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Bachelor thesis

Least cost healthy diet

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Thesis title

Least cost healthy diet

Objectives of thesis

The object of the study is to find the solution for least cost diet, for that needs to set up the menu, which includes healthy foods and satisfies person's nutritional requirements. The diet problem regulates the number of calories and the amounts of vitamins and minerals to be taken despite of the final aim of a person either to gain muscle, to lose weight or to keep fit. However, the output might not be with regard to taste and variety that should be taken into account before considering the menu as "optimal".

Methodology

To solve the least cost healthy diet problem can be used linear programming model. Linear programming is a general method to find the best possible solution with limited resources to achieve maximum profit or minimum cost. The objective of the diet problem is to minimize the cost of the food while allocating the specific nutritional requirements as the constraints and assigning variables for amounts of food that should be solved and parameters for the data that is known. When the variables are defined, the cost of food can be found with the minimum optimal value.

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Keywords

Healthy lifestyle, diet, nutritional requirements, healthy food, minimize cost.

Recommended information sources

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Declaration

I declare that I have developed and written the Bachelor Thesis titled "Least cost healthy diet" completely by myself, and have not used sources or means without declaration in the text. Any thoughts from others or literal quotations are clearly marked.

In Prague on ___________________________

Alexandra Ganzyuk

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Least cost healthy diet

Nejméně nákladná zdravá strava

Summary

This thesis examines linear programming approach used in the healthy diet. The main goal is to minimize costs within meeting daily nutritional requirements.

In the theoretical part, the several reasons are reviewed, which influence people's eating behavior. These are national food habits, human stubbornness to changes and high prices on food, considered healthy. Furthermore, the global problems, which are directly related to the research, are examined. There are analyzed the tight relations between obesity, hunger, and food wastage and even suggested some solutions to the problems.

Moreover, all the criteria, which are used in the practical part, are fully explained. The further nutritional requirements are established according to the set of criterions. The linear programming model is used for two cases – male and female – within specified for both of them amounts of nutrients. The simplex algorithm as a basic method of linear programming is applied to the healthy diet problem to achieve the optimal solution.

Keywords: healthy lifestyle, diet, nutritional requirements, healthy food, minimize cost.

Souhrn

Tato práce zkoumá lineární programovací přístup použitý ve zdravé výživě. Hlavním cílem je minimalizovat náklady v rámci splnění denních výživových požadavků.

V teoretické časti jsou rozebrány některé fakty, které ovlivňují lidské stravovací chování. Jsou to národní stravovací zvyky, lidská tvrdohlavost ke změnám a vysoké ceny na jídlo, které je považováno za zdravé. Kromě toho globální problémy, které jsou přímo spojené s výzkumem, byly prozkoumány. Byl analyzován těsný vztah mezi obezitou, hladem a plýtvaní potravinami a dokonce bylo nabídnuto několik řešení těchto problémů.

Více méně, všechna kritéria, která byly použity v praktické časti, jsou zcela vysvětlovány. Další nutriční požadavky jsou stanoveny v závislosti na souboru kritérií. Lineární programovací model je používán ve dvou případech – mužský a ženský – spolu s určenými pro ně dávkami živin. Simplexový algoritmus jako základní metodou lineárního programování je používán ve zdravé výživě pro dosažení optimálního řešení.

Klíčová slova: zdravý životní styl, strava, výživné požadavky, zdravá výživa, minimalizovat náklady.

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1. Introduction

Nowadays one of the biggest issues considering in our society over and over again is a diet. Fashion dictates us how the ideal body shape should be. Skinny body images are constantly appearing in magazines, television's shows, on the Internet pop-up advertisements. That is why the diet is commonly used in the meaning of loose weight, which is actually not true. Initially, this term means to keep your body healthy consuming the needed amount of nutrition according to the final goal of a person – either to loose weight or to gain muscles.

The social pressure for thinness is rising, which influences people, especially teenagers, and causes eating disorders. In pursuit of happiness, which is by media brainwashing equals to have an ideal figure; people are starving, over-exercising – basically, exhausting their bodies. As the result, some of them suffer from anorexia, bulimia and other diseases of eating disorders, which may cause problems with human mental health conditions and even to the fatal outcome.

Moreover, they spend a lot of money on special diet programs, consultations of nutritionists and bio healthy food. They are led by marketers and forget that the main aim of fashion and diet industries to make a profit rather than to help them.

However, there is another global problem – obesity. It is even bigger than worldwide hunger. This problem arises from the lack of money and time. In megalopolises people are so busy all the time: they are used to have fast food for ingestion at least once and sometimes even more during the day. On the average workers have sedentary work; hence the result – obesity.

The knowledge of linear programming approach can help people, who have a strong desire to change their lives and not to stress themselves about the diet anymore, to solve the diet problem once and for all.

2. Thesis Objectives and Methodology

2.1. Objectives

The object of the study is to find the solution for least cost diet, for that needs to set up the menu, which includes healthy foods and satisfies person's nutritional requirements. The diet problem regulates the number of calories and the amounts of vitamins and minerals to be taken despite of the final aim of a person either to gain muscle, to lose weight or to keep fit. However, the output might not be with regard to taste and variety that should be taken into account before considering the menu as "optimal".

2.2. Methodology

To solve the least cost healthy diet problem can be used linear programming model. Linear programming is a general method to find the best possible solution with limited resources to achieve maximum profit or minimum cost. The objective of the diet problem is to minimize the cost of the food while allocating the specific nutritional requirements as the constraints and assigning variables for amounts of food that should be solved and parameters for the data that is known. When the variables are defined, the cost of food can be found with the minimum optimal value.

2.3. The importance of Study

The study focuses on the possibility of using linear programming approach to solve real life problems. This work may help to simplify a person's decision-making regarding the healthy diet without spending a lot of money on food. The least cost healthy diet output can show a person that it is not necessary to abandon the favourite kinds of food and overpay for bio and healthy goods. Making the research for the nutritional amounts needed and setting up an individual desirable menu is the key for a preferable solution.

The study provides an opportunity to create new, alternative and various options to eat healthy with minimum costs.

3. Theoretical Part

The books, articles, research papers were examined and considered by the author of this thesis as relevant to determine the research subject. All resources used are mentioned below.

3.1. Eating habits of different countries

There are a lot of different people with huge variety opinions on everything. They are from different countries and nations, have unlike religious and political views, and differentiate by social status and financial position. That is exactly the reason why people have dissimilar eating habits all over the world.

Even though a person decides to eat healthy or not, the country's food habit influences a lot his or her choice. Some countries initially have healthy eating habits.

Japan has very low obesity rates. Traditional Japanese food, such as sushi, is low in saturated fats, high in fiber and packed with vitamins, minerals, and omega-3s from the fresh fish. The main staple – rice - is filled with healthy nutrition, while tofu and seaweed are full of protein. Seaweed is also rich in zinc, antioxidants, and vitamins A and C. Japanese also use small and colorful portions, which referring to the advice of dietitians may help to keep calories in check and seasonal vegetables make it visually appealing (Shoemaker, 2013).

Therefore, the population of Japan has one of the highest life expectancies in the world. It can be definitely pinpointed to its diet, which is high in certain carbohydrates, vegetables, fruits as well as fish and meat. Additionally, healthy drinks such as tea and water are also regularly consumed in Japan (Gander, 2016).

The Nordic nations including Sweden, Denmark, Norway, Finland and Iceland usually eat rye bread, oily fish, local fruits such as rose hip, root vegetables, and fermented milk and cheese. A recent study in "The American Journal of Clinical Nutrition" showed that the Nordic diet helps people to reduce inflammation, which has been linked to chronic conditions and an increased risk of colon cancer (Gander, 2016).

The traditional food of Nordic countries is high in fiber, low in sugar and contains plenty of fruits and vegetables. For instance, rye has tons of fiber, and the strong-flavored loaves have been approved to keep people fuller longer than regular wheat bread. Moreover, the Nordics consume not so much meat dishes and processed dairy foods (Gander, 2016).

The well-known Mediterranean diet is one of the world's healthiest - thankful to included in the daily ration lots of fresh fruits and vegetables, whole grains, beans, nuts and seeds, herbs and spices, and olive oil and supplemented with occasional dairy, poultry, fish, and red wine. The Mediterranean diet "doesn't just promote a healthy body, but can actually make us happier, too" (Breene, 2014).

BDNF, a protein that controls many important brain activities, affects human cognitive function and mood. Studies show that changes in BDNF level may cause the risk of mental disorders like schizophrenia and depression. However, sticking to the Mediterranean diet can help to stabilize the level of BDNF (Wenk, 2015).

Nevertheless, according to the World Health Organization's recent study, the level of obesity raises each year and overweight can cause diabetes, coronary artery disease, strokes and certain forms of cancer (who.int/en, 2016).

The highest percent of human eating disorders are in the countries of the unhealthiest food habits. The United States is well known as the king of junk food. According to the statistics, there were 242,611 establishments in the U.S. fast food industry, which had generated approximately 206,3 billion U.S. dollars in 2016 (statista.com, 2016).

Regarding the incredible statistics about the fast food industry, it is not surprising that the obesity is one of the biggest threats to the national health of the U.S., putting millions of Americans at increased risk for a range of chronic diseases. Overall, 38 percent of adults and 17 percent of teenagers are obese. (niddk.nih.gov.aspx, 2017).

Although the USA are known to have the unhealthy diet, a factor that causes the obesity epidemic, a new study reveals that the country does not have the worst diet in the world. The research was based on the diet patterns such as the amount of healthy and unhealthy items consuming by different nations. Armenia takes the first place among the unhealthiest diet countries. Armenian cuisine is as ancient as its history and certainly tightly connected to the nation's eating habits. The rank is followed by Hungary, which is famous for its rich goulash and Belgium, known for its chocolate and waffle. Even though the researchers could rank the countries, they pointed that in comparison to the previous study there is not such large difference seen between countries anymore (Micha, 2015).

3.1.1. Do people want to change their food habits?

Although the media keeps saying that the problem of overweight is rising each year and offers the methods to combat the adiposity. It propagandizes the healthy lifestyle, publishes articles with advice on the web pages, but the obesity rates still do not change.

There is no need to dig deep, trying to get to know the truth – the answer lies on the surface. People simply do not want to change, to leave their comfort zone.

The recent research project, made by National Geographic and Globe Scan in 2014, tried to get an insight related to the food consumption and behavior change. The report is based on the results of online interviews with approximately a thousand consumers in each of the 18 countries, representing both developed and developing. The study found that the vast majority of the countries, including the U.S., agree that food is an essential part of their culture. The half of all consumers admitted that they prefer to "eat the food and recipes they grew up with, rather than the latest trends in food." Especially it refers to French and Russians, who turned out to be the most stubborn to change their food culture (nationalgeographic.com, 2014).

The results are definitely interesting, because Russia, for instance, is among the top ten countries, which were scored as the highest for consuming unhealthy foods (niddk.nih.gov.aspx, 2017).

French, as well as Russians, are tied up to their cultural food. However, only 24 percent of the French population is considered obese. This is mostly due to their eating habits. Even though they consume food that is high in saturated fat, they eat slowly and in small portions, rarely go to fast food restaurants and buy highly processed foods from supermarkets (Ballinger, 2011).

Moreover, summarizing the data, the research showed that the developed countries are more resistant to change their eating habits rather than the developing ones. Referring to the U.S. as a good example of developed and at the same time stubborn country to explain why people behave like that. The Americans' long-standing preference for packaged foods and entrenched already unhealthy eating habits make a choice in favor of healthy and less heavy foodstuffs, enriched with nutrients more difficult, even if they understand the problem and its consequences (nationalgeographic.com, 2014).

3.2. How the price influences people's choice of food

The price of food is defined by the quantity and the quality of nutrients included. Added sugars and fats, which are surely necessary for the health in the specified amounts of intake, became the most harmful nutrients since people overeat them. Processed foods, rich in added sugars and fats, are relatively cheap because they provide people the needed energy to live, but short-term and not meeting the daily nutritional requirements. The long-term consumption of the foods, providing mostly empty calories and poor amounts of vitamins and minerals, which are highly needed for the organism to survive, puts people at the risk of metabolic syndrome, diabetes, cardiovascular diseases and, of course, obesity (Siriwardhana, 2012).

On the other hand, the food such as fruits and vegetables are more expensive than junk food. However, it is rich in healthy nutrients and helps to achieve the daily nutritional intake without too many empty calories, which will be converted into fat if there is a surplus of them. The healthy foods, abundant with vitamins and minerals, keep a person full for a longer period of time than added sugars and fats foods. That can be the most likely explanation of higher prices for nourishing food (Siriwardhana, 2012).

According to the Dietary Guidelines 2015-2020, nowadays there are under-consumed nutrients such as magnesium, calcium, potassium, choline, dietary fiber, iron and vitamins A, D, E, and C. They are considered as nutrients of public health concern. The low intakes of potassium, magnesium, vitamin C, which are obtained from fruits and vegetables, and calcium and vitamin D - from dairy products and fortified foods, are explained by the higher prices on these types of goods (Dietary Guidelines Advisory Committee, 2015).

One of the most basic economics laws is "Law of Supply and Demand", which defines the dependence of supply and demand of goods at the market on their prices. People's choice of food in favor of cheaper option of fulfillment is easily explained by the law of demand, which states that an increase in the price of a good or service will decrease demand, holding all other factors constant, and vice versa.

The reduction of prices of healthful food definitely will push consumers to buy more rich-nourishment foods and, as result, the national health will rise in the countries. But the public health strategy will not have a success until it gets the initiative from policies and industry collaborations (French, 2003).

The studies, made by Simone A. French, are good examples of the strategies that can be applied to reach an optimal solution regarding the public health concern.

The first study estimated consumers' behavior among adults by reducing the prices on lower fat snacks relatively to the higher fat snacks by 10%, 25%, and 50%. As the result, the percentage of lower fat snack sales significantly increased by 9%, 39% and 93% accordingly. Overall, the sales volume equalized the price reduction and the average profit of vending machines did not change essentially (French, 2003).

The second study examined a teenage group and the change of their choice towards fresh fruits and vegetables then the prices of these goods were reduced. The results showed again the positive effect of cutting the prices. Contrariwise, sales returned back to basic level with the usual price renewal (French, 2003).

Summarizing the studies, adjusting the hierarchy of food prices is a method to affect the individual food purchases. The public health improvement strategies can be implemented to the society to encourage people for healthier food choice. The small increase of prices on the high-fat foods and the decrease on low-fat foods might be a long-term and financially feasible strategy. However, at the population level, it is difficult to set up without policy changes, governmental funding or the help of food assistance programs, sponsored by the government (French, 2003).

3.3. Global problems concerning food

The world moves on, constantly developing and improving. The mankind always faces the challenges, many of which are global, planetary in nature and affect the interests of all countries and people. There are global problems, concerning food, which stay still unsolved. The issues are obesity, hunger and food wasting, which have a paradoxical link between each other.

3.3.1. Obesity

As previously mentioned, obesity is a growing problem all over the world. Being obese is not just to be fat or not to fit fashion standards, it can cause serious health problems.

To get to know that a person needs to rethink about his or her eating habits urgently, some individual measurements, such as height, weight, waist circumference, should be made. Height and weight are necessary to measure a Body Mass Index (BMI), which is the main indicator in estimation if a person is overweight or not. Waist circumference is currently recognized as a critical marker of obesity-related diseases (Zelman, 2008).

Body Mass Index (BMI) is weight of a person in kilograms divided by the square of his or her height in meters. This method is relatively easy way to monitor the predominance of overweight people among the world's population. A person can also estimate his or her BMI individually to keep the weight under control (noo.org.uk, 2009).

Moreover, BMI is used by the majority of the researchers, who try to study the obesity problem deeper, as an indicator of health status. The relationship between raising BMI and accordingly increasing a risk of illness or fatal outcome is a powerful argument in favor of the importance of knowing a Body Mass Index (noo.org.uk, 2009).

However, BMI does not take into account other important factors, which can help to estimate people's fatness more precisely. For example, individual daily activity, ethnic origin, puberty and also other measurements such as waist circumference and skin thickness, which surely make the results of the studies veracious and accurate (noo.org.uk, 2009).

According to World Health Organization, which uses a BMI to estimate world's population obesity, generally for adults overweight is when a BMI greater than or equal to 25; and obesity is a BMI greater than or equal to 30. Since 1980 the worldwide obesity already doubled and still raising. The statistics, provided by World Health Organization, says that "39% of adults aged 18 years and over were overweight in 2014, and 13% were obese" and "41 million children under the age of 5 were overweight or obese in 2014" (who.int/en, 2016).

The numbers are frightening, but the circumstances are even more terrible. As reported by The Global Burden of Disease Study, between 1990 and 2010 there were three times more deaths worldwide cause of heart strokes and diabetes than fatal outcomes related to hunger and malnourishment (who.int/en, 2016).

There are more obesity-related health problems, which all those overweight people run the risk of, conforming to The National Heart, Lung, and Blood Institute (nhlbi.nih.gov, 2012):

- High Blood Pressure
- Stroke
- Type 2 Diabetes
- Abnormal Blood Fats
- Metabolic Syndrome
- Cancer
- Osteoarthritis
- Sleep Apnea
- Obesity Hypoventilation Syndrome
- Reproductive Problems
- Gallstones

Considering the research studies and statistics made, the obesity epidemic problem can not longer stay inessential. Society does not still take the problem seriously, though doctors are sounding the alarm for a long time. There is an urgent need in proper solution on the governmental level, which seems the only optimal option.

3.3.2. Hunger

The world, in general, produces enough food to feed the whole population of 7 billion people. However, according to the World Hunger Statistics, 7,665,000 people die every year from hunger and most of them are children. There are still 850,000,000 people in the world who suffer from hunger and malnutrition (statisticbrain.com, 2016).

One of the main reasons of hunger is poverty. Most of the people, who suffer from hunger, live in developing countries. Nowadays, there are 896 million poor people who live on $1.90 a day or less. They live below the international poverty line and simply cannot afford to buy enough food for themselves and their families. As the result, 98 % of world's hungry people, who are from developing countries, do not have enough food to live active and healthy lives (worldhunger.org, 2016).

In agreement with the World Food Programme report, there are other causes, related to the world's hunger (wfp.org, 2013):

- Lack of investment in agriculture.

The lack of storage facilities, high transport costs, and unreliable water supplies is the result of not well-developed agricultural infrastructure in developing countries such as irrigation, warehouses, and sufficient roads. All of these factors lead to agricultural yields' limits and poor access to food.

- Climate and weather

In many countries natural disasters intensify already bad climate conditions. Droughts cause crops and livestock losses. Human deforestation accelerates the erosion of territory, which people could utilize to develop the nourishment.

- War and displacement

After war conflicts the farming and food production are usually left ruined. Because of war fights, civilians urgently leave their homes, which can lead to hunger emergencies. Sometimes soldiers starve people, using food as a weapon against opponents.

- Unstable markets

High prices at the food market force people to buy cheaper and less nutritious food, which put them at the risk of malnutrition. Because of unstable prices poor people do not have an adequate access to food constantly.

- Food wastage

About one-third of all food in the world is squandered and has never been consumed by people. Food insecurity situation misses the chance to be improved. The production of food, which has been used or not, anyway utilizes natural resources necessary to feed a destitute part of the world.

There are a lot of decisions already proposed to solve the global hunger problem such as food donations, birth control, increase of food production and so on. However, the reasons created the world's food insecurity will still remain, if attempts are only aimed at the growth of food production and the improvement of distribution. Because the concern of the problem is not over the accessibility of food, it is rather over the ability of people to pay. Thereby, to solve the hunger problem is firstly needed to solve the poverty one (Shah, 2010).

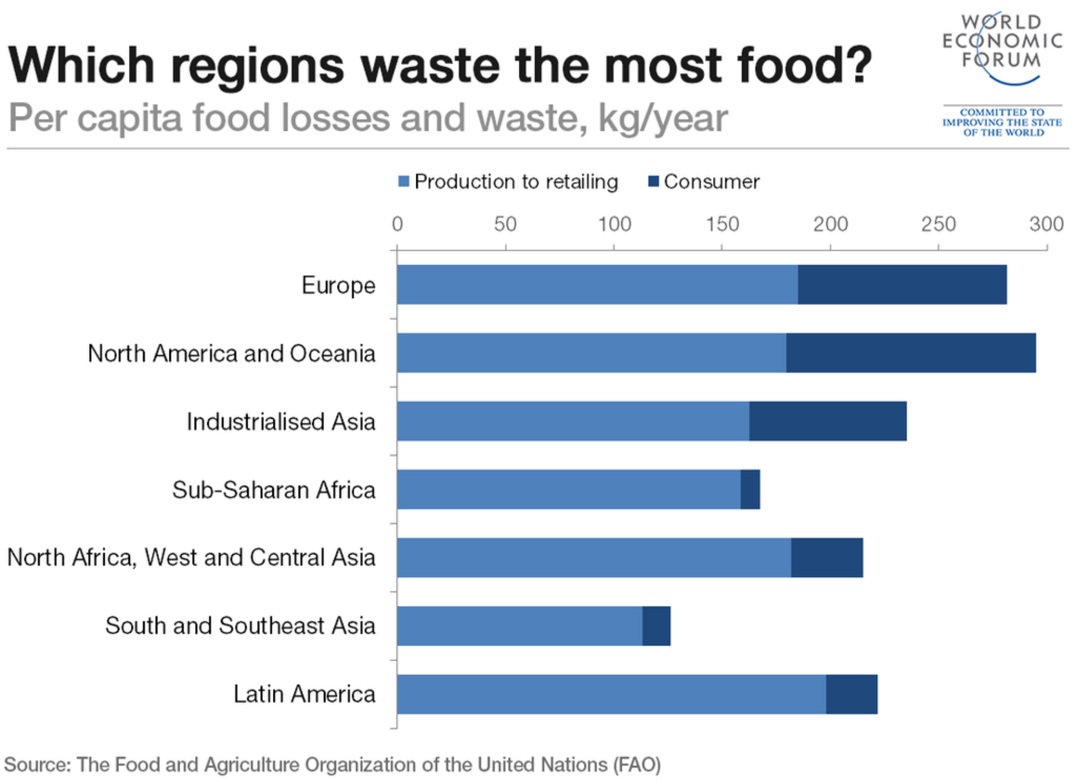
3.3.3. Food wasting

According to Food and Agriculture Organization, around 30 to 40 percent of food is lost or wasted. That would be enough to feed 3 billion people, who suffer from hunger. The food, which never reaches the final consumer, is more likely to be thrown away, because of the quality standards that play too much emphasis on appearance. Not only food is wasted, but also the resources used for production such as water, energy, fertilizers, pesticides, seeds, and labour. The burnt fuel, which is used to process, transportation and the energy wasted to refrigerate, that all has an effect on the climate change (fao.org, 2011).

Moreover, most of the food leftovers or wastage are buried in landfills that emit methane, greenhouse gas, during the decomposition process and constantly affect the environment. It creates about 7 percent of total greenhouse gas emissions per year globally (Nixon, 2015).

Each year in rich countries consumers waste more food than in poorer ones. For instance, the population of Europe and North America waste 95-115 kg a year on average per person, meanwhile in sub-Saharan Africa, south and southeastern Asia only 6-11 kg. In developing countries the losses mostly happen at post-harvest and processing level. The reasons can be weak storage and refrigeration facilities as well as limited financing, management and technical restraints during harvesting. In developed countries, contrariwise, the losses usually occur at retailing and consuming levels. Medium- and high-income consumers are instigated to buy more food, but overestimate their nutritional needs and fail in managing the amounts of food needed (Gustavsson, 2011).

Figure 1 - Food wastage in different regions



Source: The Food and Agriculture Organization of the United Nations (FAO), 2011

The food wastage constantly arises, because preventive measures are not applied properly. In industrialized countries sometimes the supply of food increases the demand that happens when farmers want to prevent risks of non-prolificness, because of droughts or pests attacks, and overproduce the agreed amounts. Cooperation and communication of farmers can reduce the total overproduction and thereby food waste (Gustavsson, 2011).

As the result of high appearance quality standards a lot of suitable for consuming food is rejected by supermarkets, left at the farms, never reaches the market. Although according to consumer surveys, they are not less willing to buy food, because of the wrong size, shape if the taste and the inside quality of the product remain the same. Instead of persuading the market to lower appearance standards, another option can be to promote and expand the farmer's markets closer to the city's center and make them easier to achieve (Gustavsson, 2011).

Basically, the best option is to start educating people through mass media that the expiration date, printed on the products, usually is poorly defined. It is not indicated, if the food is actually spoiled, the visual examination and taste may tell the person better about the consumption deadline of it. Additionally, there are some foods that can be used for cooking even if they get spoiled. This knowledge can help people not to waste their money and food.

3.4. Criteria to set an appropriate menu

To designate an appropriate menu for daily consuming, it is necessary to know the gender, age and level of physical activity of a person. Each of these criteria plays an important role in creating personal health menu to achieve a desirable goal either to keep fit, gain muscles or loose weight (Dietary Guidelines Advisory Committee, 2005).

Men and women are more similar than different: their DNA is identical to 98.5%. However, women burn fewer calories than men and need less to do the same activities (Schwartz, 2010).

There are two reasons for that:

- The average woman weighs less than the average man that means burns less calories, because heavier people burn more calories.
- Even if the weight is the same, women also burn less calories than men, because the last usually are more muscular. Muscles burn more calories than fat.

Within the age, personal body's dietary needs change, because energy demand differs at the particular stage of body development. The changes appear during all life stages and vary the requirements of calories, protein, carbohydrates, fat, vitamins and minerals (nutrition.org.uk, 2016):

There are significant changes that can occur within different life stages (nutrition.org.uk, 2016):

- <u>Infants</u>

  For the first six months of babies' lives breastfeeding is the optimal formula to provide a baby with all nutritional needs. Full of nutrients and antibodies breast milk guarantees the best start in life.

  After the six months, the solid foods should be gradually included in daily feeding of babies with an additional supplement in liquid forms such as vitamins A, C and D, because breast milk is not able to provide all nutrition needed.

- <u>Toddlers and pre-school children</u>

  The stage of life when children are mostly active and grow rapidly, that is why their bodies need lots of amount of energy. The diet should be enriched with protein, carbohydrates, and good quality fats, vitamins A, C, calcium, zinc and iron.

- <u>School children</u>

  Still active and growing organism permanently needs relatively same adequate amounts of healthful nutrients. However, children from 5 to 12 years tend to eat unhealthy snacks at school such as crisps, biscuits and chocolate instead of fruits and vegetables, for example. As a consequence there is the lower intake of necessary dietary fiber, vitamin A and higher of sugar, salt and fat.

- <u>Teenagers</u>

  During this period of life, a human organism is in transition to become fully mature. The deficient intake of vitamins and minerals may lead to the deceleration of the process. Teenagers may skip one or more ingestions per day, instead of eating unhealthy snacks or change their diet in favor of fast food. At this age people suffer from eating disorders the most. Therefore, it is so important to control over-consumed nutrients, especially saturated fatty acids, salt and added sugars.

- Adults

  Between ages 19 and 50 years the nutritional requirements do not change much because till this time the process of body growth and development is mostly over. The main focus is to maintain healthy weight and physical activity. The problem of over intake the specific nutrients from teenage years remains the same. Iron, calcium and folic acid are important nutrients for women's health as well as selenium and lycopene for men that may protect against prostate cancer.

- Older adults

  Getting older means decreasing physical activity and as a result reducing energy requirements. The body balance changes with advancing age and therefore old people have more fat than muscles. It becomes difficult for an organism to synthesize in the skin vitamin D, that is why it is highly recommended to take supplements and continue getting the vitamin from foods.

There is one specific women's stage, which is not related to age or even never is passed by a person (nutrition.org.uk, 2016).

- Pregnancy and pre-conception

  The appropriate healthy diet is both important before conception and during pregnancy, because it influences the health of not only a mother, but a child too. Energy consumption should remain the same as for an ordinary woman; only in the third trimester, it can be increased by 200 calories per day. The additional supplements of vitamin D, iron and folic acid are recommended as well as decrease of vitamin A, liver products, alcohol and caffeine.

Physical activity roughly divided into three levels (Dietary Guidelines Advisory Committee, 2010):

- Sedentary, which means a person does only light physical activity usually needed for day-to-day life.

- Moderately active, which means a person does physical activity equal to walking about 1.5 to 3 miles per day (30-40 minutes) and additionally do daily life activities.
- Active, which means a person does physical activity equal to walking more than 3 miles per day (more than 40 minutes), in addition to daily life activities.

Gender, age and the type of physical activity define a person's calories requirements per day.

Table 1 - Calories needed each day for boys and men

Age	Sedentary	Moderately Active	Active
2–3 years	1,000–1,200 calories	1,000–1,400 calories	1,000–1,400 calories
4–8 years	1,200–1,400 calories	1,400–1,600 calories	1,600–2,000 calories
9–13 years	1,600–2,000 calories	1,800–2,200 calories	2,000–2,600 calories
14–18 years	2,000–2,400 calories	2,400–2,800 calories	2,800–3,200 calories
19–30 years	2,400–2,600 calories	2,600–2,800 calories	3,000 calories
31–50 years	2,200–2,400 calories	2,400–2,600 calories	2,800–3,000 calories
51 years and older	2,000–2,200 calories	2,200–2,400 calories	2,400–2,800 calories

Source: HHS/USDA Dietary Guidelines for Americans, 2010

Table 2 - Calories needed each day for girls and women

Age	Sedentary	Moderately Active	Active
2–3 years	1,000 calories	1,000–1,200 calories	1,000–1,400 calories
4–8 years	1,200–1,400 calories	1,400–1,600 calories	1,400–1,800 calories
9–13 years	1,400–1,600 calories	1,600–2,000 calories	1,800–2,200 calories
14–18 years	1,800 calories	2,000 calories	2,400 calories
19–30 years	1,800–2,000 calories	2,000–2,200 calories	2,400 calories
31–50 years	1,800 calories	2,000 calories	2,200 calories
51 years and older	1,600 calories	1,800 calories	2,000–2,200 calories

Source: HHS/USDA Dietary Guidelines for Americans, 2010

4. Practical Part

To describe the practical part of the research the author of this thesis uses cases for better explanation of the problem.

4.1. Linear programming application to the diet problem

The diet problem is one of the earliest daily-life problems, which are applied to linear programming model to solve. Linear programming is a process of finding optimal solution by system of linear inequalities.

There are three main components of linear programming model (people.richland.edu, 2016):

- Decision variables are the set of quantities, which should be defined to find the best solution. For the diet problem, the decision variables are the number of servings of each food applied to.
- Objective function represents profit or cost or some other values to be maximized or minimized subject to constraints. The main goal, in this case, is to minimize the cost of daily diet.
- Constraints are a set of linear inequalities. The constraints in this case should meet the nutritional requirements, preferences and standards of linear programming.

The leading option for the diet problem is to use the simplex method in linear programming. The simplex method is an algorithm, which can be used to find the best solution to multivariable problems (wps.prenhall.com, 2016)

4.2. Mathematical formulation

Sets:

$\boldsymbol{F}$ = set of foods

$\boldsymbol{N}$ = set of nutrients

Parameters:

$\boldsymbol{a_{nf}}$ = amount of nutrient n in one serving of food f

$\boldsymbol{c_f}$ = cost of one serving of food

Min F = minimum number of servings of food

Max F = maximum number of servings of food

Min N = minimum amount of nutrient required

$\boldsymbol{Max\ N}$ = maximum amount of nutrient required

Variables:

$\boldsymbol{x_f}$ = number of servings of food to consume daily

Objective function:

Minimize $\sum_{f \in F} c_f x_f$

Constraint Set 1:

For each food $f \in F$, meet the minimum number of servings of food.

$$x_f \geq Min\ F$$

Constraint Set 2:

For each food $f \in F$, do not exceed the maximum number of servings of food.

$$x_f \leq Max\ F$$

Constraint set 3:

For each nutrient $n \in N$, meet the minimum amount of nutrient required.

$$\sum_{f \in F} a_{nf} x_f \geq Min\ N$$

Constraint set 4:

For each nutrient $n \in N$, do not exceed the maximum amount of nutrient required.

$$\sum_{f \in F} a_{nf} x_f \leq Max\ N$$

4.3. Set of food and nutrients

The set of foods, which is based on the menu, provided by fitness community, was chosen. The menu satisfies healthful criteria and fundamental daily nutritional requirements such as protein (g), carbohydrates (g), fat (g), calories (Cal), includes basic and accessible in ordinary stores food.

The table below shows the foods' name, their serving size in grams or pieces and the amounts of protein (g), carbohydrates (g), fat (g), calories (Cal) per portion.

Table 3 - Set of foods and nutrients

Food	Serving size	Protein (g)	Carbohydrates (g)	Fat (g)	Calories (Cal)
Eggs whites	8psc	24,80	1,60	0,00	104,00
Egg whole	1psc	3,50	0,30	3,00	43,00
Oats	100g	16,90	66,30	6,90	389,00
Peanut butter	30g	8,00	6,40	16,10	188,00
Wheat bread	70g	7,63	33,25	2,52	186,00
Strawberries	120g	0,84	9,24	0,36	38,40
Apples	150g	0,40	20,60	0,30	77,00
Frozen mix vegetables	220g	6,38	28,82	0,44	132,00
Potatoes	200g	5,00	42,40	0,10	186,00
Broccoli	100g	2,80	6,60	0,40	34,00
Olive oil	27g	0,00	0,00	28,00	248,00
Chicken	280g	86,80	0,00	10,08	462,00
Brown rice	168g	4,37	38,64	1,51	187,00
Spinach	100g	2,90	3,60	0,40	23,00
Avocado	65g	1,30	5,53	9,56	104,00
White fish	170g	32,47	0,00	10,03	227,80
TOTAL		204,09	263,28	89,70	2629,20

Source: bodybuilding.com, 2014; nutritiondata.self.com, 2017

Moreover, nutritional requirements are complemented with nutrients, which are important for healthy and normal body functioning. All amounts of vitamins and minerals added to correspond to the serving size of chosen foods. These are added components and their importance for human body (top10homeremedies.com, 2016):

- Vitamin A (IU) is important for growth of an organism, cell development, skin health, influences vision, especially night one, reproduction system, increases immunity and plays an antioxidant role.
- Vitamin C (mg) is an antioxidant, helps to heal wounds and form scar tissue, keeps gums and teeth healthy, stimulates the immune system and decreases the risk of cancers.
- Vitamin E (mg) is a fat-soluble vitamin, important in the formation of red blood cells and improves interactions between cells, protects skin from damage by ultraviolet light, fights free radicals.
- Omega-3 (mg) are essential fatty acids, which help to build cells, manage the nervous system and lessen an effect of mental disorders such as depression and anxiety, reduce risk of diabetes, cancer cell growing and becoming obese.

- Dietary fiber (g) is not digested by your body, but reduces cholesterol level, helps to control blood sugar levels, decreases the risk of heart strokes, cancer and type 2 diabetes, regulates bowel movements.
- Calcium (mg) builds strong teeth and bones, boost healthy nerves and muscles functioning, helps to clot blood, convert food into energy and to release hormones.
- Iron (mg) is an important component in red blood cells, which helps to transport oxygen throughout the body. It also helps immune system to function normally and supports metabolic processes.
- Magnesium (mg) strengthens bones, keeps normal nerve and muscle operating and heart beat steady, support immune system and the production of energy and protein.

The table below shows the foods' name, their serving size in grams or pieces and the amounts of vitamin A (IU), vitamin C (mg), vitamin E (mg), omega-3 (mg), dietary fiber (g), calcium (mg), iron (mg), magnesium (mg) per portion.

Table 4 - Set of foods and added nutrients

Food	Serving size	Vitamin A (IU)	Vitamin C (mg)	Vitamin E (mg)	Omega-3(mg)	Dietary Fiber(g)	Calcium(mg)	Iron(mg)	Magnesium(mg)
Eggs whites	8psc	0,00	0,00	0,00	0,00	0,00	16,00	0,00	24,80
Egg whole	1psc	164,00	0,00	0,30	21,80	0,00	14,00	0,30	2,80
Oats	100g	0,00	0,00	0,00	111,00	10,60	54,00	4,70	177,00
Peanut butter	30g	0,00	0,00	2,90	24,30	1,90	13,80	0,60	49,30
Wheat bread	70g	0,00	0,14	0,14	94,50	2,52	99,40	2,45	33,60
Strawberries	120g	14,40	70,56	0,36	78,00	2,40	19,20	0,48	15,60
Apples	150g	80,50	6,90	0,30	13,40	3,60	8,90	0,20	7,50
Frozen mix vegetables	220g	9409,40	7,04	0,88	41,80	9,68	55,00	1,76	48,40
Potatoes	200g	20,00	19,20	0,00	26,00	4,40	30,00	2,20	56,00
Broccoli	100g	623,00	89,20	0,80	21,00	2,60	47,00	0,70	21,00
Olive oil	27g	0,00	0,00	4,00	213,00	0,00	0,30	0,20	0,00
Chicken	280g	58,80	0,00	0,84	196,00	0,00	42,00	2,80	81,20
Brown rice	168g	0,00	0,00	0,00	23,52	3,02	16,80	0,67	72,24
Spinach	100g	9376,00	28,10	2,00	138,00	2,20	99,00	2,70	79,00
Avocado	65g	94,90	6,50	1,37	71,50	4,36	7,80	0,33	18,85
White fish	170g	204,00	0,00	0,34	27,27	0,00	44,20	0,68	56,10
TOTAL		20045,00	227,64	14,23	1101,09	47,28	567,40	20,77	743,39

Source: nutritiondata.self.com, 2017

The table below shows the foods' name, their serving size in grams or pieces, the price per 1 kilogram in CZK and the calculated price per portion in CZK.

Table 5 - Prices of foods

Food	Serving size	CZK/1 kg	CZK/serving
Eggs whites	8psc	32,86/10psc	26,29
Egg whole	1psc	32,86/10psc	3,29
Oats	100g	28,70	2,87
Peanut butter	30g	188,30	5,65
Wheat bread	70g	44,62	3,12
Strawberries	120g	187,60	22,51
Apples	150g	29,75	4,46
Frozen mix vegetables	220g	79,70	17,53
Potatoes	200g	15,91	3,18
Broccoli	100g	79,80	7,98
Olive oil	27g	239,80/litre	7,04
Chicken	280g	77,90	21,81
Brown rice	168g	69,00	11,59
Spinach	100g	263,20	26,32
Avocado	65g	99,40	6,46
White fish	170g	283,00	48,11
TOTAL		1752,40	218,22

Source: own field research, 2017

4.4. Male case

Suppose an average man, who is related to the adult life stage and has moderately active physical activity during a day, wants to maintain weight.

Sets:

The set of foods and nutrients remains the same as given.

Nutrients (n) are shortly denominated by first letters.

Foods (f) are denominated by numbers accordingly.

Parameters:

$a_{nf} \geq 0$

The amount of nutrient *n* in one serving of food should be greater than or equal to 0

$c_f > 0$

The cost of one serving of food certainly should be a positive number.

There are lower and upper limits for foods on the number of portions:

Min F ≥ 0

The minimum number of servings of food should be greater than or equal to 0, because of the standard linear programming formulation, which states that all the variables should be non-negative.

Max F ≤ 10

The maximum number of servings of food should be less than or equal to 10 in order to avoid too much of one food to be eaten.

In order to gain the least amounts of nutrients required daily for healthy physiological functioning the following lower limits should be applied (ods.od.nih.gov, 2016):

Min Pr. ≥ 68

The minimum amount of protein (g) should be greater than or equal to 68. The lack of protein can cause loss of muscle mass, edema, swelling, decrease immunity, weakness of skin, hair, nails. A person becomes easily tired, apathetic and irritable.

Min Car. ≥ 304

The minimum amount of carbohydrates (g) should be greater than or equal to 304. Carbohydrates deficiency causes depression mood, lack of energy, headaches and even ketosis.

Min Fat. ≥ 60

The minimum amount of fat (g) should be greater than or equal to 60. The lack of fat leads to poor absorption of vitamin A, D, E and K, dry skin, slowing the brain and deterioration of vision.

Min V.A. ≥ 3000

The minimum amount of vitamin A (IU) should be greater than or equal to 3000. Vitamin A deficiency can cause poor night vision, chronic diarrhea, decrease immunity, and even blindness.

Min V.C. ≥ 90

The minimum amount of vitamin C (mg) should be greater than or equal to 90. The lack of Vitamin C can cause weakness and tiredness; easy bruising, muscle and joint pain, dry skin. Constant deficiency can lead to scurvy, which generates poor wound healing, inflammation of the gums, loss of teeth, small red or purple spots on the skin.

Min V.E. ≥ 15

The minimum amount of vitamin E (mg) should be greater than or equal to 15. The lack of Vitamin E can lead to decrease in immune system, nerve injury, muscle weakness, and problems with vision and even with control of body movements.

Min O-3. ≥ 500

The minimum amount of omega-3 (mg) should be greater than or equal to 500. The omega-3 deficiency causes dry, rough and scaly skin, dandruff, soft and brittle nails, constant thirst, frequent urination, problems with sleep and eyesight, depression, mood swings, memory loss, joint pain.

Min D.F. ≥ 38

The minimum amount of dietary fiber (g) should be greater than or equal to 38. Dietary Fiber deficit causes constipation, weight gain, increase in cholesterol level, risk of heart attacks.

Min C. ≥ 1000

The minimum amount of calcium (mg) should be greater than e or equal to 1000. The lack of calcium leads to muscle cramps, bone weakness and fractures, dry skin, psoriasis, brittle nails, chest pains, backaches, tooth decay, heart failure, fainting.

Min I. ≥ 8

The minimum amount of iron (mg) should be greater than or equal to 8. Iron deficiency can result in anemia. The signs of anemia are headaches, weakness, cold hands and feet, brittle nails, pale skin, fast heartbeat, pain in chest, tongue swelling or soreness.

Min M. ≥ 400

The minimum amount of magnesium (mg) should be greater than or equal to 400. The lack of magnesium causes irritability and anxiety, constant weakness, nausea and vomiting, muscle and coronary spasms, irregular heart rhythms.

Min Cal. ≥ 2600

The minimum amount of calories (Cal) should be greater than or equal to 2600, if a person wants to maintain weight as in this case, according to the 2010 Dietary Guidelines for Americans (Dietary Guidelines Advisory Committee, 2010).

In order not to over intake on daily basis the amounts of nutrients, which might be harmful for the health, the following upper limits should be applied (ods.od.nih.gov, 2016):

Max Pr. $\leq$ 237

The maximum amount of protein (g) should be less than or equal to 237. Protein overdose can cause nausea, vomiting, diarrhea, gases, stomach cramps and loss of appetite.

Max Car. $\leq$ 439

The maximum amount of carbohydrates (g) should be less than or equal to 439. Carbohydrates over intake leads to weight gain, tiredness and weakness, abdominal discomfort and gases, belching, increase in cholesterol level.

Max Fat. $\leq$ 105

The maximum amount of fat (g) should be less than or equal to 105. Fat over intake causes obesity, coronary heart disease, increase in cholesterol level and even cancer.

Max V.A. $\leq$ 10000

The maximum amount of vitamin A (IU) should be less than or equal to 10000. Vitamin A overdose causes headaches, vertigo, queasiness, skin flaking, hair loss, pain in joints and bones, coma, and even death.

Max V.C. $\leq$ 2000

The maximum amount of vitamin C (mg) should be less than or equal to 2000. Vitamin C overdose causes gastrointestinal problems such as diarrhea, nausea, and stomach cramps and can increase risk of oxalate kidney stones.

Max V.E. $\leq$ not defined

The upper limit of Vitamin E intake is not defined because getting this vitamin from food in bug amounts cannot be harmful for a human organism.

Max O-3. $\leq$ 3000

The maximum amount of omega-3 (mg) should be less than or equal to 3000. The upper intake of omega-3 causes vomiting, diarrhea, abdominal pain, exacerbation of pancreatitis and easy bruising.

Max D.F. $\leq$ 50

The maximum amount of dietary fiber (g) should be less than or equal to 50. Dietary fiber overdose causes besides diarrhea, gases, cramping, constipation and malabsorption, but also intestinal blockage, which prevents any other foods to pass through intestines.

Max C. ≤ 2500

The maximum amount of calcium (mg) should be less than or equal to 2500. Calcium overdose causes nausea and vomiting, drowsiness and muscle weakness, diarrhea or constipation, frequent urination and the formation of kidney stones.

Max I. ≤ 45

The maximum amount of iron (mg) should be less than or equal to 45. Iron overdose firstly affects the stomach. The signs of iron poisoning are nausea, vomiting, diarrhea, vomiting blood, bluish-colored lips and fingernails, pale skin, dehydration, low blood pressure, irritability, dizziness, headache, liver damage and even coma.

Max M. ≤ not defined

The maximum recommended amount of magnesium (mg) is not defined because too much intake of this mineral from food is not dangerous for health since the kidneys get rid of excessive amounts through the urine.

Max Cal. ≤ 2800

The maximum amount of calories (Cal) should be less than or equal to 2800, according to the 2010 Dietary Guidelines for Americans (Dietary Guidelines Advisory Committee, 2010).

Variables:

x_1 – Eggs whites, x_2 – Egg whole, x_3 – Oats , x_4 – Peanut butter, x_5 – Wheat bread, x_6 – Strawberries, x_7 – Apples, x_8 – Frozen mixed vegetables, x_9 – Potatoes, x_{10} – Broccoli, x_{11} – Olive oil, x_{12} – Chicken, x_{13} – Brown rice, x_{14} – Spinach, x_{15} – Avocado, x_{16} – White fish.

Objective function:

Minimize

$$26{,}29\,x_1 + 3{,}29\,x_2 + 2{,}87\,x_3 + 5{,}65\,x_4 + 3{,}12\,x_5 + 22{,}51\,x_6 + 4{,}46\,x_7 + 17{,}53\,x_8 + 3{,}18\,x_9 + 7{,}98\,x_{10} + 7{,}04\,x_{11} + 21{,}81\,x_{12} + 11{,}59\,x_{13} + 26{,}32\,x_{14} + 6{,}46\,x_{15} + 48{,}11\,x_{16}$$

Constraint Set 1:

The minimum number of servings of food should be greater than or equal to 0.

$x_{1\text{-}16} \geq 0$

Constraint Set 2:

The maximum number of servings of food should be less than or equal to 10.

$x_{1\text{-}16} \leq 10$

Constraint set 3:

The minimum amount of protein (g) should be greater than or equal to 68.

Protein (g): $24{,}80\,x_1 + 3{,}50\,x_2 + 16{,}90\,x_3 + 8{,}00\,x_4 + 7{,}63\,x_5 + 0{,}84\,x_6 + 0{,}40\,x_7 + 6{,}38\,x_8 + 5{,}00\,x_9 + 2{,}80\,x_{10} + 0{,}00\,x_{11} + 86{,}80\,x_{12} + 4{,}37\,x_{13} + 2{,}90\,x_{14} + 1{,}30\,x_{15} + 32{,}47\,x_{16} \geq 68{,}00$

The minimum amount of carbohydrates (g) should be greater than or equal to 304.

Carbohydrates (g): $1{,}60\,x_1 + 0{,}30\,x_2 + 66{,}30\,x_3 + 6{,}40\,x_4 + 33{,}25\,x_5 + 9{,}24\,x_6 + 20{,}60\,x_7 + 28{,}82\,x_8 + 42{,}40\,x_9 + 6{,}60\,x_{10} + 0{,}00\,x_{11} + 0{,}00\,x_{12} + 38{,}64\,x_{13} + 3{,}60\,x_{14} + 5{,}53\,x_{15} + 0{,}00\,x_{16} \geq 304{,}00$

The minimum amount of fat (g) should be greater than or equal to 60.

Fat (g): $0{,}00\,x_1 + 3{,}00\,x_2 + 6{,}90\,x_3 + 16{,}10\,x_4 + 2{,}52\,x_5 + 0{,}36\,x_6 + 0{,}30\,x_7 + 0{,}44\,x_8 + 0{,}10\,x_9 + 0{,}40\,x_{10} + 28{,}00\,x_{11} + 10{,}08\,x_{12} + 1{,}51\,x_{13} + 0{,}40\,x_{14} + 9{,}56\,x_{15} + 10{,}03\,x_{16} \geq 60{,}00$

The minimum amount of vitamin A (IU) should be greater than or equal to 3000.

Vitamin A (IU): $0{,}00\,x_1 + 164{,}00\,x_2 + 0{,}00\,x_3 + 0{,}00\,x_4 + 0{,}00\,x_5 + 14{,}40\,x_6 + 80{,}50\,x_7 + 9409{,}40\,x_8 + 20{,}00\,x_9 + 623{,}00\,x_{10} + 0{,}00\,x_{11} + 58{,}80\,x_{12} + 0{,}00\,x_{13} + 9376{,}00\,x_{14} + 94{,}90\,x_{15} + 204{,}00\,x_{16} \geq 3000{,}00$

The minimum amount of vitamin C (mg) should be greater than or equal to 90.

Vitamin C (mg): $0{,}00\,x_1 + 0{,}00\,x_2 + 0{,}00\,x_3 + 0{,}00\,x_4 + 0{,}14\,x_5 + 70{,}56\,x_6 + 6{,}90\,x_7 + 7{,}04\,x_8 + 19{,}20\,x_9 + 89{,}20\,x_{10} + 0{,}00\,x_{11} + 0{,}00\,x_{12} + 0{,}00\,x_{13} + 28{,}10\,x_{14} + 6{,}50\,x_{15} + 0{,}00\,x_{16} \geq 90{,}00$

The minimum amount of vitamin E (mg) should be greater than or equal to 15.

Vitamin E (mg): $0{,}00\,x_1 + 0{,}30\,x_2 + 0{,}00\,x_3 + 2{,}90\,x_4 + 0{,}14\,x_5 + 0{,}36\,x_6 + 0{,}30\,x_7 + 0{,}88\,x_8 + 0{,}00\,x_9 + 0{,}80\,x_{10} + 4{,}00\,x_{11} + 0{,}84\,x_{12} + 0{,}00\,x_{13} + 2{,}00\,x_{14} + 1{,}37\,x_{15} + 0{,}34\,x_{16} \geq 15{,}00$

The minimum amount of omega-3 (mg) should be greater than or equal to 500.

Omega-3 (mg): 0,00 x_1 + 21,80 x_2 + 111,00 x_3 + 24,30 x_4 + 94,50 x_5 + 78,00 x_6 + 13,40 x_7 + 41,80 x_8 + 26,00 x_9 + 21,00 x_{10} + 213,00 x_{11} + 196,00 x_{12} + 23,52 x_{13} + 138,00 x_{14} + 71,50 x_{15} + 27,27 $x_{16} \geq$ 500,00

The minimum amount of dietary fiber (g) should be greater than or equal to 38.

Dietary Fiber (g): 0,00 x_1 + 0,00 x_2 + 10,60 x_3 + 1,90 x_4 + 2,52 x_5 + 2,40 x_6 + 3,60 x_7 + 9,68 x_8 + 4,40 x_9 + 2,60 x_{10} + 0,00 x_{11} + 0,00 x_{12} + 3,02 x_{13} + 2,20 x_{14} + 4,36 x_{15} + 0,00 $x_{16} \geq$ 38,00

The minimum amount of calcium (mg) should be greater than e or equal to 1000.

Calcium (mg): 16,00 x_1 + 14,00 x_2 + 54,00 x_3 + 13,80 x_4 + 99,40 x_5 + 19,20 x_6 + 8,90 x_7 + 55,00 x_8 + 30,00 x_9 + 47,00 x_{10} + 0,30 x_{11} + 42,00 x_{12} + 16,80 x_{13} + 99,00 x_{14} + 7,80 x_{15} + 44,20 $x_{16} \geq$ 1000,00

The minimum amount of iron (mg) should be greater than or equal to 8.

Iron (mg): 0,00 x_1 + 0,30 x_2 + 4,70 x_3 + 0,60 x_4 + 2,45 x_5 + 0,48 x_6 + 0,20 x_7 + 1,76 x_8 + 2,20 x_9 + 0,70 x_{10} + 0,20 x_{11} + 2,80 x_{12} + 0,67 x_{13} + 2,70 x_{14} + 0,33 x_{15} + 0,68 $x_{16} \geq$ 8,00

The minimum amount of magnesium (mg) should be greater than or equal to 400.

Magnesium (mg): 24,80 x_1 + 2,80 x_2 + 177,00 x_3 + 49,30 x_4 + 33,60 x_5 + 15,60 x_6 + 7,50 x_7 + 48,40 x_8 + 56,00 x_9 + 21,00 x_{10} + 0,00 x_{11} + 81,20 x_{12} + 72,24 x_{13} + 79,00 x_{14} + 18,85 x_{15} + 56,10 $x_{16} \geq$ 400,00

The minimum amount of calories (Cal) should be greater than or equal to 2600.

Calories: 104,00 x_1 + 43,00 x_2 + 389,00 x_3 + 188,00 x_4 + 186,00 x_5 + 38,40 x_6 + 77,00 x_7 + 132,00 x_8 + 186,00 x_9 + 34,00 x_{10} + 248,00 x_{11} + 462,00 x_{12} + 187,00 x_{13} + 23,00 x_{14} + 104,00 x_{15} + 227,80 $x_{16} \geq$ 2600,00

Constraint set 4:

The maximum amount of protein (g) should be less than or equal to 237.

Protein (g): 24,80 x_1 + 3,50 x_2 + 16,90 x_3 + 8,00 x_4 + 7,63 x_5 + 0,84 x_6 + 0,40 x_7 + 6,38 x_8 + 5,00 x_9 + 2,80 x_{10} + 0,00 x_{11} + 86,80 x_{12} + 4,37 x_{13} + 2,90 x_{14} + 1,30 x_{15} + 32,47 x_{16} $\leq$ 237,00

The maximum amount of carbohydrates (g) should be less than or equal to 439.

Carbohydrates (g): 1,60 x_1 + 0,30 x_2 + 66,30 x_3 + 6,40 x_4 + 33,25 x_5 + 9,24 x_6 + 20,60 x_7 + 28,82 x_8 + 42,40 x_9 + 6,60 x_{10} + 0,00 x_{11} + 0,00 x_{12} + 38,64 x_{13} + 3,60 x_{14} + 5,53 x_{15} + 0,00 x_{16} ≤ 439,00

The maximum amount of fat (g) should be less than or equal to 105.

Fat (g): 0,00 x_1 + 3,00 x_2 + 6,90 x_3 + 16,10 x_4 + 2,52 x_5 + 0,36 x_6 + 0,30 x_7 + 0,44 x_8 + 0,10 x_9 + 0,40 x_{10} + 28,00 x_{11} + 10,08 x_{12} + 1,51 x_{13} + 0,40 x_{14} + 9,56 x_{15} + 10,03 x_{16} ≤ 105,00

The maximum amount of vitamin A (IU) should be less than or equal to 10000.

Vitamin A (IU): 0,00 x_1 + 164,00 x_2 + 0,00 x_3 + 0,00 x_4 + 0,00 x_5 + 14,40 x_6 + 80,50 x_7 + 9409,40 x_8 + 20,00 x_9 + 623,00 x_{10} + 0,00 x_{11} + 58,80 x_{12} + 0,00 x_{13} + 9376,00 x_{14} + 94,90 x_{15} + 204,00 x_{16} ≤ 10000,00

The maximum amount of vitamin C (mg) should be less than or equal to 2000.

Vitamin C (mg): 0,00 x_1 + 0,00 x_2 + 0,00 x_3 + 0,00 x_4 + 0,14 x_5 + 70,56 x_6 + 6,90 x_7 + 7,04 x_8 + 19,20 x_9 + 89,20 x_{10} + 0,00 x_{11} + 0,00 x_{12} + 0,00 x_{13} + 28,10 x_{14} + 6,50 x_{15} + 0,00 x_{16} ≤ 2000,00

The maximum amount of omega-3 (mg) should be less than or equal to 3000.

Omega-3 (mg): 0,00 x_1 + 21,80 x_2 + 111,00 x_3 + 24,30 x_4 + 94,50 x_5 + 78,00 x_6 + 13,40 x_7 + 41,80 x_8 + 26,00 x_9 + 21,00 x_{10} + 213,00 x_{11} + 196,00 x_{12} + 23,52 x_{13} + 138,00 x_{14} + 71,50 x_{15} + 27,27 x_{16} ≤ 3000,00

The maximum amount of dietary fiber (g) should be less than or equal to 50.

Dietary Fiber (g): 0,00 x_1 + 0,00 x_2 + 10,60 x_3 + 1,90 x_4 + 2,52 x_5 + 2,40 x_6 + 3,60 x_7 + 9,68 x_8 + 4,40 x_9 + 2,60 x_{10} + 0,00 x_{11} + 0,00 x_{12} + 3,02 x_{13} + 2,20 x_{14} + 4,36 x_{15} + 0,00 x_{16} ≤ 50,00

The maximum amount of calcium (mg) should be less than or equal to 2500.

Calcium (mg): 16,00 x_1 + 14,00 x_2 + 54,00 x_3 + 13,80 x_4 + 99,40 x_5 + 19,20 x_6 + 8,90 x_7 + 55,00 x_8 + 30,00 x_9 + 47,00 x_{10} + 0,30 x_{11} + 42,00 x_{12} + 16,80 x_{13} + 99,00 x_{14} + 7,80 x_{15} + 44,20 x_{16} ≤ 2500,00

The maximum amount of iron (mg) should be less than or equal to 45.

Iron (mg): 0,00 x_1 + 0,30 x_2 + 4,70 x_3 + 0,60 x_4 + 2,45 x_5 + 0,48 x_6 + 0,20 x_7 + 1,76 x_8 + 2,20 x_9 + 0,70 x_{10} + 0,20 x_{11} + 2,80 x_{12} + 0,67 x_{13} + 2,70 x_{14} + 0,33 x_{15} + 0,68 x_{16} $\leq$ 45,00

The maximum amount of calories (Cal) should be less than or equal to 2800.

Calories: 104,00 x_1 + 43,00 x_2 + 389,00 x_3 + 188,00 x_4 + 186,00 x_5 + 38,40 x_6 + 77,00 x_7 + 132,00 x_8 + 186,00 x_9 + 34,00 x_{10} + 248,00 x_{11} + 462,00 x_{12} + 187,00 x_{13} + 23,00 x_{14} + 104,00 x_{15} + 227,80 x_{16} $\leq$ 2800,00

The results:

Using the simplex method, the feasible solution for the male case was found.

Table 6 - Achieved results – Objective function (male case)

Function	
Variables	**Price (CZK/portion)**
Eggs whites	26,29
Egg whole	3,29
Oats	2,87
Peanut butter	5,65
Wheat bread	3,12
Strawberries	22,51
Apples	4,46
Frozen mix vegetal	17,53
Potatoes	3,18
Broccoli	7,98
Olive oil	7,04
Chicken	21,81
Brown rice	11,59
Spinach	26,32
Avocado	6,46
White fish	48,11
Final Value	65,06

Source: Own calculations, 2017

Table 7 - Achieved results – Variables (male case)

Variables	Values (times)
Eggs whites	0,00
Egg whole	0,00
Oats	0,25
Peanut butter	4,41
Wheat bread	8,71
Strawberries	0,00
Apples	0,00
Frozen mix vegetables	0,25
Potatoes	0,00
Broccoli	0,98
Olive oil	0,00
Chicken	0,00
Brown rice	0,00
Spinach	0,00
Avocado	0,00
White fish	0,00

Source: Own calculations, 2017

The cost was decreased from 218,22 CZK to 65,06 CZK, which is the final value of the objective function.

The optimal solution shows that to satisfy the daily nutritional requirements and simultaneously reduce the costs an average man needs to eat the following numbers of servings of foods per day:

1. Oats 0,25 within the serving size 100g
2. Peanut butter 4,41 within the serving size 30g
3. Wheat bread 8,71 within the serving size 70g
4. Frozen mixed vegetables 0,25 within the serving size 220g
5. Broccoli 0,98 within the serving size 100g

Table 8 - Achieved results – Nutrients (male case)

Constraints	Protein(g)	Carbohydrates(g)	Fat (g)	Vitamin A(IU)	Vitamin C(mg)	Vitamin E(mg)	Omega-3(mg)	Dietary Fiber(g)	Calcium(mg)	Iron(mg)	Magnesium(mg)	Calories(Cal)
Eggs whites	24,80	1,60	0,00	0,00	0,00	0,00	0,00	0,00	16,00	0,00	24,80	104,00
Egg whole	3,50	0,30	3,00	164,00	0,00	0,30	21,80	0,00	14,00	0,30	2,80	43,00
Oats	16,90	66,30	6,90	0,00	0,00	0,00	111,00	10,60	54,00	4,70	177,00	389,00
Peanut butter	8,00	6,40	16,10	0,00	0,00	2,90	24,30	1,90	13,80	0,60	49,30	188,00
Wheat bread	7,63	33,25	2,52	0,00	0,14	0,14	94,50	2,52	99,40	2,45	33,60	186,00
Strawberries	0,84	9,24	0,36	14,40	70,56	0,36	78,00	2,40	19,20	0,48	15,60	38,40
Apples	0,40	20,60	0,30	80,50	6,90	0,30	13,40	3,60	8,90	0,20	7,50	77,00
Frozen mix veg.	6,38	28,82	0,44	9409,40	7,04	0,88	41,80	9,68	55,00	1,76	48,40	132,00
Potatoes	5,00	42,40	0,10	20,00	19,20	0,00	26,00	4,40	30,00	2,20	56,00	186,00
Broccoli	2,80	6,60	0,40	623,00	89,20	0,80	21,00	2,60	47,00	0,70	21,00	34,00
Olive oil	0,00	0,00	28,00	0,00	0,00	4,00	213,00	0,00	0,30	0,20	0,00	248,00
Chicken	86,80	0,00	10,08	58,80	0,00	0,84	196,00	0,00	42,00	2,80	81,20	462,00
Brown rice	4,37	38,64	1,51	0,00	0,00	0,00	23,52	3,02	16,80	0,67	72,24	187,00
Spinach	2,90	3,60	0,40	9376,00	28,10	2,00	138,00	2,20	99,00	2,70	79,00	23,00
Avocado	1,30	5,53	9,56	94,90	6,50	1,37	71,50	4,36	7,80	0,33	18,85	104,00
White fish	32,47	0,00	10,03	204,00	0,00	0,34	27,27	0,00	44,20	0,68	56,10	227,80
Left-side	110,33	348,34	95,13	3000,00	90,00	15,00	989,31	38,00	1000,00	26,30	587,45	2613,46
Right-side(min)	68,00	304,00	60,00	3000,00	90,00	15,00	500,00	38,00	1000,00	8,00	400,00	2600,00
Right-side(max)	237,00	439,00	105,00	10000,00	2000,00	ND	3000,00	50,00	2500,00	45,00	ND	2800,00

Source: Own calculations, 2017

Additionally, the left-side row represents the amounts of nutrients a person consumes, which respect the upper and lower bounds applied.

Protein (g): the obtained amount of the protein ***110,33*** g is greater than the minimum recommended intake 68,00 g and less than the maximum one 237,00 g.

Carbohydrates (g): the obtained amount of the carbohydrates ***348,34*** g is greater than the minimum recommended intake 304,00 g and less than the maximum one 439,00 g.

Fat (g): the obtained amount of the fat ***95,13*** g is greater than the minimum recommended intake 60,00 g and less than the maximum one 105,00 g.

Vitamin A (IU): the obtained amount of the vitamin A ***3000,00*** IU is equal to the minimum recommended intake 3000,00 IU.

Vitamin C (mg): the obtained amount of the vitamin C ***90,00*** mg is equal to the minimum recommended intake 90,00 mg.

Vitamin E (mg): the obtained amount of the vitamin E ***15,00*** mg is equal to the minimum recommended intake 15,00 mg.

Omega-3 (mg): the obtained amount of the omega-3 ***989,31*** mg is greater than the minimum recommended intake 500,00 mg and less than the maximum one 3000,00 mg.

Dietary Fiber (g): the obtained amount of the dietary fiber ***38,00*** g is equal to the minimum recommended intake 38,00 g.

Calcium (mg): the obtained amount of the calcium ***1000,00*** mg is equal to the minimum recommended intake 1000,00 mg.

Iron (mg): the obtained amount of the iron ***26,30*** mg is greater than the minimum recommended intake 8,00 mg and less than the maximum one 45,00 mg.

Magnesium (mg): the obtained amount of the magnesium ***587,45*** mg is greater than the minimum recommended intake 400,00 mg.

Calories: the obtained amount of the calories ***2613,46*** is greater than the minimum recommended intake 2600,00 and less than the maximum one 2800,00.

4.5. Female case

Suppose an average woman, who is related to the adult life stage and has moderately active physical activity during a day, wants to maintain weight.

Sets:

The set of foods and nutrients remains the same as for men, because women if they are not pregnant, can consume the amounts of nutrients needed from the identical food.

Nutrients (*n*) are shortly denominated by first letters.

Foods (*f*) are denominated by numbers accordingly.

Parameters:

$\boldsymbol{a_{nf}} \geq 0$

The amount of nutrient *n* in one serving of food should be greater than or equal to 0.

$\boldsymbol{c_f} > 0$

The cost of one serving of food certainly should be a positive number.

There are lower and upper limits for foods on the number of portions:

Min F ≥ 0

The minimum number of servings of food should be greater than or equal to 0, see the male case.

Max F ≤ 10

The maximum number of servings of food should be less than or equal to 10, see the male case.

In order to gain the least amounts of nutrients required daily for healthy physiological functioning the following lower limits should be applied (ods.od.nih.gov, 2016):

Min Pr. ≥ 53

The minimum amount of protein (g) should be greater than or equal to 53, see the male case.

Min Car. ≥ 237

The minimum amount of carbohydrates (g) should be greater than or equal to 237, see the male case.

Min Fat. ≥ 47

The minimum amount of fat (g) should be greater than or equal to 47, see the male case.

Min V.A. ≥ 2310

The minimum amount of vitamin A (IU) should be greater than or equal to 2310, see the male case.

Min V.C. ≥ 75

The minimum amount of vitamin C (mg) should be greater than or equal to 75, see the male case.

Min V.E. ≥ 15

The minimum amount of vitamin E (mg) should be greater than or equal to 15, see the male case.

Min O-3. ≥ 500

The minimum amount of omega-3 (mg) should be greater than or equal to 500, see the male case.

Min D.F. ≥ 25

The minimum amount of dietary fiber (g) should be greater than or equal to 25, see the male case.

Min C. ≥ 1000

The minimum amount of calcium (mg) should be greater than e or equal to 1000, see the male case.

Min I. ≥ 18

The minimum amount of iron (mg) should be greater than or equal to 18, see the male case.

Min M. ≥ 310

The minimum amount of magnesium (mg) should be greater than or equal to 310, see the male case.

Min Cal. ≥ 2000

The minimum amount of calories (Cal) should be greater than or equal to 2000, if a person wants to maintain weight as in this case, according to the 2010 Dietary Guidelines for Americans (Dietary Guidelines Advisory Committee, 2010).

In order not to over intake on daily basis the amounts of nutrients, which might be harmful for the health, the following upper limits should be applied (ods.od.nih.gov, 2016):

Max Pr. ≤ 184

The maximum amount of protein (g) should be less than or equal to 184, see the male case.

Max Car. ≤ 342

The maximum amount of carbohydrates (g) should be less than or equal to 342, see the male case.

Max Fat. ≤ 82

The maximum amount of fat (g) should be less than or equal to 82, see the male case.

Max V.A. ≤ 10000

The maximum amount of vitamin A (IU) should be less than or equal to 10000, see the male case.

Max V.C. ≤ 2000

The maximum amount of vitamin C (mg) should be less than or equal to 2000, see the male case.

Max V.E. $\leq$ not defined

The upper limit of vitamin E intake is not defined see the male case.

Max O-3. ≤ 3000

The maximum amount of omega-3 (mg) should be less than or equal to 3000, see the male case.

Max D.F. ≤ 50

The maximum amount of dietary fiber (g) should be less than or equal to 50, see the male case.

Max C. ≤ 2500

The maximum amount of calcium (mg) should be less than or equal to 2500, see the male case.

Max I. ≤ 45

The maximum amount of iron (mg) should be less than or equal to 45, see the male case.

Max M. $\leq$ not defined

The upper limit of magnesium intake is not defined see the male case.

Max Cal. ≤ 2200

The maximum amount of calories (Cal) should be less than or equal to 2200, according to the 2010 Dietary Guidelines for Americans (Dietary Guidelines Advisory Committee, 2010).

Variables:

x_1 – Eggs whites, x_2 – Egg whole, x_3 – Oats , x_4 – Peanut butter, x_5 – Wheat bread, x_6 – Strawberries, x_7 – Apples, x_8 – Frozen mixed vegetables, x_9 – Potatoes, x_{10} – Broccoli, x_{11} – Olive oil, x_{12} – Chicken, x_{13} – Brown rice, x_{14} – Spinach, x_{15} – Avocado, x_{16} – White fish.

Objective function:

Minimize

$$26{,}29\, x_1 + 3{,}29\, x_2 + 2{,}87\, x_3 + 5{,}65\, x_4 + 3{,}12\, x_5 + 22{,}51\, x_6 + 4{,}46\, x_7 + 17{,}53\, x_8 + 3{,}18\, x_9 + 7{,}98\, x_{10} + 7{,}04\, x_{11} + 21{,}81\, x_{12} + 11{,}59\, x_{13} + 26{,}32\, x_{14} + 6{,}46\, x_{15} + 48{,}11\, x_{16}$$

Constraint Set 1:

The minimum number of servings of food should be greater than or equal to 0.

$x_{1\text{-}16} \geq 0$

Constraint Set 2:

The maximum number of servings of food should be less than or equal to 10.

$\boldsymbol{x_{1\text{-}16}} \leq 10$

Constraint set 3:

The minimum amount of protein (g) should be greater than or equal to 53.

Protein (g): $24{,}80\, x_1 + 3{,}50\, x_2 + 16{,}90\, x_3 + 8{,}00\, x_4 + 7{,}63\, x_5 + 0{,}84\, x_6 + 0{,}40\, x_7 + 6{,}38\, x_8 + 5{,}00\, x_9 + 2{,}80\, x_{10} + 0{,}00\, x_{11} + 86{,}80\, x_{12} + 4{,}37\, x_{13} + 2{,}90\, x_{14} + 1{,}30\, x_{15} + 32{,}47\, x_{16} \geq 53{,}00$

The minimum amount of carbohydrates (g) should be greater than or equal to 237.

Carbohydrates (g): $1{,}60\, x_1 + 0{,}30\, x_2 + 66{,}30\, x_3 + 6{,}40\, x_4 + 33{,}25\, x_5 + 9{,}24\, x_6 + 20{,}60\, x_7 + 28{,}82\, x_8 + 42{,}40\, x_9 + 6{,}60\, x_{10} + 0{,}00\, x_{11} + 0{,}00\, x_{12} + 38{,}64\, x_{13} + 3{,}60\, x_{14} + 5{,}53\, x_{15} + 0{,}00\, x_{16} \geq 237{,}00$

The minimum amount of fat (g) should be greater than or equal to 47.

Fat (g): $0{,}00\, x_1 + 3{,}00\, x_2 + 6{,}90\, x_3 + 16{,}10\, x_4 + 2{,}52\, x_5 + 0{,}36\, x_6 + 0{,}30\, x_7 + 0{,}44\, x_8 + 0{,}10\, x_9 + 0{,}40\, x_{10} + 28{,}00\, x_{11} + 10{,}08\, x_{12} + 1{,}51\, x_{13} + 0{,}40\, x_{14} + 9{,}56\, x_{15} + 10{,}03\, x_{16} \geq 47{,}00$

The minimum amount of vitamin A (IU) should be greater than or equal to 2310.

Vitamin A (IU): $0{,}00\, x_1 + 164{,}00\, x_2 + 0{,}00\, x_3 + 0{,}00\, x_4 + 0{,}00\, x_5 + 14{,}40\, x_6 + 80{,}50\, x_7 + 9409{,}40\, x_8 + 20{,}00\, x_9 + 623{,}00\, x_{10} + 0{,}00\, x_{11} + 58{,}80\, x_{12} + 0{,}00\, x_{13} + 9376{,}00\, x_{14} + 94{,}90\, x_{15} + 204{,}00\, x_{16} \geq 2310{,}00$

The minimum amount of vitamin C (mg) should be greater than or equal to 75.

Vitamin C (mg): $0{,}00\, x_1 + 0{,}00\, x_2 + 0{,}00\, x_3 + 0{,}00\, x_4 + 0{,}14\, x_5 + 70{,}56\, x_6 + 6{,}90\, x_7 + 7{,}04\, x_8 + 19{,}20\, x_9 + 89{,}20\, x_{10} + 0{,}00\, x_{11} + 0{,}00\, x_{12} + 0{,}00\, x_{13} + 28{,}10\, x_{14} + 6{,}50\, x_{15} + 0{,}00\, x_{16} \geq 75{,}00$

The minimum amount of vitamin E (mg) should be greater than or equal to 15.

Vitamin E (mg): $0{,}00\, x_1 + 0{,}30\, x_2 + 0{,}00\, x_3 + 2{,}90\, x_4 + 0{,}14\, x_5 + 0{,}36\, x_6 + 0{,}30\, x_7 + 0{,}88\, x_8 + 0{,}00\, x_9 + 0{,}80\, x_{10} + 4{,}00\, x_{11} + 0{,}84\, x_{12} + 0{,}00\, x_{13} + 2{,}00\, x_{14} + 1{,}37\, x_{15} + 0{,}34\, x_{16} \geq 15{,}00$

The minimum amount of omega-3 (mg) should be greater than or equal to 500.

Omega-3 (mg): 0,00 x_1 + 21,80 x_2 + 111,00 x_3 + 24,30 x_4 + 94,50 x_5 + 78,00 x_6 + 13,40 x_7 + 41,80 x_8 + 26,00 x_9 + 21,00 x_{10} + 213,00 x_{11} + 196,00 x_{12} + 23,52 x_{13} + 138,00 x_{14} + 71,50 x_{15} + 27,27 x_{16} ≥ 500,00

The minimum amount of dietary fiber (g) should be greater than or equal to 25.

Dietary Fiber (g): 0,00 x_1 + 0,00 x_2 + 10,60 x_3 + 1,90 x_4 + 2,52 x_5 + 2,40 x_6 + 3,60 x_7 + 9,68 x_8 + 4,40 x_9 + 2,60 x_{10} + 0,00 x_{11} + 0,00 x_{12} + 3,02 x_{13} + 2,20 x_{14} + 4,36 x_{15} + 0,00 x_{16} ≥ 25,00

The minimum amount of calcium (mg) should be greater than e or equal to 1000.

Calcium (mg): 16,00 x_1 + 14,00 x_2 + 54,00 x_3 + 13,80 x_4 + 99,40 x_5 + 19,20 x_6 + 8,90 x_7 + 55,00 x_8 + 30,00 x_9 + 47,00 x_{10} + 0,30 x_{11} + 42,00 x_{12} + 16,80 x_{13} + 99,00 x_{14} + 7,80 x_{15} + 44,20 x_{16} ≥ 1000,00

The minimum amount of iron (mg) should be greater than or equal to 18.

Iron (mg): 0,00 x_1 + 0,30 x_2 + 4,70 x_3 + 0,60 x_4 + 2,45 x_5 + 0,48 x_6 + 0,20 x_7 + 1,76 x_8 + 2,20 x_9 + 0,70 x_{10} + 0,20 x_{11} + 2,80 x_{12} + 0,67 x_{13} + 2,70 x_{14} + 0,33 x_{15} + 0,68 x_{16} ≥ 18,00

The minimum amount of magnesium (mg) should be greater than or equal to 310.

Magnesium (mg): 24,80 x_1 + 2,80 x_2 + 177,00 x_3 + 49,30 x_4 + 33,60 x_5 + 15,60 x_6 + 7,50 x_7 + 48,40 x_8 + 56,00 x_9 + 21,00 x_{10} + 0,00 x_{11} + 81,20 x_{12} + 72,24 x_{13} + 79,00 x_{14} + 18,85 x_{15} + 56,10 x_{16} ≥ 310,00

The minimum amount of calories (Cal) should be greater than or equal to 2000.

Calories: 104,00 x_1 + 43,00 x_2 + 389,00 x_3 + 188,00 x_4 + 186,00 x_5 + 38,40 x_6 + 77,00 x_7 + 132,00 x_8 + 186,00 x_9 + 34,00 x_{10} + 248,00 x_{11} + 462,00 x_{12} + 187,00 x_{13} + 23,00 x_{14} + 104,00 x_{15} + 227,80 x_{16} ≥ 2000,00

Constraint set 4:

The maximum amount of protein (g) should be less than or equal to 184.

Protein (g): 24,80 x_1 + 3,50 x_2 + 16,90 x_3 + 8,00 x_4 + 7,63 x_5 + 0,84 x_6 + 0,40 x_7 + 6,38 x_8 + 5,00 x_9 + 2,80 x_{10} + 0,00 x_{11} + 86,80 x_{12} + 4,37 x_{13} + 2,90 x_{14} + 1,30 x_{15} + 32,47 x_{16} ≤ 184,00

The maximum amount of carbohydrates (g) should be less than or equal to 342.

Carbohydrates (g): 1,60 x_1 + 0,30 x_2 + 66,30 x_3 + 6,40 x_4 + 33,25 x_5 + 9,24 x_6 + 20,60 x_7 + 28,82 x_8 + 42,40 x_9 + 6,60 x_{10} + 0,00 x_{11} + 0,00 x_{12} + 38,64 x_{13} + 3,60 x_{14} + 5,53 x_{15} + 0,00 x_{16} ≤ 342,00

The maximum amount of fat (g) should be less than or equal to 82.

Fat (g): 0,00 x_1 + 3,00 x_2 + 6,90 x_3 + 16,10 x_4 + 2,52 x_5 + 0,36 x_6 + 0,30 x_7 + 0,44 x_8 + 0,10 x_9 + 0,40 x_{10} + 28,00 x_{11} + 10,08 x_{12} + 1,51 x_{13} + 0,40 x_{14} + 9,56 x_{15} + 10,03 x_{16} ≤ 82,00

The maximum amount of vitamin A (IU) should be less than or equal to 10000.

Vitamin A (IU): 0,00 x_1 + 164,00 x_2 + 0,00 x_3 + 0,00 x_4 + 0,00 x_5 + 14,40 x_6 + 80,50 x_7 + 9409,40 x_8 + 20,00 x_9 + 623,00 x_{10} + 0,00 x_{11} + 58,80 x_{12} + 0,00 x_{13} + 9376,00 x_{14} + 94,90 x_{15} + 204,00 x_{16} ≤ 10000,00

The maximum amount of vitamin C (mg) should be less than or equal to 2000.

Vitamin C (mg): 0,00 x_1 + 0,00 x_2 + 0,00 x_3 + 0,00 x_4 + 0,14 x_5 + 70,56 x_6 + 6,90 x_7 + 7,04 x_8 + 19,20 x_9 + 89,20 x_{10} + 0,00 x_{11} + 0,00 x_{12} + 0,00 x_{13} + 28,10 x_{14} + 6,50 x_{15} + 0,00 x_{16} ≤ 2000,00

The maximum amount of omega-3 (mg) should be less than or equal to 3000.

Omega-3 (mg): 0,00 x_1 + 21,80 x_2 + 111,00 x_3 + 24,30 x_4 + 94,50 x_5 + 78,00 x_6 + 13,40 x_7 + 41,80 x_8 + 26,00 x_9 + 21,00 x_{10} + 213,00 x_{11} + 196,00 x_{12} + 23,52 x_{13} + 138,00 x_{14} + 71,50 x_{15} + 27,27 x_{16} ≤ 3000,00

The maximum amount of dietary fiber (g) should be less than or equal to 50.

Dietary Fiber (g): 0,00 x_1 + 0,00 x_2 + 10,60 x_3 + 1,90 x_4 + 2,52 x_5 + 2,40 x_6 + 3,60 x_7 + 9,68 x_8 + 4,40 x_9 + 2,60 x_{10} + 0,00 x_{11} + 0,00 x_{12} + 3,02 x_{13} + 2,20 x_{14} + 4,36 x_{15} + 0,00 x_{16} ≤ 50,00

The maximum amount of calcium (mg) should be less than or equal to 2500.

Calcium (mg): 16,00 x_1 + 14,00 x_2 + 54,00 x_3 + 13,80 x_4 + 99,40 x_5 + 19,20 x_6 + 8,90 x_7 + 55,00 x_8 + 30,00 x_9 + 47,00 x_{10} + 0,30 x_{11} + 42,00 x_{12} + 16,80 x_{13} + 99,00 x_{14} + 7,80 x_{15} + 44,20 x_{16} ≤ 2500,00

The maximum amount of iron (mg) should be less than or equal to 45.

Iron (mg): 0,00 x_1 + 0,30 x_2 + 4,70 x_3 + 0,60 x_4 + 2,45 x_5 + 0,48 x_6 + 0,20 x_7 + 1,76 x_8 + 2,20 x_9 + 0,70 x_{10} + 0,20 x_{11} + 2,80 x_{12} + 0,67 x_{13} + 2,70 x_{14} + 0,33 x_{15} + 0,68 x_{16} $\leq$ 45,00

The maximum amount of calories (Cal) should be less than or equal to 2200.

Calories: 104,00 x_1 + 43,00 x_2 + 389,00 x_3 + 188,00 x_4 + 186,00 x_5 + 38,40 x_6 + 77,00 x_7 + 132,00 x_8 + 186,00 x_9 + 34,00 x_{10} + 248,00 x_{11} + 462,00 x_{12} + 187,00 x_{13} + 23,00 x_{14} + 104,00 x_{15} + 227,80 x_{16} $\leq$ 2200,00

The results:

Using the simplex method, the feasible solution for the female case was found.

Table 9 - Achieved results – Objective function (female case)

Function	
Variables	**Price (CZK/portion)**
Eggs whites	26,29
Egg whole	3,29
Oats	2,87
Peanut butter	5,65
Wheat bread	3,12
Strawberries	22,51
Apples	4,46
Frozen mix vegetables	17,53
Potatoes	3,18
Broccoli	7,98
Olive oil	7,04
Chicken	21,81
Brown rice	11,59
Spinach	26,32
Avocado	6,46
White fish	48,11
Final Value	79,74

Source: Own calculations, 2017

Table 10 - Achieved results – Variables (female case)

Variables	Values (times)
Eggs whites	0,00
Egg whole	0,00
Oats	0,00
Peanut butter	3,55
Wheat bread	7,40
Strawberries	0,00
Apples	0,00
Frozen mix vegetables	0,00
Potatoes	0,00
Broccoli	4,58
Olive oil	0,00
Chicken	0,00
Brown rice	0,00
Spinach	0,00
Avocado	0,00
White fish	0,00

Source: Own calculations, 2017

The cost was decreased from 218,22 CZK to 79,74 CZK, which is the final value of the objective function.

The optimal solution indicates that in order to meet the required amounts of nutrition and at the same time decrease the costs an average woman needs to consume the following numbers of servings of foods during the day:

1. Peanut butter 3,55 within the serving size 30g
2. Wheat bread 7,40 within the serving size 70g
3. Broccoli 4,58 within the serving size 100g

Table 11 - Achieved results – Nutrients (female case)

Constraints	Protein(g)	Carbohydrates(g)	Fat (g)	Vitamin A(IU)	Vitamin C(mg)	Vitamin E(mg)	Omega-3(mg)	Dietary Fiber(g)	Calcium(mg)	Iron(mg)	Magnesium(mg)	Calories
Eggs whites	24,80	1,60	0,00	0,00	0,00	0,00	0,00	0,00	16,00	0,00	24,80	104,00
Egg whole	3,50	0,30	3,00	164,00	0,00	0,30	21,80	0,00	14,00	0,30	2,80	43,00
Oats	16,90	66,30	6,90	0,00	0,00	0,00	111,00	10,60	54,00	4,70	177,00	389,00
Peanut butter	8,00	6,40	16,10	0,00	0,00	2,90	24,30	1,90	13,80	0,60	49,30	188,00
Wheat bread	7,63	33,25	2,52	0,00	0,14	0,14	94,50	2,52	99,40	2,45	33,60	186,00
Strawberries	0,84	9,24	0,36	14,40	70,56	0,36	78,00	2,40	19,20	0,48	15,60	38,40
Apples	0,40	20,60	0,30	80,50	6,90	0,30	13,40	3,60	8,90	0,20	7,50	77,00
Frozen mix veg.	6,38	28,82	0,44	9409,40	7,04	0,88	41,80	9,68	55,00	1,76	48,40	132,00
Potatoes	5,00	42,40	0,10	20,00	19,20	0,00	26,00	4,40	30,00	2,20	56,00	186,00
Broccoli	2,80	6,60	0,40	623,00	89,20	0,80	21,00	2,60	47,00	0,70	21,00	34,00
Olive oil	0,00	0,00	28,00	0,00	0,00	4,00	213,00	0,00	0,30	0,20	0,00	248,00
Chicken	86,80	0,00	10,08	58,80	0,00	0,84	196,00	0,00	42,00	2,80	81,20	462,00
Brown rice	4,37	38,64	1,51	0,00	0,00	0,00	23,52	3,02	16,80	0,67	72,24	187,00
Spinach	2,90	3,60	0,40	9376,00	28,10	2,00	138,00	2,20	99,00	2,70	79,00	23,00
Avocado	1,30	5,53	9,56	94,90	6,50	1,37	71,50	4,36	7,80	0,33	18,85	104,00
White fish	32,47	0,00	10,03	204,00	0,00	0,34	27,27	0,00	44,20	0,68	56,10	227,80
Left-side	97,71	299,05	77,66	2854,27	409,71	15,00	881,90	37,31	1000,00	23,47	519,96	2200,00
Right-side(min)	53,00	237,00	47,00	2310,00	75,00	15,00	500,00	25,00	1000,00	18,00	310,00	2000,00
Right-side(max)	184,00	342,00	82,00	10000,00	2000,00	ND	3000,00	50,00	2500,00	45,00	ND	2200,00

Source: Own calculations, 2017

Additionally, the left-side row represents the amounts of nutrients a person consumes, which respect the upper and lower bounds applied.

Protein (g): the obtained amount of the protein ***97,71*** g is greater than the minimum recommended intake 53,00 g and less than the maximum one 184,00 g.

Carbohydrates (g): the obtained amount of the carbohydrates ***299,05*** g is greater than the minimum recommended intake 237,00 g and less than the maximum one 342,00 g.

Fat (g): the obtained amount of the fat ***77,66*** g is greater than the minimum recommended intake 47,00 g and less than the maximum one 82,00 g.

Vitamin A (IU): the obtained amount of the vitamin A ***2854,27*** IU is greater than the minimum recommended intake 2310,00 IU and less than the maximum one 10000,00 IU.

Vitamin C (mg): the obtained amount of the vitamin C ***409,71*** mg is greater than the minimum recommended intake 75,00 mg and less than the maximum one 2000,00 mg.

Vitamin E (mg): the obtained amount of the vitamin E ***15,00*** mg is equal to the minimum recommended intake 15,00 mg.

Omega-3 (mg): the obtained amount of the omega-3 ***881,90*** mg is greater than the minimum recommended intake 500,00 mg and less than the maximum one 3000,00 mg.

Dietary Fiber (g): the obtained amount of the dietary fiber ***37,31*** g is greater than the minimum recommended intake 25,00 g and less than the maximum one 50,00 g.

Calcium (mg): the obtained amount of the calcium ***1000,00*** mg is equal to the minimum recommended intake 1000,00 mg.

Iron (mg): the obtained amount of the iron ***23,47*** mg is greater than the minimum recommended intake 18,00 mg and less than the maximum one 45,00 mg.

Magnesium (mg): the obtained amount of the magnesium ***519,96*** mg is greater than the minimum recommended intake 310,00 mg.

Calories: the obtained amount of the calories ***2200,00*** is equal to the maximum recommended intake 2200,00.

5. Conclusion

The main goal of the thesis is to understand and solve the least cost diet problem in consideration of healthy issues. From the theoretical aspect, it is important to realize what affects people's behavior in choosing their individual diet. Setting up the diet it is necessary to take into account food habits of the person's nationality and consider that the elimination of national cuisine might be difficult even though the traditional meals are initially unhealthy. Another obstacle eat healthily is high prices on nutritionally - enriched food. Most of the people do not tend to pay more money for healthy nutritional composition in foods. As the result of not applied on global level healthy eating habits people get obese. Obesity is worldwide spread problem, which is the consequence of the lack of money and time. There are two more problems tightly related to the global obesity: hunger and food wastage. Even one-quarter of wasted food could feed 795 million people, who suffer from hunger. The people, who waste the most, are from high obesity rates countries. These three global problems are strongly tied up and the solution of one of them is the first step in solving the rest.

Moreover, as initial criteria, it is necessary to know the gender, age and level of physical activity to set up an individual diet. This personal information is used not only to define how much calories and fundamental nutrients such as protein, carbohydrates and fat a person needs, but also the amounts of vitamins and minerals.

Two different cases – male and female – were applied to linear programming model with the essential aim to minimize costs and subsequently successfully solved. However, the results of both cases show that the less a person needs in calories the more he or she should pay for food daily. Anyway, the difference in costs between initial and obtained is significant.

The research demonstrates that using linear programming model can help people to achieve their goals in healthy diet within their budget. It can be the first step in treating obesity and anorexia or other eating disorders, either decreasing or increasing the nutritional requirements. The simplicity of the model enables all people to work with it and get desirable results.

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