidify organism. Furthermore, there is overloading the pancreas that produces insulin to offset blood sugar levels (Gibney, 2009). According to Dunn et al. (2001) in perspective of long term overloading can be the production of insulin limited, what furthermore leads to civilization diseases – diabetes. Ness (1997) also adds that this process is also often accompanied by obesity.

3.3.1.1 Monosaccharides and disaccharides

The most important monosaccharides include glucose which is the form of smartest source energy for the body to produce energy the fastest and easiest way (Gibney, 2009). Disaccharides are sugars composed of two monosaccharides, and both these groups are called simple carbohydrates. Schweizer and Edwards (1992) provides an explanation of the term "sugars" and conclude that it is conventionally used to describe the mono and disaccharides. All the saccharide groups have to be broken down to monosaccharides in order to be absorbed.

3.3.2 Lipids

Fats are an essential component of the cell membrane, and internal fatty tissues protect the vital organs from trauma and temperature change by providing padding and insulation. They are naturally occurring organic substances insoluble in water and soluble in organic solvents. Fats are for example required for tissue growth and hormone production as mentioned U.S. Department of Health and Human Services (2005) and are broken down into fatty acids and glycerol. Lipids are transported in the blood circulation as lipoprotein particles: the chylomicrons, very low-density, low-density, and high-density lipoproteins (American Dietetic Association, 2003). Fats are healthy, as long as we get the right ones. The body doesn´t produce essential fatty acids so we need to get them from our food intake. Fats exist not just in oils but in vegetables and nuts, which may be the healthiest source of all. For example, namely these sources are very efficient: almonds, avocados, chia seeds, freshly ground flaxseeds, and walnuts.

3.3.2.1 Fatty acids

An important component of lipids is the fatty acids. According to Australian Government Department of Health (2013) three essential fatty acids (linoleic acid, arachidonic acid, and linolenic acid) are needed biochemically by our bodies and are available only in diet intake. All are contained in plant oils. Furthermore is important to state that fatty acids differ in their length and their degree of saturation.

3.3.2.1.1 Saturated vs. unsaturated fats

Saturated fats are commonly found in animal products, but from plant kingdom, it is represented in coconut oil or palm oil, states Singh et al. (2003). Foods containing unsaturated fats include avocado, nuts, canola and olive oils and are considered the "healthy" fats and help reduce heart disease and lower cholesterol levels. According to Rimm et al. (2000), "healthy" fats should replace saturated fats in the diet.

3.3.2.2 Cholesterol

According to Lorgeril et al. (1999), CVD and related mortality are strongly associated with elevated plasma concentrations of total cholesterol (TC) and low-density lipoprotein (LDL) cholesterol. However, many adult people in the Western word have TC levels very high. The value is the desirable upper limit established by the National Institut of Health (2002), suggesting that factors other than genetics are involved in hyperlipidemia. The populations consuming plant-based diets typically have significantly lower blood concentrations of TC and LDL cholesterol and correspondingly lower rates of coronary artery disease compared to the general population (Cote, 2013).

3.3.3 Protein

Protein is the most abundant nitrogen-containing compound in the diet and the body. By definition of New Oxford American Dictionary (2010), proteins are nitrogenous organic compounds, which have large molecules composed of one or more long chains of amino acids and are an essential part of all living organisms. Dietary proteins are broken down through digestion into peptides and amino acids. These amino acids are then used to synthesize protein replacements (Walker et al. 2011). Of the 20 amino acids, 9 are essential amino acids (Gibney, 2009).

It hasbeen argued that the excessive promotion of animal protein led to the societal belief that animal protein was of better quality than plant-based protein.

Campbell (2006) states that those that could afford it in past history were mostly the rich and consumed it as often as possible. Meanwhile, plant-based proteins were perceived to have minor value, and its consumption was associated with impoverished diet. Gender was also a major factor that controlled the consumption of meat in the past. Cambell (2006) sees major influence of conviction that men were seen as strong supporters of the family and hence,deserved a diet consisting of energyrich nutrition . These social class differences then led to elitism and influenced the field of nutrition.

Debate exists over decades whether animal proteins or plant proteins are better for human health. Young and Pellet (1994) states that plant proteins can provide all essential amino acids, and they are not of inferior quality for human health. According to Pimentel and Pimentel (1996) the recommended daily allowance (RDA) of protein from a mixed diet for adults is 56 g per day and for example, the average adult American consumes approximately 112 g per day, and nearly 73 g of this is animal protein. Approximately, this is two times the recommended amount.

However, lower availability of some amino acids in plant foods does not signify that animal protein is a better protein for human health. This merely suggests that to ensure dietary adequacy, a diet based on plant proteins must be diverse. For instance, fewer quantities of the essential amino acid lysine are known to be available in plant-based proteins (Walker et al. 2011).

3.4 Micronutrients

Term micronutrients suppose need in minuscule amounts, these substances are the important elements to enable the body to produce enzymes, hormones and other substances essential for proper growth and development (WHO, 2003). No single food contains all of the vitamins and minerals we need. Therefore, a balanced and varied diet is necessary for an adequate intake. Some researchers argue that only the animal-based diet (ABD) can provide the necessary micronutrients such as iron or B12, so especially these micronutrients will be discussed further more in *Chapters 3.4.1.2 and 3.4.2.* In addition to highlight plant sources for crucial vitamins and minerals in Appendix B, there are created different tables of best sources.

3.4.1 Vitamins

The vitamins are a chemically disparate group of compounds with a variety of functions in the body. According to Gibney (2009), vitamins are required in very small amounts (milligrams or micrograms) per day. Vitamins that are higher in animal-based

foods include vitamin A and vitamin D. However, the higher amount of vitamin D is due to the fortification by industries in dairy products. For instance vitamin A can be synthesized in our body from the break down of beta-carotene, which is commonly found in carrots. Harland and Morris (1995) explains positive effects in extinction of the activity of vitamin C. The vitamin C act as antioxidants and protect LDL cholesterol from oxidation to unsafe cholesterol oxides.

3.4.1.1 Vitamin D

Vitamin D is naturally present in very few foods, but its main benefit is that it is produced endogenously by ultraviolet rays from sunlight. Simply by going outside the sunshine hits a skin and vitamin D is produced. Cambell (2006), states that the vitamin must be activated in kidneys to be useful. However, the activation of vitamin D can be affected by the food we consume. It is inhibited by foods that are high in calcium (Campbell, 2006).

3.4.1.2 Vitamin B_{12}

Vitamin B_{12} is unique among the vitamins in that it is derived exclusively from microbial synthesis. In developed countries, many foods are fortified with vitamin B_{12}. Providing these foods are consumed regularly, the hazard of vitamin B_{12} deficiency is easily avoided. Plant foods do not naturally contain vitamin B_{12}, although it has been claimed. Some plant foods such as seaweed and tempeh might provide true vitamin B_{12}, but this claim has not been established yet. According to Dagnelie (1997), it might contain only vitamin B_{12} analogs that are unfortunately inactive. Early studies of vitamin B12 status in vegetarians according to Armstrong et al. (1974) have shown that dietary intake and plasma concentrations are lower in comparison to meat-eaters. However, according to Man (2000), recent research has shown that substantial proportions of vegans and even of vegetarians have suboptimal vitamin B_{12} status. It is thanks to modern and more sensitive indicators of vitamin B_{12}.

3.4.2 Minerals

Essential minerals are inorganic elements that have a physiological function within the body. These must be supplied in the diet and vary from grams per day for the major (macro) minerals through milligrams to micrograms per day for the trace elements. Essential elements have the potential to cause deficiency symptoms. Two of

these deficiencies, iodine, and iron, are widespread in human populations. Other two, zinc and selenium, according to Hunt (2002), only occur in some population groups.

Gibson et al. (1997) state that bioavailability of zinc is enhanced by dietary protein, but plant sources of protein are also generally high in phytic acid. Thus, less zinc may be absorbed from a vegetarian compared with an omnivorous diet because of both reduced zinc content and bioavailability (Gibson et al. 19997). However, current models predicting zinc absorption from human diets have not been sufficiently verified by research with practical, whole diets consumed for extended periods.

Sodium is essential mineral, but most people consume too much. For example, Campbell (2006) states that by decreasing sodium and increasing potassium intakes we can help control body pressure and lower risk of heart disease, heart attacks, and strokes. The best sources of potassium are fresh foods with limited processing because processing can impact the potassium level.

3.5 Diet recommendation

Diets recommended by various medical authorities and other expert groups are amazingly similar and have been relatively consistent over the past 25 years promoting consumption of fruit, vegetables and unprocessed grains (American Dietetic Association (2003); European Community (2003); Australian Government Department of Health (2013). In particular, a healthy adult diet mentioned in Orlich et al. (2013); Heimendinger and Van Duyn (1995) should be high in complex carbohydrates, fruit and vegetables and low in fat. Much research has addressed the role of diet in health and although at times controversial, studies in Beardsworth and Keil (1991); FAO (2006); Lorgeril et al. (1999) suggest that foods such as fruits and vegetables and oat fiber can be protective while salt and saturated fats can increase the risk of poor health. Other studies which have shown fruit and vegetable rich diets as beneficial for your health were made by Singh et al. (2002); Lorgeril et al. (1999); Trichopoulou (2003); Fung et al. (2001).

The adequacy of meatless diets has been a recurrent theme in the nutrition literature. By a higher concentration of essential nutrients in animal products, meat and dairy were considered essential in large proportions foradequate nutrition in the daily diet, and consumption of PBD was considered inadequate. According to Roos et al. (2015), this nutritional paradigm has changed in the past few decades as data now support

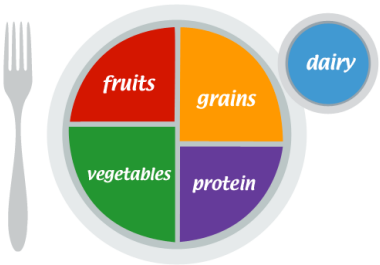
that most PBD are healthier than meat-based diets and yield greater longevity and lower chronic diseases.

3.5.1 Diet guidelines

An important factor affecting the consumption of animal proteins are wide global guidelines. Unfortunately, some of these guidelines still continue to promote the consumption of large amounts of animal sources. For example the most knowen US nutrition guide "MyPlate" was introduced and replaced the food pyramid in 2011. According to Chiuve and Willet (2007) both previous food pyramids were criticized for not taking into consideration scientific evidence about healthy food choices and by that misleading the public. Generally, very criticized on My Plate was the high recommended content of dairy and missing water supply representation in graphic. Other facts are also missing healthy fats and other plant-based oils.

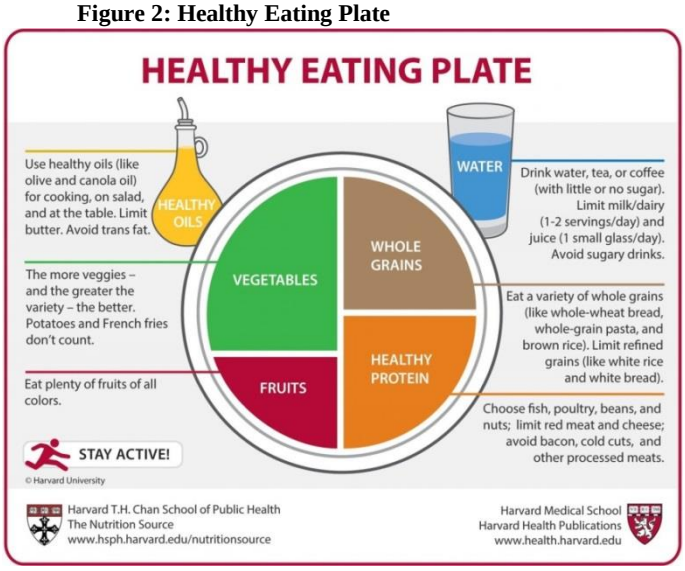
Later on, the Healthy Eating Plate was created by nutrition experts at Harvard School of Public Health to cover deficiencies in the USDA´s MyPlate. The Healthy Eating Plate provides detailed guidance, in a simple format, to help people make the best eating choices. It is based exclusively on the best available science and was not subjected to commercial purposes from food industry lobbyists. Fortunately, this guideline is open to animal-free eating and notes that for beings who exclude animal products there is a need to eat a variety of protein-containing foods each day in order to get all the amino acids needed to make new protein.

Figure 1: MyPlate chart



Source: USDA (2011)

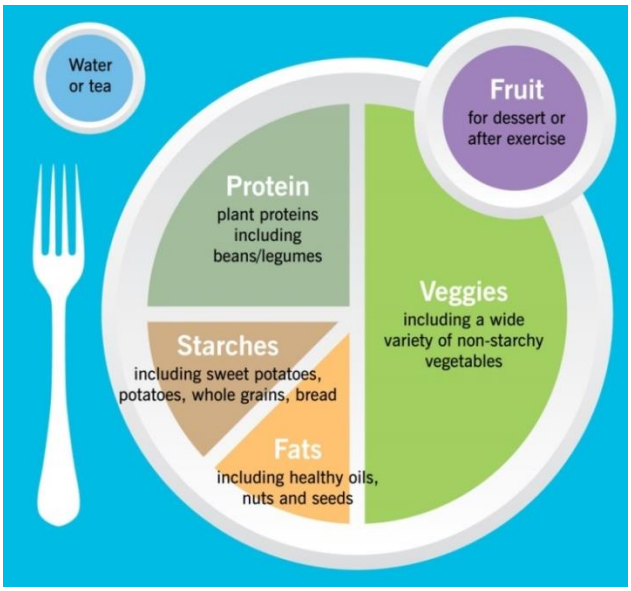
Figure 2: Healthy Eating Plate



Source: Harvard School of Public Health (2016)

Further more was created a Plant-Based Plate by doctors from Precion Nutrition Organization. What´s special on this guideline is a wide variety of non-starchy vegetables, combined with a protein source and healthy fat.

Figure 3: Plant-Based Plate



Source: Precision Nutrition organization (2016)

3.6 Vegetarianism

Vegetarianism traditionally falls outside of the accepted eating patterns in Western nations. Furthermore, the meat-free lifestyle can be classified as a form of positive deviance. In reality, very few people eat the same type of diet over the course of their lives, and hence their dietary choice patterns change. For example in comparison to omnivorous diets, vegetarian diets can provide several health benefits. According to Academy of Nutrition and Dietetics (2016), vegetarians tend to have a lower body weight and lower overall cancer rates, lower intakes of saturated fat and cholesterol, and higher levels of dietary fiber, magnesium, potassium, vitamins C and E, folate, carotenoids, flavonoids, and other phytochemicals. These beneficial health effects will be discussed more detailed in *Chapter 3.7.*

3.6.1 Vegetarianism vs. whole foods plant-based

Mann (2000) defines a whole foods raw plant-based as diet rich in fruits, vegetables and whole grains. The common misconception to a plant-based diet is that an individual would be considered to be a vegetarian, which is just a partial truth. A strict vegetarian diet is vastly different than a raw plant-based diet, because some vegetarians only cut

out animal products. However, they still consume large amounts of oils, refined carbohydrates and sweets. This diet is not nutritious at all, it is only filled with empty carbohydrates. Well, ”well-planned” vegetarian diets are completely healthful and nutritionally adequate for people throughout all stages of life (Craig et al., 2009).

3.6.2 Types of vegetarian diets

The American Council on Science and Health (ACSH) organized a simple typology of different forms of vegetarianism and are based on what kind of food is eliminated. Other types of vegetarians define Internation Vegetarian Union (2008) and it is based on personal philosophies and divides them as freegans and raw foodists. According to Tilman et al. (2014), the freegan philosophy will permit even meat eating if the food containing meat will end up just being wasted or placed in the garbage. Raw foodists are another strict kind of vegan that requires all of the food to be prepared in its raw, uncooked form. Godfray et al. (2010) add that cooking food tends to reduce the health benefits of the vegetable as well as changes the natural flavor.

International Vegetarian Union (2008) divides vegetarian diets as follows:

Table 1: Division of vegetarian diets

Semi-vegetarian	A person who eats vegetables, fruits, nuts, legumes, grains, dairy products, eggs, seafood, and poultry. The only types of meat that are avoided are red meats such as beef and pork
Pollo-vegetarian	A person who eats vegetables, fruits, nuts, legumes, grains, dairy products, eggs, and poultry. The person here has eliminated red meat and seafood
Pesco-vegetarian	A person who consumes vegetables, fruits, nuts, legumes, grains, dairy products, eggs, and seafood. The individual abstains from poultry and red meat
Ovo-lacto-vegetarian	This is the stereotypical vegetarian. A person who follows this kind of diet consumes vegetables, fruits, nuts, legumes, grains, dairy products, and eggs. All red meat, poultry, and seafood are refrained from eating
Lacto-vegetarian	A person enjoys vegetables, fruits, nuts, legumes, grains, and dairy products. Eggs, red meat, poultry and seafood are eliminated
Ovo-vegetarian	An individual eats vegetables, fruits, nuts, legumes, grains, and eggs, but will abstain from dairy, red meat, seafood, and poultry
Vegan	A person will attempt to eliminate all animal products. He or she will only consume vegetables, fruits, nuts, legumes, and grains. All meat, dairy, eggs, fur, and leather will be avoided as best as possible
Fruitarian	This type of vegetarian is considered the strictest and only consumes the fruit portion of the plant

Source: International Vegetarian Union (2008)

According to Beardsworth and Keil (1991), more consumers have become "flexitarians". Flexitarians are those people who consciously reduce their meat intake for health reasons but still occasionally enjoy animal protein. One of the best evidence of this trend is the growing popularity and social media following of the nonprofit Meatless Monday initiative.

3.7 Deaths and illnesses

3.7.1 Situation in the world

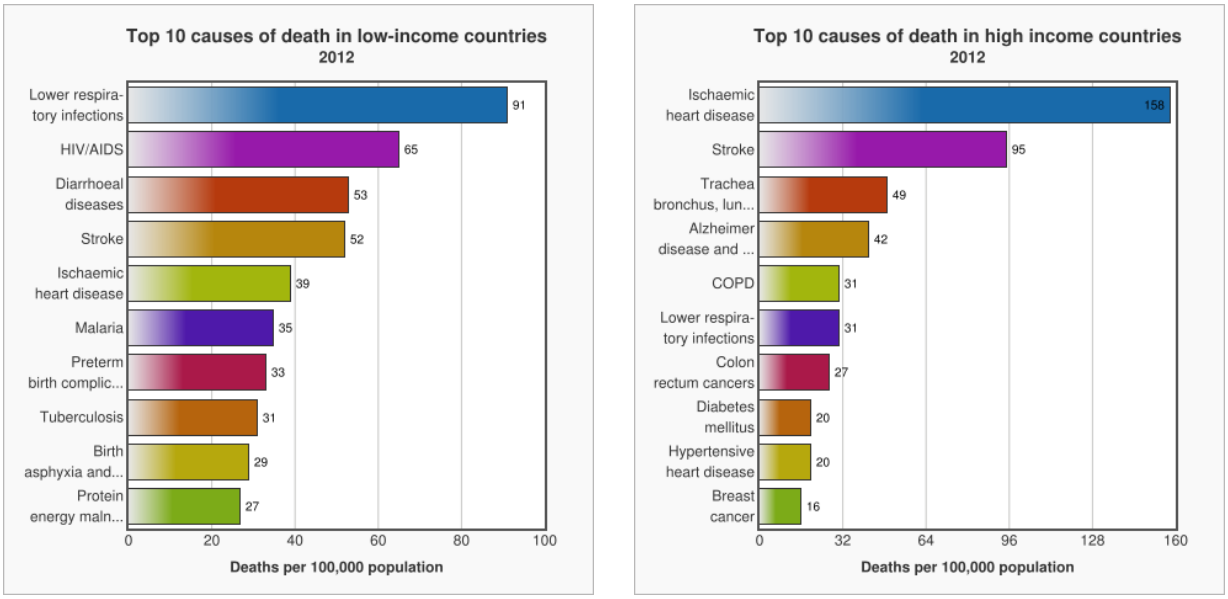
Cause-of-death statistics help authorities determine their focus for public health actions. Countries where deaths from heart disease and diabetes rapidly rise, have a strong interest in starting a vigorous programme to encourage lifestyles to help prevent these illnesses.

According to statistics on the WHO (2016) webpage, cardiovascular diseases killed 17.5 million people in 2012, of these, 7.4 million people died of ischaemic heart disease and 6.7 million from stroke. Noncommunicable diseases were responsible for 68% of all deaths globally in 2012, up from 60% in 2000. The four main NCDs[1] are cardiovascular diseases, cancers, diabetes and chronic lung diseases. In terms of proportion of deaths that are due to NCDs, high-income countries have the highest proportion. Exactly 87% of all deaths were caused by NCDs, followed by upper-middle income countries (81%). The proportions are lower in low-income countries (37%) and lower-middle income countries (57%).

In high-income countries, seven in every ten deaths are among people aged 70 years and older. In conclusion, people predominantly die of chronic diseases: cardiovascular diseases, cancers, dementia, chronic obstructive lung disease or diabetes. In comparison to this fact, in low-income countries, nearly four in every ten deaths are among children under 15 years, and only two in every ten deaths are among people aged 70 years and older. People predominantly die of infectious diseases. Lower respiratory infections, HIV/AIDS, diarrhoeal diseases, malaria and tuberculosis collectively account for almost one-third of all deaths in these countries. All the information are sourced and concluded in Figure 4.

[1] Non-communicable disease (NCD) is a medical condition or disease that is non-infectious or non-transmissible. NCDs can refer to chronic diseases which last for long periods of time and progress slowly.

Figure 4: Causes of death in world based on country income



Source: WHO (2016)

3.7.2 The role of diet in contributing to illnesses

An individual´s health is influenced by a maltitude of factors including their genetic makeup, their behavior, and their environment. Burlingame and Dernini (2012) confirms that diet plays a central role and can contribute dierectly towards health. It can also impact on health through an interaction with a genetic predisposition. Research has also examined whether changes in diet can improve health after the diagnosis of a problem. There is a proof by Campbell et al. (1998) that the impact of dietary change on coronary heart disease and diabetes is significant.

PBD reduces plasma cholesterol concentrations through several mechanisms. For example Hu (2003) provides an example how reduced dietary intake of total fat, saturated fat, and cholesterol leads to less absorption and conversion to blood cholesterol. Trading saturated fats for unsaturated fats in the diet is found to be more effective in lowering the risk of CVD also by Ness and Powles (1997).

3.7.3 Diabetes mellitus

There are two types of diabetes and according to Hu (2011) in both cases the disease involves dysfunctional glucose metabolism. Type 1 diabetes always requires insulin and is also called childhood onset diabetes and is found to develop in children. Type 2 diabetes tends to develop later on in life and can be managed by diet alone. This form of diabetes shows a clear relationship with diets high in sugar content (Hu, 2011).

In both cases, there is an inadequate production of insulin and the sugar in the blood has no place to be used, explains Campbell (2006). These findings indicate that a lifestyle intervention can cure and prevent common diseases such as diabetes.

3.7.4 Heart disease

An elevated level of LDL´s present in the blood and a decreased level of HDL or leads to hypercholesterolemia. Patients diagnosed with angina or heart disease, or who have had a heart attack, are recommended to change their lifestyle according to Hu (2011); Campbell (1998) and adopting a healthy diet according to Schweizer and Edwards (1992). Therefore changing diet as part of a complex series of lifestyle changes seems to result in improved health both in the short and longer term. According to National Research Council Committee on Diet and Health (1989) a whole foods PBD is able to prevent and even reverse heart disease.

3.7.5 Cancer

Cancer can be a very encompassing topic because there are many different variations based on the anatomical location. However, the effects of nutrition on cancer according to Campbell (2006) are all virtually the same for all cancers, no matter if they are initiated by different factors. According to Steinmetz and Potter (1996), diet is believed to account for more variation in the incidence of all cancers than any other factor. How diet affects cancer is unclear. Campbell (2006) introduce a theory that all foodstuffs contain natural non-nutrients which can trigger cancer. A second theory claims that a poor diet weakens the body´s defense mechanisms. The cancers most clearly related to diet are those of the esophagus, stomach, and large intestine. According to Tantamango et al. (2013), there is also a possible link with breast cancer.

3.7.6 Obesity

Obesity is the turn of this millennium because it has become the most common metabolic disease nowadays due to living conditions and lifestyles. In this regard, there is a consensus that obesity is a source of major health risks for which it is rightly considered a disease.

3.7.6.1 Causes of overweight and obesity

Obesity is caused by several factors, some of which are directly dependent on the nutrient requirements. On a very simple level, the balance of calories stored and burned

depends on genetic makeup, a level of physical activity, and resting energy expenditure (Dunn et al., 2001). Excess calories are stored throughout body as fat. According to Ness and Powles (1997) genetic factors are the forces that help gain weight and stay overweight; environmental factors are the outside forces that contribute to these problems. They encompass anything in our environment that makes people to eat too much or exercise too little.

3.7.6.2 BMI Index

Body Mass Index (BMI) is a measure of body fat based on your weight in relation to your height, shown in Formula 1. A high BMI can be an indicator of high body fatness and used to screen for weight categories that may lead to health problems. It applies to most adult men and women over twenty years old. BMI is used as a screening tool to indicate whether a person is underweight, overweight, obese or a healthy weight for their height. According to the WHO (2016), the metric BMI formula is defined as follows:

Formula 1: BMI counting

$$\text{weight (kg)} / \text{height (m)}^2$$

3.8 Sustainability

Sustainability is increasingly viewed as a desired goal of development and environmental management. Sustainability means the enactment of practices that fulfill the needs of society while protecting the physical basis of our long-term survival. According to Seidl and Tisdell (1999), population tended to grow geometrically while food production only arithmetic series. Human population really began to grow exponentially, which enabled higher offer of livelihood. Food systems throughout the world are currently not sustainable, even though at present almost a billion persons are not getting enough food.

The imbalance between the total energy required by the food system and the total food energy produced by the effort was reported for instance by Gliessman (2000). According to Yunlong and Smit (1994) large amounts of energy go into processing, transporting, storing, and serving food. From the energy perspective, the industrial food system is very inefficient. Thanks to that the current system most of the energy inputs are from nonrenewable sources and it is unsustainable. From historical progress Fanzo et al. (2012) explains that since 1963, there has been a 62% increase worldwide in meat

consumption. The projected increased size of the world´s population and the increase in the appetite for meat are pushing our food systems to unsustainable levels.

Previously, the main solution to food shortages was to bring more land into agriculture and to exploit fish stocks. Harris (2003) says that these practices are not sustainable. According to Gliesmann (2000); Harris (2003); Harrison and Hester (2005) here comes question of importance of changing the current farming practices.

3.8.1 Livestock impact on environment

According to Raman (2006), there is no doubt that animal protein production leads to significant environmental problems. The process of animal protein production is mainly associated with severe problems. Tilman and Clark (2014) see main problems in land degradation, high greenhouse gas emissions, biodiversity loss, water use, and water pollution.

3.8.2 Soil and land degradation

Pasture animals occupy 26% (FAO, 2006) of the land surface of the planet without glaciated areas. Additionaly quote that expansion of livestock production is a key factor in deforestation, especially in Latin America. For example, approximately 70% (Tilman et al., 2011) of the previously forested land in the Amazon is currently occupied by pastures and much of the rest occupies feed for animals, like soybean feed. Obvious is also extended damage caused by animals activity due to excessive pasteurizing. Soil can suffer from loss of humus, soil organisms or devastation degradation mainly due to waterlogging or salinization. Deforestation isn´t the only problem of debasement of livestock production. According to FAO (2006), liquid manure and manure[2] used to fertilize can be more dangerous on permeable soils, than the industry fertilizers. Tilman et al. (2002) say that nutrient overloading leads to soil erosion or lack infiltration of rainwater. All these problems are furthemore discussed in following *Chapters 3.8.3-3.8.7.*

3.8.3 Deforestation

The deforestation leads to several environmental threats, including wind and soil erosion, flooding, loss of forest resources, siltation of reservoirs, landslides, reduction in precipitation, crops and fodder for the local population. Raman (2006) says that this approach reduces the gene pool, perhaps disappearing drugs and wild varieties of crops.

[2] Livestock sector produce 65% of anthropogenic emissions of NO_2 mainly from manure.

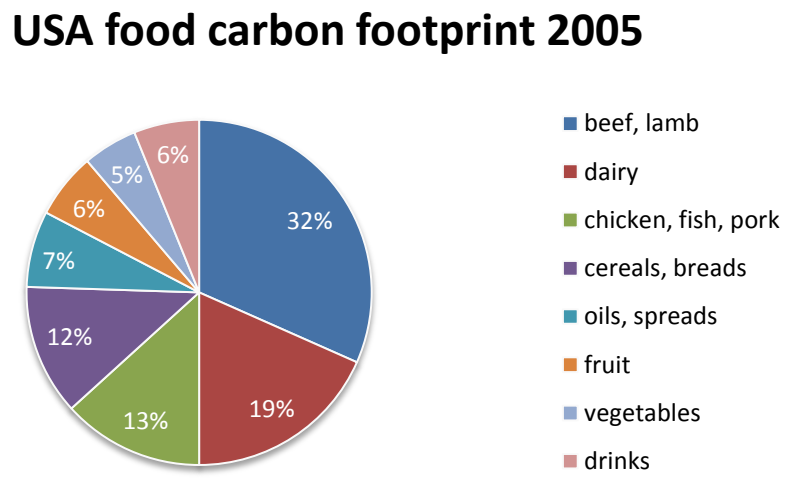
Gliessman (2000) states that deforestation may also mean increasing global warming and other negative impacts on the global climate.

3.8.4 Greenhouse gas emissions and carbon footprint

The animals themselves emit methane [3] through "enteric fermentation by ruminants". Not to mention, FAO (2009) estimates that livestock production is responsible for 14,5 % [4] of global greenhouse gas emissions, while other organizations like the Worldwatch Institute (2015) have estimated it could be 51%. According to Robert (1997), even organic animal protein production does not represent a solution to reduce GHG emissions within the livestock sector.

Furthermore Cote (20013) quote that the average person who eats PBD can save 163,000 of water a year, and cut their carbon footprint in half. But the most efficient shift is a fact that according to Nijdam et al. (2012) we could redirect enough grain from the livestock system to feed 1.4 billion people if every American stopped eating meat.

Figure 5: Food carbon footprint 2005 of the USA agriculture



Source: USDA (2005)

3.8.5 Water pollution and usage

The world in general faces a growing problem of shortage of drinking water. The agricultural sector is a vital source of increasing water consumption. According to Tilman et al. (2002), the sector represents more than 8% of global human water use, mainly for irrigation of feed crops. It is probably the broadest sectoral source of water

[3] Livestock production releases 37% of anthropogenic methane.
[4] It means even higher impact than causes transport pollution, which represents roughly 14%.

pollution, which contributes to eutrophication, the occurrence of "dead" zones in coastal areas, degradation of coral reefs, health problems, emergence of antibiotic resistance and many others. According to Harris (2003), the main sources of pollution are animal wastes, antibiotics, and hormones, chemicals from fertilizers and the pesticides used for feed crops and all that is discharged into freshwater supplies. Nevertheless, FAO (2006) states that animal feedstock production in the US uses more land compared to food crop production and thus has a larger impact on water quality.

3.8.6 Comparison of animal and plant-base farming

Vegan farming can be less demanding option. Tilman et al. (2014) calculate that a similar piece of land (2 ha) provides food for an omnivores or fourteen vegetarian or fifty vegans. For instance from 11 kg of protein (wheat, legumes) which calf eats, only ½ of kilogram of animal protein would we gain. According to Tilman and Clark (2014), it means only 5% of what was inserted. Smil (2000) calculates that from 1 acre of land it can get 150-200 kg of vegetable protein (peas, beans). If the same area is used for animal feed production, the gain for humans from slaughtered animal is only 20-50 kg of protein. Gliessman (2000) state that if the consumption of water for the animals, energy expend and labor is counted, the result is that 15 times more plant base food could be produced instead of.

The production of 1 kg of animal protein needs 100 times more fresh water than the production of 1 kg grain. The land required to raise the feed to produce animal protein is 6-17 times greater than for soy protein. Thus, the conversion of plant foods to foods of animal origin is an intrinsically inefficient process (10:1) (Reijnders and Soret, 2003).

In Pimentel and Pimentel (1996) was compared and analyzed a meat-based diet with a lactoovovegetarian (plant-based) diet. In both diets, the daily quantity of calories consumed is kept constant at about 3500 kcal per person. The meat-based food system requires more energy, land, and water resources than the lactoovovegetarian diet. In this limited sense, Pimentel and Pimentel (1996) states that the lactoovovegetarian diet is more sustainable than the average American meat-based diet. In animal foods, the degree of protein concentration seems to decrease the efficiency ratio of energy inputs compared with protein outputs.

3.8.7 Sustainable diet practices

Societal demand, which includes consumer preferences and demands is a major driver of the food system. FAO (2006) defined sustainable diets as those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Furthermore, according to Fanzo et al. (2012), the determinants of a sustainable diet are nutritional adequacy, environmental sustainability, cultural and low-cost accessibility. For example in the US only 2 percent of US crop acreage account for vegetables, fruits, and nuts production (Gliessman, 2000). By contrast, Roos et al. (2015) says that nearly 60 percent is devoted to cereal grains and seeds grown primarily for the production of edible oils. The greatest uses of corn and soybeans include fuel (ethanol and biodiesel), livestock feed, and ingredients such as high-fructose corn syrup, which are used in highly processed food products with low nutrient value. According to Harris (2003), only 10% of grains grown in the US are for direct consumption of humans.

3.8.7.1 Associated diseases and human health

As stated by the FAO (2009) the change to an high (saturated) fat, energy dense diet largely comprising of animal proteins has been known to increase NCDs such as diabetes mellitus, obesity, strokes, heart disease and certain types of cancer. All these NCDs are in detail described in subchapters of main *Chapter 3.7*. Osteoporotic fractures in elderly women have also been suggested to be linked with increased consumption of animal protein in research of Frassetto et al. (2000).

Other matters of concern are drug residues in meat, which may pose a negative effect on human health. This is particularly concerning when the antibiotics that are given to animals, are also given to humans. The magnitude of this problem according to Mellon et al. (2001) should not be underestimated, taking into consideration that more than 70 % of all produced antibiotics in the US are used on livestock for non-therapeutic purposes.

4 METHODS AND MATERIALS

4.1 Samples and method of data collection

The method of data collection was gathered via random sampling and using a questionnaire method. Individual answers on given questions were collected and used for data to be analyzed statistically. Each individual was chosen randomly and entirely by chance via social media or in presence. Hovewer, most of the participants attend BOKU University, Vienna.

4.2 Survey and data administration

The administration mode used was an online survey, which was fully computerized via Google Drive for its free accessibility. This application was used because of its availability, ease of creating a questionnaire, ease of distribution by reference, and particularly for its ability to export data in different formats. Questionnaires were predefined series of questions used to collect information from individuals. Response formats were closed-ended questions so respondents´ asnwer was chosen from a given number of options. Closed-ended questions were preferred in survey research because of the ease of counting the frequency of each response.

The investigation sheet consisted of 11 questions, see *Appendix A.* The questions were divided into four categories:

- demographic information (gender, height, weight, highest reached education level)
- diet preference
- health overview
- willingness to contribute in future sustainability solution

4.3 Data analysis

After data collection each data file was exported to Microsoft Excel for evaluating of given answers. All analyses were conducted with SPSS for Windows statistical software (exact version IBM SPSS Statistics 23), MS Excel and MS Word. Different types of charts and diagrams were created for better graphical data visualization. The numerical data are provided through conclusive tables. Graphical representation varies, but histograms, box plot bars, or pie charts are mostly used.

4.3.1 Statistical hypotheses testing

The stated hypotheses are tested for statistical provement. The data meets the assumptions to conduct The Analysis of Variance (ANOVA). One-Way ANOVA was implemented to test Hypothesis 1. The other hypotheses were analysed via Generalized Linear Models (GLM), which were more suitable. GLMs are extensions of traditional regression models that allow the mean to depend on the explanatory variables through a link function. These models are used for analyzing linear and non-linear effects of continuous and categorical predictor variables on a discrete or continuous dependent variable. After determining the level of significance, a decision is made on whether to accept the null hypothesis or the alternative hypothesis. Hypothesis testing will indicate which of these opposing hypotheses is most likely to be true.

6 RESULTS

6.1 Characteristic of responses

There were 117 online surveys collected. The respondents were divided by gender. The absolute and relative frequency distribution is marked in Table 2. The distribution of gender is in partial imbalance accounting 43% representation of men and 57% of women. Mean weight of all participants was 69 kilos, height 172 cm and BMI 22,2.

Table 2: Gender characteristics of respondents

Value	Absolute frequency	Relative frequency [%]
Male	50	42.74
Female	67	57.26
Total	**117**	**100.00**

In Table 3, weight classification was determined using the participants´ BMI division, according to the WHO. BMI of respondents´ was calculated using Formula 1. As we can see from the table, the most represented group was the normal range of BMI, accounting for 88%. Notice the results of Obese class 2 and Obese class 3 are zero.

Table 3: BMI category distribution according to WHO categorization

Classification	BMI	Absolute frequency	Relative frequency [%]
Underweight	< 18.50	2	1.71
Normal range	18.50 - 24.99	103	88.03
Pre - obese	25.00 - 29.99	11	9.40
Obese class 1	30.00 - 34.99	1	0.86
Obese class 2	35.00 - 39.99	0	0
Obese class 3	≥ 40.00	0	0
Total		**117**	**100.00**

Note: Pre – obese is in section overweight (≥ 25.00), Obese classes in class obese (≥ 30.00)

One of the other questions asked was regarding the level of highest education reached. Table 4 shows the division of education level between participants. The group most represented hold bachelor´s degree accounting for 43%. Those with only "high school" education represent the minority accounting for 4%.

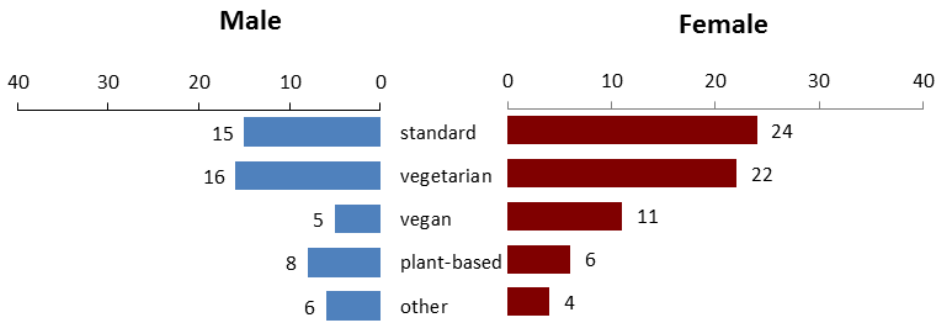
Table 4: Educational characteristics

Highest reached education	Absolute frequency	Relative frequency [%]
High school	4	3.42
College	37	31.62
Bachelor´s degree	50	42.74
Master´s degree	22	17.95
More than Master´s degree	5	4.27
Total	**117**	**100.00**

6.2 Graphical representation

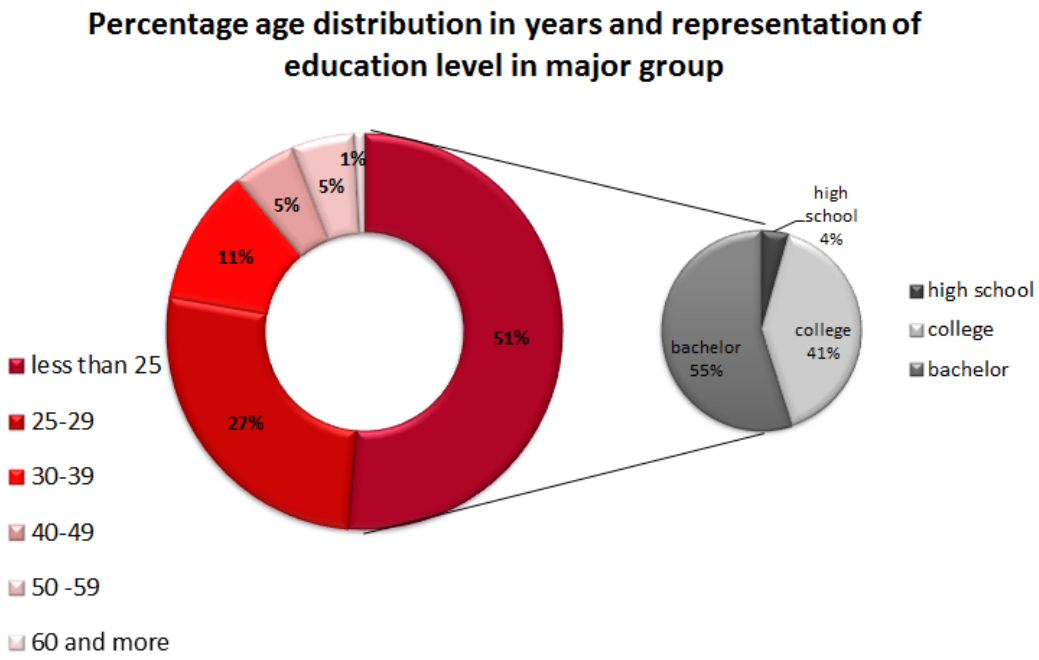
The main results of the investigation are graphically represented and visualized in this chapter. Figure 6 represents gender distribution of different types of diets. The majority represented are women.

Figure 6: Numerical representation of different diets according to gender



Most participants of this survey attend BOKU University, Vienna. In Figure 7, the percentage of participants is represented according to age and education level. An additional pie chart was created representing the education level of the 51 % majority group of participants, which are younger than 25 years of age.

Figure 7: Percentage age distribution related to major education level group



Surprisingly, the "vegetarian" diet accounts for approximately the same distribution as the casual "standard" diet for both genders. The "plant-based" diet represents the minority and the "non-listed" represents unspecified diet. Further more, representation of diets in its percentual distribution was accounted for and registered in Figure 8.

Figure 8: Different types of diets – percentage distribution

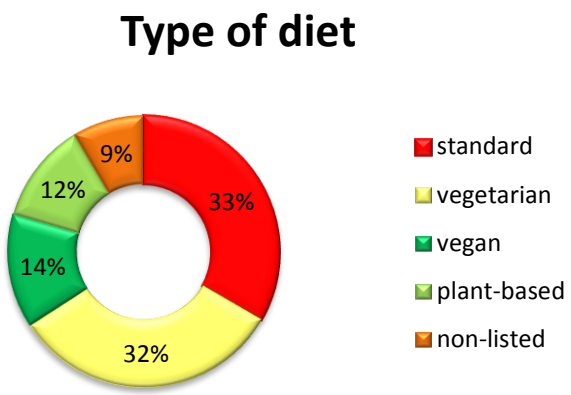


Figure 9 and Figure 10 were created by combining sets of data from previous figures to show a relationship between the diet type and education level. Diet representation within "bachleor´s degree" participants is the most distributed and numerous.

Figure 9: Type of diet related to education level – percentage distribution

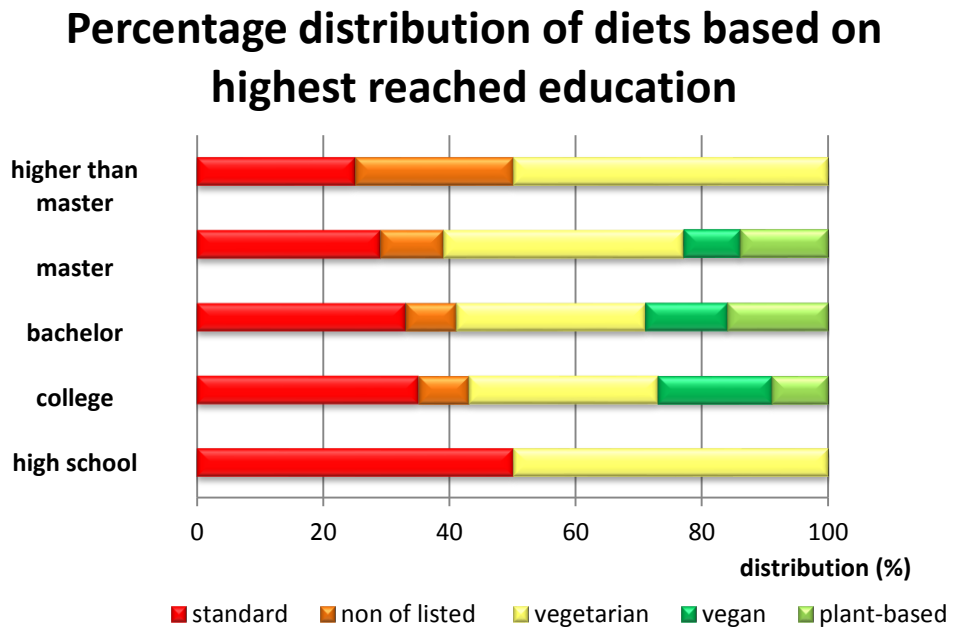


Figure 10: Type of diet related to education level – numerical distribution

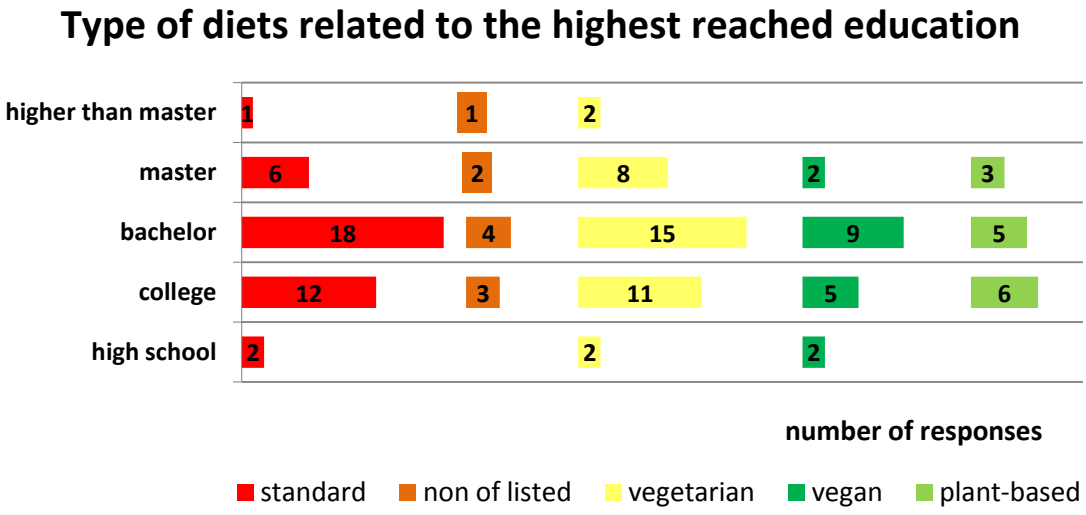


Figure 11 shows a health oveview analysis representing levels of well-being and health. Healthy individuals represent the majority followed by the group “no CVD”. “CVD diagnosed” represents minority group. Figure 12 shows a bar chart representing the percentage pf distribution related to types of diets and health status.

Figure 11: Health overview - percentage distribution

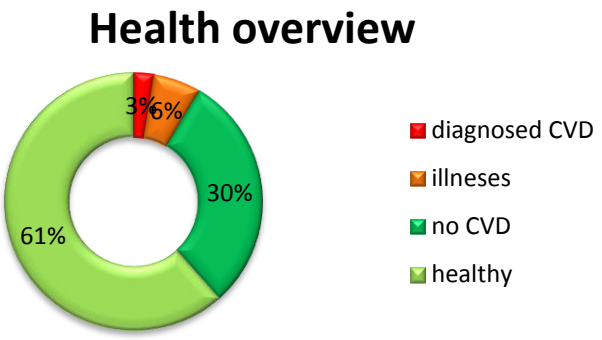
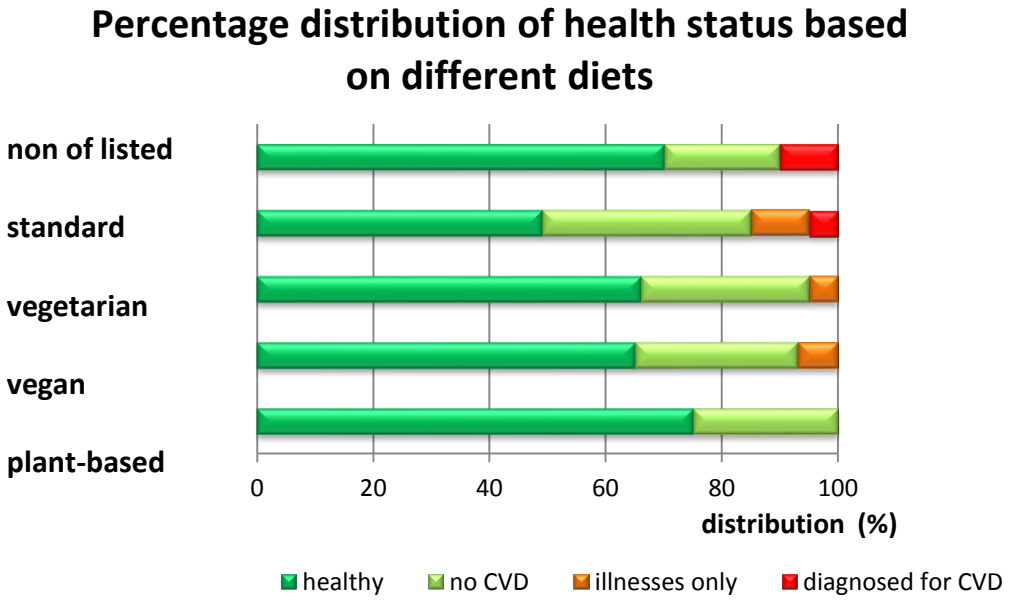


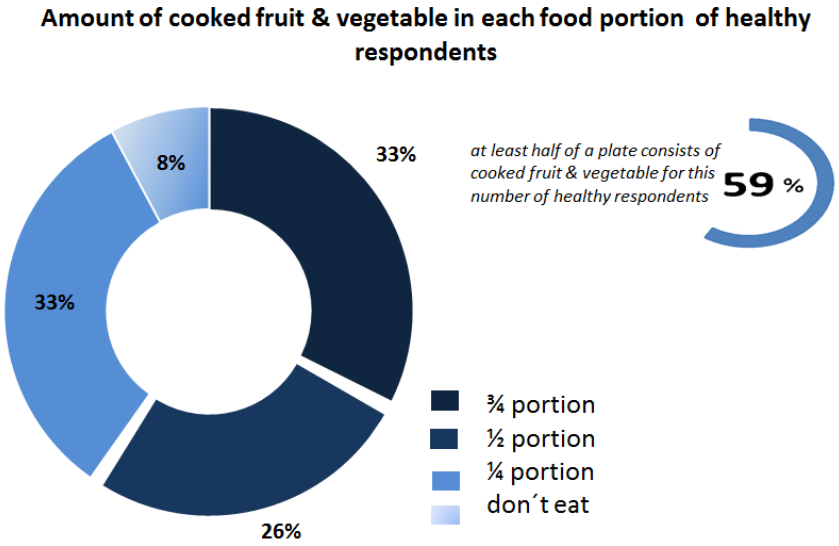
Figure 12: Health status based on type of diet – percentage distribution



Some of the questions in the survey concerned the amount of fruit & vegetables consumed daily which were divided into cooked and uncooked (raw) groups. Seeds, nuts, and beans were counted with fruit & vegetables. Pie charts were created to show a comparison of the participants who claimed they were “healthy” and the amount of fruit & vegetables they consumed daily. The results are graphically illustrated in Figure 13 and Figure 14, and show a percentage of concumption per portion.

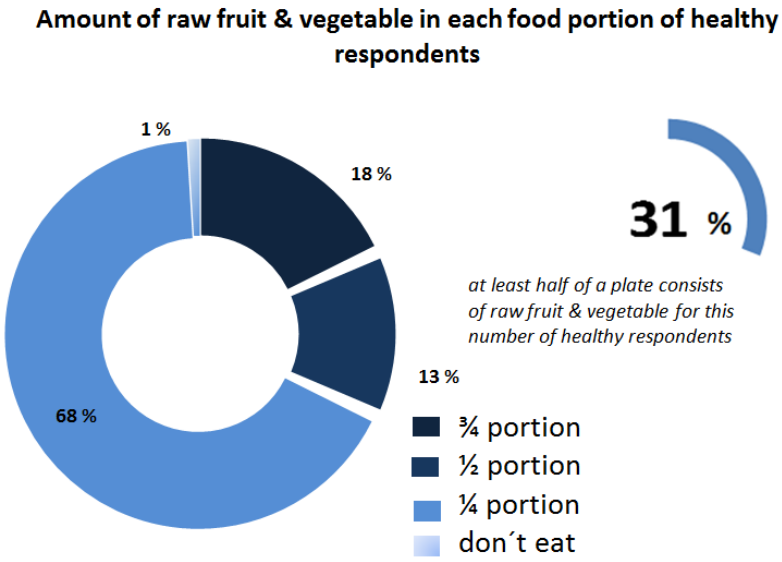
Interesting on this outcome is fact that 59 % of people who confirmed their healthness include mostly cooked fruit & vegetable to their diet in each portion. Furthemore, 31% of them implement half in content of raw fruit & vegetable on their plate.

Figure 13: Amount of cooked fruit & vegetable in diet of healthy respondents



For example: The 26 % represents the number of individuals who consume cooked fruit & vegetables, which accounts for 50% of their daily food intake.

Figure 14: Amount of raw fruit & vegetable in diet of healthy respondents



One's willingnes to convert to a Plant Based Diet (PBD) was also included in the investigation. Respondents were given two choices explaining why they would transition to a PBD, for the health of environment, or for individual health improvement. These aspects were also investigated according to gender. Results are shown in Figure 15 and Figure 16.

Results in Figure 15 indicate that 58% of the investigation group wouldn´t convert to a PBD for environmental reasons. On the other hand, 65% of respondants would change their diet

preference for health improvement. Figure 16 shows that women were the most willing to change to a PBD. Despite their reasons for converting to a PBD both genders had positive feelings about PBD. A staggering 73% of all women and 74% of all men were willing convert to a PBD.

Figure 15: Willingness to go PBD

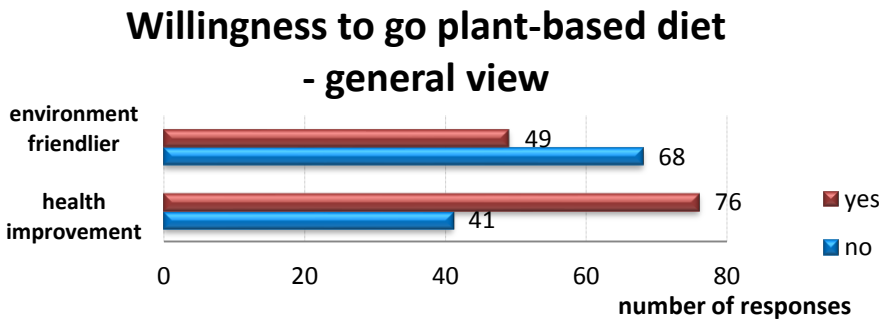
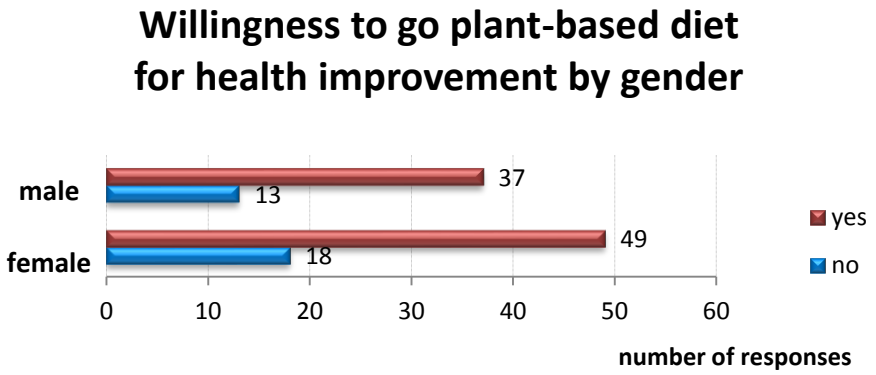


Figure 16: Willingness to go PBD for health improvement



A further look into the willingness to change to a PBD revealed a different result than expected from voters of different diets. When comparing the results for respondants reasoning behind the conversion to a PBD, the results sky rocket for health improvement. Results show that not only "vegetarian" diets were willing to transition to a PBD for health improvement. Respondants of "standard" diets also considered changing to a PBD, which accounts for 82% representing the second majority. On the other hand, there was a negative willingness transition to a PBD for environmental concerns. There were similar findings with the "standard" and "non-listed" groups. However, "vegan" and "vegetarian" groups top the charts with 75% and 60% respectively in Figure 17.

Figure 17: Willingness to go PBD dependent on type of diet for health benefit

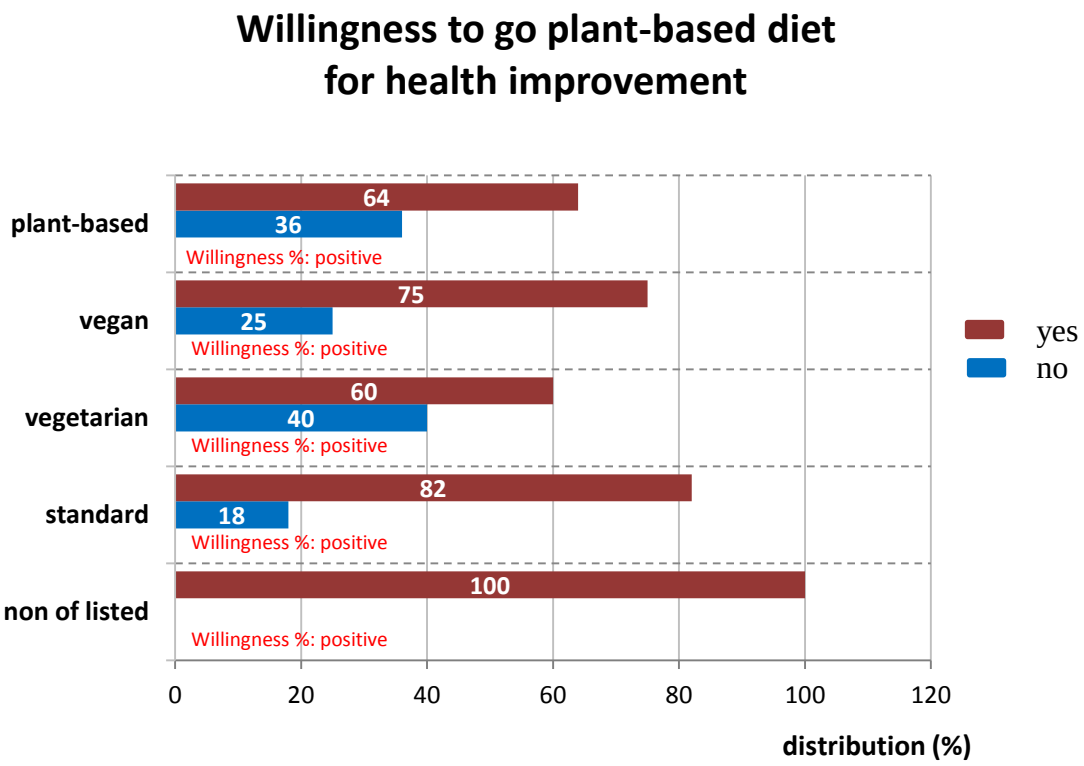
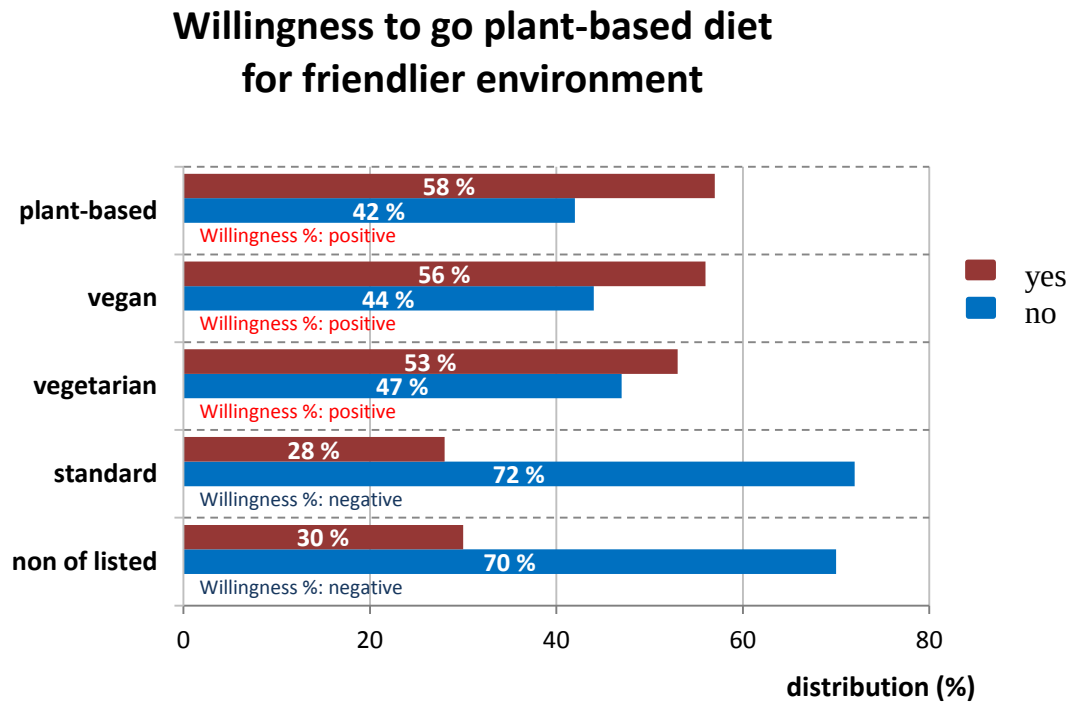


Figure 18: Willingness to go PBD dependent on a type of diet for environmental improve



Envrionment friendly in positive willingness to transition to a PBD were respondants who are already on “PBD” (58%), “vegans” (56%) and “vegetarians” (53%). The percent of distribution shows approximately the same attitude for these groups. Individuals on “standard” diets and “non-listed” diets showed lot less willingness to change their diet with regard to environment sustainability. The percentage for negative willingness shows 72% and 70% respectively.

6.3 Statistical significance

6.3.1.1 Hypothesis number 1

$H1_0$: BMI does not depend on the diet type.
$H1_A$: BMI depends on the diet type.

The pair of hypothesis stated above can be tested using the Analysis of Variance approach (ANOVA). ANOVA requires a normality assumption, independent observations and equal variances in groups. Outcome of ANOVA test (Table 5) is that BMI significantly differs in various diet groups (p-value < 0.000, the corresponding F statistic equals 12.68 on 4 and 112 degrees of freedom). On base of this fact we **reject null hypothesis $H1_0$ and accept the alterantive hypothesis $H1_A$.**

The “standard” diet was considered the reference group, and using contrast statements we compared all other groups with the baseline group. There is no statistical difference among the first three types (standard, vegeterian, and vegan) however, “plant-based” as well as “non-listed” types express statistically larger values of the expected BMI (p-values=0.0230 for difference in “standard” and “plant-based”; p-value < 0.0001 for “standard” and “non-listed”). All tests were perfomed using a significancy level of $\alpha = 0.05$.

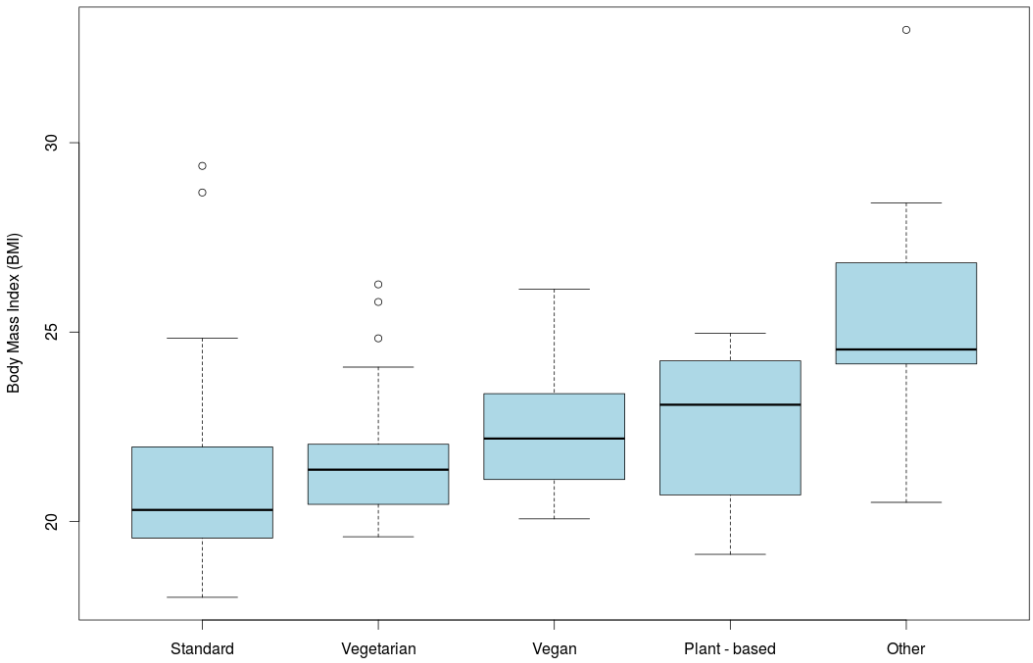
Table 5: Hypothesis 1 – One-way ANOVA table

ANOVA

BMI

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	245,374	4	61,343	12,680	,000
Within Groups	541,817	112	4,838		
Total	787,191	116			

Figure 19: Hypothesis 1 – Boxplots



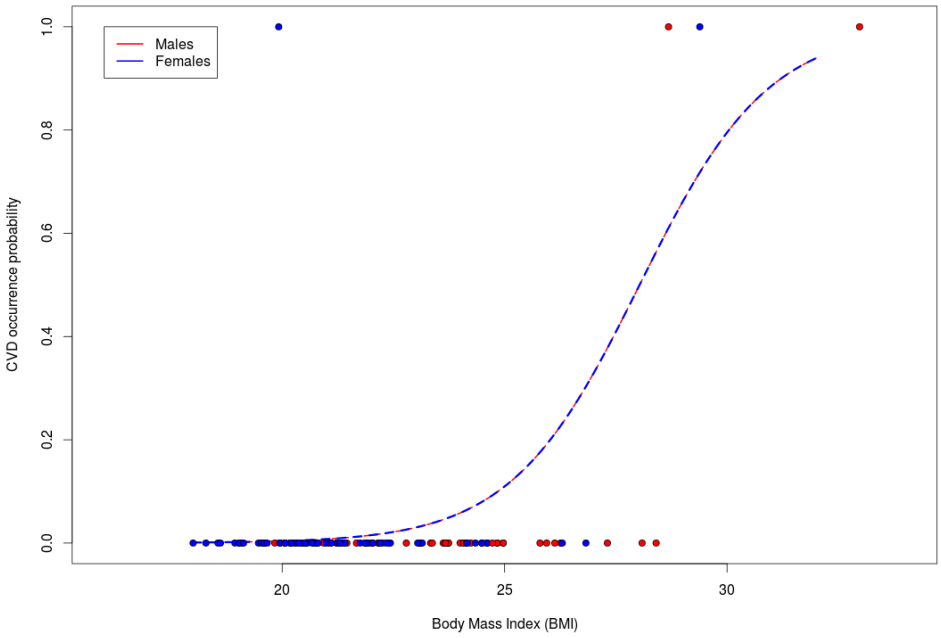
6.3.1.2 Hypothesis number 2

$H2_0$: The CVD occurrence does not depend on BMI, Diet, and Gender.

$H2_A$: The CVD is effected by at least one of BMI, Diet, and Gender.

For this pair of hypothesis we used a concept of a generalized linear model (GLM) for binomial data with a logit link where the CVD occurrence was modelled as 0 (no CVD) and 1 (CVD present). The BMI, gender and diet were used as independent covariates. The only significant predictor for the CVD occurrence turned out to be the BMI (p-value= 0.0019) while gender and the diet type are not significant for the model. The estimated probability of CVD occurrence given by BMI (individually for males and female) is given in Figure 20. The model was constructed using a stepwise forward procedure and the significance level of $\alpha = 0.05$.

Figure 20: Hypothesis 2 – GLM model



For a given subject with male/female specific value of BMI the predicted probability of having CVD can be calculated from the model using a following Formula 2. Formula 2 was created by using data from Table 6.

Formula 2: Prediction probability of having CVD

$$p(CVD) = \frac{e^{(-21.06 + 0.69 * BMI)}}{1+e^{(-21.06 + 0.69 * BMI)}}$$

Table 6: Hypothesis 2 - GLM coefficients

	Estimate	Std. Error	P - value
Intercept	- 21.06	6.14	0.0006
BMI	0.69	0.22	0.0019

6.3.1.3 Hypothesis number 3

$H3_0$: Plant-based diet reduces an occurrence of CVD.

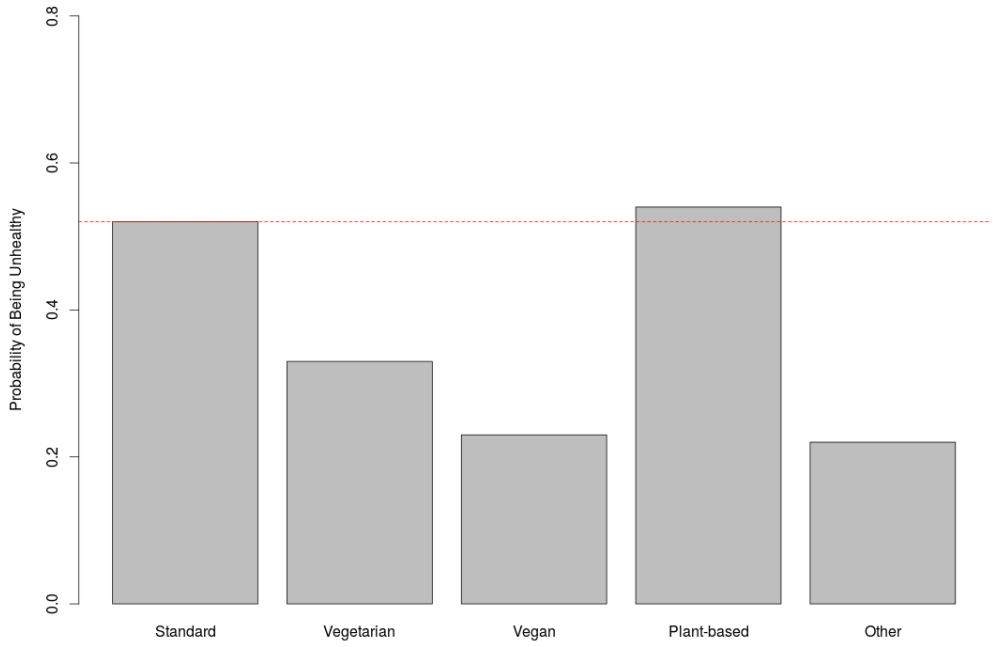
$H3_A$: Plant-based diet doesn´t reduce an occurrence of CVD.

The above listed **hypothesis H3 couldn´t be proved and verified** because of missing data for this category. There was no occurrence of CVD in the dataset for PBD as shown in Figure 12. Based on this fact, after reconsidering possibile solutions a spare hypothesis was added and defined as follows:

$H3^*_0$: Health status does not depend on the diet type and BMI.
$H3^*_A$:Health status does depend on the diet type and BMI.

For this hypothesis, the GLM model was used for binomial data. The logit link was used to model the health status (0 – health subject, 1 – unhealth subject) given the considered covariates. The only significant covariate which turned out to be statistically important for the model is the diet type. However, there is no significant difference between "standard", "vegeterian", "vegan" and "plant-based" diet respectively, but the "non-listed" type of diet significantly differs from "standard" (p-value 0.03), "vegan" and "plant-based". On base of this fact we **reject null hypothesis $H3^*_0$ and accept alterantive hypothesis $H3^*_A$.** Empirically (see Figure 21) one can conclude that there are differences in all types of diets, but these differences are too small to be statistically significant in our sample size. For determining the probability of being unhealthy Formula 3 was created with specific numbers listed in Table 7.

Figure 21: Hypothesis 3 – GLM bar chart model



Formula 3: Probability of being unhealthy

$$p\,(being\ unhealthy) = \frac{e^{(0.10\ +corrector\ estimate)}}{1+e^{(0.10\ +corrector\ estimate)}}$$

Table 7: Hypothesis 3* coefficients

	Estimate	Std. Error	P - value
Intercept	0.10	0.31	0.75
Corrector for vegetarian	-0.79	0.48	0.10
Corrector for vegan	-1.30	0.73	0.07
Corrector for plant-based	0.05	0.64	0.93
Corrector for other diet	-1.35	0.64	0.03

7 DISCUSSION

Who has a healthy diet and what is a healthy diet are questions scientists have been trying to answer for decades. Overall, eating plant-based foods are vastly different nutritionally than eating animal-based foods. Plant-based foods have a drastically higher amount of antioxidants, fiber, and minerals than animal-based foods *(Appendix B).*

The past decades has seen an expansion of epidemiologic and clinical research on the role of plant-based foods and eating patterns in the prevention of CVD. This research has revolutionized our thinking about heart-healthy foods, and the biological mechanisms linking dietary factors concerning CVD. If nutrition were better understood and prevention more accepted, avoidance of CVD coud be easily met.

The main aim of this thesis is to highlight the significance of PBD and its positive impact on human health and prevention of civilization diseases. This thesis investigates a relationship between different diets and CVD. In addition, PBD were investigated from the perspective of environmental and food-sustainability.

7.1 Data collected

The fact of surveyed participants has to be brought into account and considered. The majority of respondents are daily full-time students at BOKU University, Vienna, and 51% of them are younger than 25 years old. Kelder et al. (1994), indicates that dietary habits acquired in childhood persist through to adulthood. However, students in this investigation having extensive knowledge about human nutrition are more likely to be influenced in their diet preference than the standardized wide population. Therefore, specific diet types like “veganism” and “plant-based diet” might appeared only within this educational status (Figure 9 and Figure 10). The “high school” group was represented by two diet categories, “standard” and “vegetarian”. No wonder the “standard” diet was mostly represented within this group. Females in general, are more willing to diet for an ideal thin body shape, weight, and general satisfaction. In the survey, females acounted for 57 %, which should be considered further understanding the data distribution.

7.2 Data outcomes

$H1_0$: BMI does not depend on the diet type.

$H1_A$: BMI depends on the diet type.

The outcome of H1 testing is rejected null hypothesis $H1_0$ and accepted alternative hypothesis $H1_A$. The dependency of BMI on a type of diet is significant. The boxplot in Figure 19 shows that the highet BMI is expected for individuals with "other" diet. The smallest BMI is expected for individuals with "standard". The level of significance for BMI dependency on diet was significant for diets: "plant-based" (p-value=0.0230) and "non-listed" (p-value<0.0001), while the other types were not statistically significant.

Davies (1997) conducted an investigation about the relationship between diet composition and BMI and his hypotheses were significant. However, other factors such as energy intake and levels of physical activity might have a more important influence on BMI.

$H2_0$: The CVD occurrence does not depend on BMI, diet, and gender.
$H2_A$: The CVD is effected by at least one of BMI, diet, and gender.

The health benefits of a PBD investigated in the theoretical part are lower cholesterol level, blood pressure, blood sugar, and prevents of heart disease. In the experimental part, an occurrence of participants with CVD appeared in four examples, which was a small sample size to divide into type categories. In statistical testing of Hypothesis 2 CVD occurrence dependent on BMI, diet, and gender was evaluated. The only significant predictor for CVD occurrence were results related to BMI (p-value=0.0019). CVD results were progressive; one unit of an increase in BMI roughly doubles the chance of having CVD. The gender and diet type covariates were not significant.

The diet predictor was not siginificant in the considered model because there were only four observations available with the CVD present. Formula 2 was created to predict the probability of having CVD.

$H3_0$: Plant-based diet reduces an occurrence of CVD.
$H3_A$: Plant-based diet doesn´t reduce an occurrence of CVD.

In Figure 12, there appears to be a direct relationship with healthy respondents on a PBD, but the facts have to be statistically proved. Hypothesis 3 illustrates the provement of plant-based diets reducing an occurance of CVD. Unfortunately, the testing couldn´t be statistically verified because of missing data for this category. There was no occurance of

CVD in the dataset for PBD. Therefore, a spare Hypothesis 3*, was added to express the unhealthy status dependency on the diet type and BMI.

$H3^*_0$: Health status does not depend on the diet type and BMI.
$H3^*_A$:Health status does depend on the diet type and BMI.

The dependency was significant for the diet "non-listed" (p-value=0.03). There is no significant difference between other diet types (see more in Figure 20). There was an additional question in the investigation sheet for those who chose the type of diet "non-listed", to specify their diet. The answers were Kosher, Hindu, Atkins, Paleo or high-protein diet. Formula 3 was modelled to determine the probability of being unhealthy on different types of diet.

The sustainable effect of PBD was investigated only theoretically in *Chapter 3.8*. There is need to change the current system because it is simply not sustainable. Gliessman (2000) states that PBD in comparison to meat-based diets are safer and sustainable because they use substantially less natural resources, and are less taxing on the environment. Therefore, in the experimental part participants were asked about their willingness go on PBD for environmental improvement. The most willing were respondents on the different types of vegetarian diets. For example, "plant-based" eaters (58%), "vegans" (56%), and "vegatarians" (53%). On the other hand, respondents of the "standard" and "non-listed" diets showed negative attitude towards the environment (Figure 18).

An unwise selection of foods can leave one short of certain nutrients and may induce deficiency symptoms and adverse health outcomes. The potentially deleterious effects of vegetarian diets include anaemia due to iron or B12 deficiency, and deficiencies of calcium, zinc, vitamin D, and vitamin B6. For example, insufficient calcium and vitamin D can compromise bone structure. Because B12 and iron assist with the production of red blood cells these elements are also necessary to be checked regularly to avoid defficinecy. According to Dunn et al. (2001), B12 supplementation may be required since they don´t consume any kind of animal products. Gliessman (2000) states that plant´s compounds as phytic acid, lectins, tannins have been shown to reduce the availability of nutrients. On the other hand, Campbell (2006) confirms in his study that the participants had reached a new equilibrium on the vegetarian diet (what is regarding vitamin and mineral daily intake).

Major topic regarding vegetarian diet in general exist on protein amount. Generally, proteins are categorized into two groups based on efficiency: high quality and low quality. High-quality proteins are more efficiently used by the human body and are derived from animal-based foods, whilst low-quality proteins have a lower efficiency and are plant-derived. Trichopoulou et al. (2003) see the main difference that high-quality proteins contain the "best amino acid matches," whereas low-quality proteins individually may not have one or more of the essential amino acids, but as a group they contain them all. However, lower availability of some amino acids in plant foods does not signify in the investigation part that animal protein is a better protein for human health. This merely suggests that to ensure dietary adequacy, a diet based on plant proteins must be diverse.

7.3 Final recommendations

The chosen topic is very interesting, but further research on PBD and public health could be specialized more in detail in these fields:

- to define a moderate balance to obtain a maximum benefit from converting to a PBD
- in the context of civilization disease prevention, it would be advisable to reconsider and change dietary recommendation and guideliness - would be appropriate to focus on deepening knowledge
- focus on a specific group of CVD diagnosed people (like patients with type 2 diabetes) and investigate probability of reversion to normal health status while being on PBD
- investigate further the category "non-listed" diet, since it resulted in being the significantly most unhealthiest

Ideally there would be one international survey of food intake which assessed a representative sample of males and females of all ages, cultures, religions, geographical locations, and used the same definitions of food as a means to describe the content of people´s diet across the world. This survey has yet to be created. However, surveys of various age groups in countries using different measures have slowly emerged representing data related to diet.

8 CONCLUSIONS

Theoretical part:

- diets with at least two-thirds of their energy coming from plant-based foods are recommended by the vast majority of health organizations
- as long as the diet consists of healthy fats, carbohydrates, high consumption of amino acids, fiber, minerals, antioxidants, vitamins, and phytochemicals it benefits our body
- get most of nutrition from a variety of whole foods
- focus on getting adequate protein, B vitamins (especially B12), vitamin D, essential fatty acids, and minerals such as iron and zinc
- B12 supplementation may be required
- the health systems in developed countries seek to cover up and reverse increased appearances of CVD, but never truly look at the start of the problem of today´s common diseases
- food sustainability is an urgent matter that depends on collaborative efforts from governments, the private and public sectors and individuals

Experimental part:

- participants on different diets expressed a positive interest in converting to a PBD
- BMI depends on the diet type because "PBD" and "non-listed" diets express statistical significance
- the significant predictor for CVD occurrence is BMI while gender and diet type are insignificant
- the unhealthiest subjects are on the "non-listed" type of diet and the smallest probability of being unhealthy is predicted for PBD
- ischaemic heart disease, stroke, lower respiratory infections, and chronic obstructive lung disease have remained the top major killers during the past decades in developed world
- individuals on "standard" diet and "non-listed" are not willing to transition to PBD for friendlier environment compared with the rest of the groups, which show a compelling interest

9 LIST OF ABBREVIATIONS

CVD	– cardiovascular disease
GLM	– Generalized Linear Model
ANOVA	– Analysis of Variance
PBD	– plant-based diet
ABD	– animal-based diet
LDL	- low-density lipoprotein
TC	- total cholesterol
RDA	- recommended daily allowance
GHG	- greenhouse gas

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11 APPENDIXES

A) INVESTIGATION SURVEY

INVESTIGATION SURVEY

Participants,

My name is Katerina Schreiberova, a native of the Czech Republic. I am conducting a survey to collect data for my master thesis. My primary focus is researching plant-based diets, its distribution and implementation in human diets and possible health benefits. The survey consists of 11 questions and should only take a minute of your time.

Thank you for your time,

Best
Katerina Schreiberova

☐ pls, check the box if you are related to BOKU Universtiy, Vienna (student, teacher, academic staff)

Please circle or fill in your answers:

1. Height in cm: _____

2. Weight in kilos: _____

3. My gender is:
   - Female
   - Male

4. My age is (yr):
   - Less than 25
   - 25-29
   - 30-39
   - 40-49
   - 50-59
   - 60 and more

5. My education is:
   - High school
   - College
   - Bachelor´s degree
   - Master´s degree
   - More than Master´s degree

6. Type of your diet:

Standard usual diet, don’t think about it
Vegetarian
Vegan
Whole plant-based
Non-listed ➢ please specify _____

7. Amount of fruit & vegetable* portion in your diet a day:

Don’t eat it at all or small amount if so
Each meal includes ¼
Each meal includes ½
Each meal includes ¾
Each meal includes more than ¾

* also count seeds, nuts and beans

8. Amount of whole raw (uncooked) fruit & vegetable* portion in your diet a day:

Don’t eat it at all or small amount if so
Each meal includes ¼
Each meal includes ½
Each meal includes ¾
Each meal includes more than ¾

* also count seeds, nuts and beans

9. My health is:

I am diagnosed for serious cardiovascular disease (CVD), cancer or obesity
Suffer only from regular illnesses time to time
I am not diagnosed for CVD for sure and don´t have even other health issues
I am healthy

10. Would I go on plant-based diet if there is possibility of my health improvement?

Yes, I would
No, I wouldn’t

11. Would I go on plant based diet in future to sustain agriculture and also decrease carbon footprint on the environment by this change?

Yes, I would
No, I wouldn’t

As a survey participant, I would like to receive the concept of final thesis via email:

B) SUMMARY OF MICRONUTRIENTS IN FOODS

Table 8: The vitamins, their principal functions and deficiency diseases.

Vitamin		Functions	Deficiency disease
A	Retinol B - Carotene	Visual pigments in the retina; cell differentiation	Night blindness
D	Calciferol	Maintenance of calcium balance	Rickets, osteomalacia
E	Tocopherols Tocotrienols	Antioxidant, especially in cell membranes	Extremely rare: serious neurological dysfunction
K	Phylloquinone Menaquinones	Coenzyme in enzymes	Impaired blood clotting
B_1	Thiamin	Coenzyme in pyruvate	Beriberi
B_2	Riboflavin	Coenzyme in oxidation &reduction reaction	Seborrheic dermatitis
B_6	Pyridoxine Pyridoxal Pyridoxamine	Coenzyme in transamination and decarboxylation	Disorders of amino acid metabolism
B_{12}	Cobalamin Pantothenic acid	Coenzyme in transfer of one-carbon fragments	Pernicious anemia, peripheral nerve damage
niacin	Nicotinic acid	Coenzyme in oxidation & reduction reaction	Pellagra: photosensitive dermatitits
folic acid		Coenzyme in transfer of one-carbon fragments	Megaloblastic anemia
H	Biotin	Coenzyme in carboxylation reactions	Dermatitis
C	Ascorbic acid	Coenzyme in hydroxylation	Scurvy

Source: Gibney (2009)

Table 9: Plant source vitamins

Vitamin A	Avocado, bell peppers, canteloupe, carrots, chili peppers, collard greens, mangoes, spinach, sweet potatoes
Vitamin B	Brown rice, cabbage, fermented foods, legumes, nutritional yeast, nuts-almonds, brazil nuts, cashews, peanuts, quinoa, seeds, wild mushrooms
Vitamin C	Bok choy, broccoli, brussels sprouts, citrus fruit, papaya, pineapple, raspberries, strawberries
Vitamin D	Bertain mushrooms including chanterelle, oyster, portobello, shiitake, and cremini
Vitamin E	Almonds, avocados, brazil nuts, chia, quinoa, sunflower seeds, walnuts
Vitamin K	Basil, beet greens, bok choy, broccoli, kale, pumpkin seeds, spinach, turnips

Source: Olien (2015)

Table 10: Percent calories from protein of certain foods

Broccoli:	44% Cal from protein (4% from fat)
Kale:	28% Cal from protein (1% from fat)
2 % milk:	26% Cal from protein (36% from fat)

Cheddar Cheese:	25% Cal from protein (75 % from fat)
Navy Beans:	23% Cal from protein (4% from fat)
Whole Milk:	21% Cal from protein (48% from fat)
McDonald´s Hamburger:	20% Cal from protein (33% from fat)

Source: USDA (2000); International Osteoporosis Foundation (2016)

Table 11: Protein content of certain foods

Lentils cooked, 1 cup	18 grams
Black beans cooked, 1 cup	15 grams
Chick peas cooked, 1 cup	15 grams
Hemp seeds, 3 tablespoons	9 grams

Source: The Vegetarian Resource Group (2016A)

Table 12: Plant source minerals

calcium	apricots, brussels sprouts, butternut squash, cabbages, chard, dandelion leaves, figs, pistachios, plums, sesame seeds or tahini, spinach, turnips
magnesium	avocado, bananas, beet greens, brazil nuts, cashews, kiwis, peas, prunes, squash
potassium	broccoli, cabbage, carrots, cherries, currant, kiwi fruit, mushrooms (white), peanuts, sweet potato
iron	coconut, legumes (beans and peas), macademia nuts, oats, raisins, sesame seeds, sun-dried tomatoes, watercress
copper	apricots, cashews, coconut, hazlenut, kale, peaches, pecans, portobello mushrooms, shitake mushrooms, walnuts
zinc	green peas, lemongrass, oats, pecans, pumpkin seeds, shitake mushrooms, spinach
phosphorus	alfalfa sprouts, avocados, broccoli, celery, chia seeds, kiwi fruit, pistachio, wild rice, zucchini, watercress
manganese	blueberries, chillies of any color, collard greens, currant, eggplant, garlic, grapes, leeks, pumpkin sees, raspberries
selenium	brazil nuts, broccoli, brussels sprouts, coconut, garlic, grapefruit, mushrooms, spinach, sunflower seeds

Source: Heimendinger (1995); Ness (1997); Rui (2003)

Table 13: Calcium content of certain foods

Broccoli cooked, 2 cups:	360 mg
Milk, 1 cup:	300 mg
Figs, 10 medium, dried:	270 mg

Source: The Vegetarian Resource Group (2016B)

Table 14: Potassium and sodium content of certain foods

Potato, medium	845mg (+ 16 mg sodium)
Black beans cooked, 1 cup	800 mg (+ 6 mg sodium)
Banana, medium	450 mg (+ 1 mg sodium)
Skim milk, 1 cup	400 mg (+125 mg sodium)
Cheddar cheese, 2 ounces	56 mg (+350mg sodium)

Source: Olien (2015)

11.1 List of Appendixes

A) Investigation sheet

B) Summary of micronutrients in plant-based foods