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What Are the Impacts of Food Losses on the Nutrition?

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Abstract

Reducing food loss and waste is enshrined in Sustainable Development Goal (SDG) 12 on Responsible Consumption and Production, and specifically in target 12.3, which seeks, by 2030, to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses. Food loss is for any food removed from the supply chain between maturity and sale, including inedible parts as these are integral to the marketed product. The main hypothesis is that the greater the loss of food, the less the supply of food per capita will be, from where the possibilities for feeding the population decrease. Based on data from the Food and Agriculture Organization (FAO), a mediation analysis will be performed with food losses as independent variables, with dependent variables measuring population nutrition and mediator variables measuring per capita food supply. Various survey methods have been applied, secondary data analysis, cimultaneous equations model(SEM), mediation analysis, as well as desktop research. The results of the study showed that the relationships between Losses Animal Products and the mediator variables are positive – greater losses lead to greater per capita supply. The relationships between per capita supply and prevalence of undernourishment are negative – larger per capita supply leads to a smaller prevalence of undernourishment.

Keywords: *Food Losses, Fao, Simultaneous Equations Model, Mediator Variables, Population Nutrition.*

Introduction

The world's population is growing, and this requires much more efforts and innovations to increase sustainable agricultural production, improve the supply chain in every country in the world, including Bulgaria, to reduce food loss and waste and to ensure that everyone has access to nutritious food. Food loss is a risk to both food security and the environment. According to the Food and Agriculture Organization of the United Nations, nearly 1/3 of the food produced worldwide is lost or wasted. The report by FAO Director-General Qu Dongyu also stated that losses related to basic agricultural products showed increasing trends. For example, cereal losses have averaged 69 million tonnes per year over the past three decades - equivalent to the entire cereal production in France in 2021 - followed by fruit and vegetables and sugar crops, each approaching average losses of 40 million tons per year. For fruits and vegetables, the losses correspond to the entire production of fruits and vegetables in Japan and Vietnam in 2021. For meat, dairy products, and eggs, losses are estimated at an average of 16 million tons per year, which corresponds to the entire production of meat, dairy products, and eggs in Mexico and India in 2021.

To understand what is meant by food loss, it is important to refer to the correct definitions of "food". This term refers to any substance or product, whether processed, partially processed or unprocessed, intended to be or reasonably expected to be consumed by humans (European Comission, 2002). It is therefore possible to distinguish food loss from food waste according to the stage at which it occurs in the food supply chain.

There are several products and definitions proposed in the literature for FLW phenomena. The products to be taken into account are only those agricultural products originally intended for human consumption, ready-to-harvest or post-harvest (FAO, 2014) The terminology used may be different. FAO (FAO, 2014) uses the term "food waste" only in relation to the final stages of retailing and consumption.

In our research for Bulgaria, the data available for losses include the amount of the commodity in question lost through wastage (waste) during the year at all stages between the level at which production is recorded and the household, i.e. storage and transportation. Losses occurring before and during harvest are excluded.

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Waste from both edible and inedible parts of the commodity occurring in the household is also excluded. Quantities lost during the transformation of primary commodities into processed products are taken into account in the assessment of respective extraction/conversion rates. Distribution wastes tend to be considerable in countries with hot humid climate, difficult transportation and inadequate storage or processing facilities.

Food loss and waste (FLW) is recognized as a serious threat to food security, the economy, and the environment (Abiad&Meho, 2018). Approximately one-third of all food produced for human consumption (1.3 billion tons of edible food) is lost and wasted across the entire supply chain every year (Gustavsson et al., 2011). Food supply chain includes the series of related activities used to produce, process, distribute and consume food (FAO, 2019). Each stage of the FSC consists of several operations, both agricultural and industrial, within which different types of losses and waste occur. Understanding the causes and identifying why food is lost and wasted is a key step in improving resource efficiency in the long term (Luo et al., 2021). The amount of FLW varies between countries, being influenced by level of income, urbanization, and economic growth (Chalak et al., 2016, 420). In less-developed countries, FLW occurs mainly in the post-harvest and processing stage (Gustavsson et al., 2011), which accounts for approximately 44% of global FLW (HLPE, 2016). Understanding the causes and identifying why food is lost is a key step improving resource efficiency in the long term FAO, 2019). Losses along the FSC generally depend on socioeconomic, biological and/or microbiological, chemical or biochemical, mechanical and/or environmental factors (WP, 2015). Urbanization is an important cause associated with the production of large amounts of food waste, as it has led to the expansion of FSC as a response to the nutritional needs of the population (Bricas, 2019).

The term "food" refers to any substance or product, whether processed, partially processed or unprocessed, intended to be or reasonably expected to be consumed by humans (European Commission, 2002). Food includes beverages, chewing gum and any substance, including water, intentionally incorporated into food during its manufacture, preparation or processing (Patel et al., 2021). Therefore, to distinguish between food loss and food waste, the stage at which this occurs in the FSC is very important.

To date, there is no commonly accepted definition of FLW (Abdelradi, 2018, 488), making it difficult to measure FLW and conduct targeted research and set policy goals. Various terms such as food waste, food loss, post-harvest loss, spoilage, food and beverage waste, bio-waste and kitchen waste are used interchangeably (see Table 1) (Schneider, 2013,191). These terms can be used to express completely different concepts (Gjerris& Gaiani, 2013, 9). Several institutions have announced and used their own definitions in their studies, as follows:

Table1. Definitions of Food Loss and Waste

Concepts	Definitions
Food Loss (by FAO)	Decrease in weight (dry matter) or quality (nutritional value) of food that was originally produced for human consumption.
FoodWaste (by FAO)	Food appropriate for human consumption being discarded, whether after it is left to spoil or kept beyond its expiry date.
Food Loss (by High Level Panel of Experts)	A decrease, at all stages of the FSC prior to the consumer level, in mass of food that was originally intended for human consumption, regardless of the cause.
Food Waste (by High Level Panel of Experts)	Food appropriate for human consumption being discarded or left to spoil at consumer level regardless of the cause
Food Loss and Waste (by United States Department of Agriculture)	FW is a subcomponent of FL and occurs when an edible food goes unconsumed. The food which is

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	still edible at the time of discard is considered as food waste.

FAO: Food and Agriculture Organization; EU: European Union; FSC: food supply chain; FW: Food Waste; FL: Food Loss.

The paper aims to promote the view that the generation of food losses after harvesting depends mainly on the supply chain (SC) strategies applied in practice, and to show in the specific case how these plant and animal losses affect the average adequacy of food energy supplies and the prevalence of undernourishment. The main hypothesis is that food losses affect the per capita supply, which in turn affects the nutrition of the population. The rationale for this hypothesis is as follows:

- According to the Food balance Domestic Supply Total is sum of Domestic Utilization as Food, Processing, Feed, Seed, Losses, Other uses (non-food), Tourist consumption and Residuals. That means that when food losses increase then other forms of domestic utilization are expected to decrease;

- Per capita supply is obtained by dividing Domestic Utilization as Food by the number of the population. Thus, when Domestic Utilization as Food decreases, per capita supply will also decrease;

- When per capita supply decreases, then the ability for population nutrition will decrease.

Materials And Methods

Data

The data source is the Food and Agriculture Organization (FAO). Data from Food Balances and from Food Security and Nutrition were used (https://www.fao.org/faostat/en/#data). The data refer to the period 2000-2021. Food losses are calculated separately for vegetal and animal products. First, the food losses of the individual vegetal and animal products, measured in million metric tons, were summed up. The resulting losses are then divided into Domestic supply total. In this way, food losses are calculated in percentages that are comparable between different years. For per capita supply, all four FAO indicators were used:

- Per Capita Supply Total (Kg/Year);
- Per Capita Supply Total (KCal/Day);
- Per Capita Supply Proteins (g/Day);
- Per Capita Supply Fat (g/Day).

These indicators are available separately for vegetal and animal products.

Two indicators were used as a measure of population nutrition:

- Average dietary energy supply adequacy;
- Prevalence of undernourishment.

Since the information for these two indicators is in the form of 3-year averages, all other indicators were also calculated as 3-year averages. In this calculation, a weighted arithmetic mean was used, with the number of population and the number of days in the respective year used as weights. As a result, 20 3-year intervals were obtained – from 2000-2002 to 2019-2021.

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Methods

First-generation multivariate data analysis techniques such as multiple regression, logistic regression, and analysis of variance belong to the core set of statistical methods used by researchers to empirically test hypothesized relationships between variables of interest. Numerous researchers have applied these methods to generate various findings.

The single equation model assumes regression of a dependent variable on explanatory variable(s), which directly means a one-way causation between the dependent variable and explanatory variable(s). But, what if the explanatory variables are not truly exogenous? This invariably means a two-way causation between the dependent and exogenous variables in which one equation cannot be treated in isolation as a single equation model. In other words, this indicates a system of equations whereby each equation cannot be treated separately as a single equation mainly because of the joint dependence of the endogenous(Y) and exogenous variables(X) or predetermined variables. This type of model is called the simultaneous equation model(SEM) which we also use in the study.

The particular indicators we have used to measure food losses, per capita supply and nutrition of the population, lead to the concretization of the main hypothesis. This concretization is presented in Fig. 1, in which expected positive relations are marked in green and expected negative relations are marked in red:

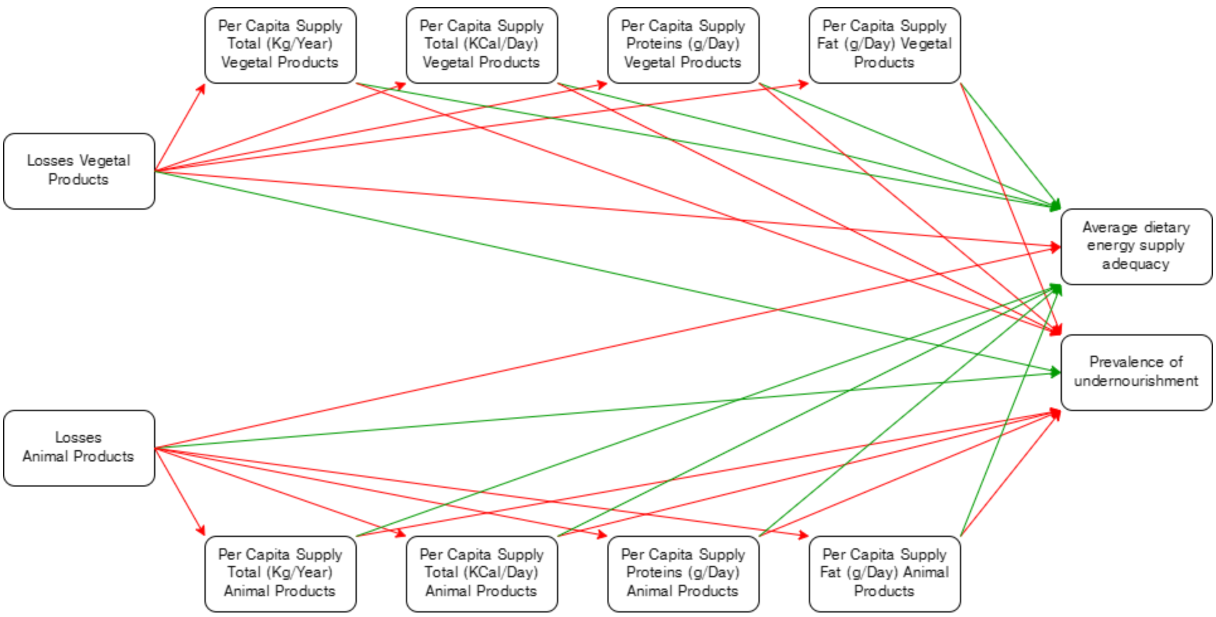

Fig. 1. Concretization Of the Main Hypothesis

Structural equation modeling (SEM) was used to model these relationships. Following Martin et al. (2013, 159), SEM is such a model where the dependent variable depends on a set of independent variables, but at the same time some of these independent variables depend on other dependent variables. The system of equations used to estimate the relationships is:

$$\left|\begin{array}{l}\hat{Y}_i = a_i + \sum_{k=1}^{2} b_{ik}X_k + \sum_{k=1}^{8} c_{ik}M_k \ \ (i = 1,2) \\ \hat{M}_{1j} = a_{1j} + b_{1j}X_1 \ (j = 1,2,3,4) \\ \hat{M}_{2j} = a_{2j} + b_{2j}X_2 \ (j = 1,2,3,4)\end{array}\right.$$

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Where:

Y_1 is Average dietary energy supply adequacy;

Y_2 is Prevalence of undernourishment;

X_1 are Losses Vegetal Products;

X_2 are Losses Animal Products;

M_1j are per capita supply vegetable products;

M_2j are per capita supply animal products.

This model allows the estimation of both the direct and indirect impacts of the independent variables on the dependent variables.

Results And Discussion

Before the application of SEM, a time series stationarity check was made. For this purpose, the Augmented Dickey-Fuller (ADF) test was used, which is the most popular and most commonly used Unit Root test.

Table 2. Augmented Dickey-Fuller TEST*

Variable	**Level – intercept**		**First differences – intercept**		**Second differences – intercept**	
	Test statistics	***p*-value**	**Test statistics**	***p*-value**	**Test statistics**	***p*-value**
Losses Vegetal Products	-2.02	0.275	**-6.84**	**0.000**		
Losses Animal Products	**-4.73**	**0.002**				
Per Capita Supply Total (Kg/Year) Vegetal Products	-0.69	0.826	**-3.23**	**0.037**		
Per Capita Supply Total (Kg/Year) Animal Products	-1.17	0.662	-2.14	0.234	**-6.51**	**0.000**
Per Capita Supply Total (KCal/Day) Vegetal Products	-1.78	0.378	-0.21	0.917	**-5.23**	**0.001**
Per Capita Supply Total (KCal/Day) Animal Products	2.23	1.000	-2.82	0.076	**-6.88**	**0.000**
Per Capita Supply Proteins (g/Day) Vegetal Products	-2.80	0.079	-2.45	0.144	**-4.29**	**0.005**
Per Capita Supply Proteins (g/Day) Animal Products	1.09	0.996	**-3.20**	**0.039**		
Per Capita Supply Fat (g/Day) Vegetal Products	-2.40	0.154	-1.79	0.373	**-3.51**	**0.021**
Per Capita Supply Fat (g/Day) Animal Products	2.53	1.000	-2.16	0.226	**-5.81**	**0.000**
Average Dietary Energy Supply Adequacy	2.83	1.000	-2.54	0.123	**-4.23**	**0.006**
Prevalence of Undernourishment	0.42	0.978	-2.68	0.103	**-5.64**	**0.001**

* Null hypothesis is that time series have unit root, i.e., time series are non-stationary.

As a result of the check, it was found that:

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- The time series of Losses Animal Products is stationary;

- The time series of Losses Vegetal Products, Per Capita Supply Total (Kg/Year) Vegetal Products and Per Capita Supply Proteins (g/Day) Animal Products are non-stationary, but the time series of the first differences are stationary. Therefore, the first differences were used in the analysis;

- The time series of Average dietary energy supply adequacy, Prevalence of undernourishment, Per Capita Supply Total (Kg/Year) Animal Products, Per Capita Supply Total (KCal/Day) Vegetal Products, Per Capita Supply Total (KCal/Day) Animal Products, Per Capita Supply Proteins (g/Day) Vegetal Products, Per Capita Supply Fat (g/Day) Vegetal Products and Per Capita Supply Fat (g/Day) Animal Products are non-stationary and the time series of the first differences are also non-stationary. However, the time series of the second differences are stationary, so the second differences are used in the analysis.

After evaluation of SEM model, the following results were obtained (table 3):

Table 3. Estimations Of Coefficients Of SEM

Independent variable	Dependent variable	Unstandardized coefficient	*z*-statistics	*p*-value	Standardized coefficient
Losses Vegetal Products	Average Dietary Energy Supply Adequacy	0.383	1.018	0.309	0.138
Losses Animal Products	Average Dietary Energy Supply Adequacy	-0.535	-0.498	0.619	-0.083
Per Capita Supply Total (Kg/Year) Vegetal Products	Average Dietary Energy Supply Adequacy	-0.007	-0.424	0.672	-0.051
Per Capita Supply Total (Kg/Year) Animal Products	Average Dietary Energy Supply Adequacy	0.049	1.622	0.105	0.222
Per Capita Supply Total (KCal/Day) Vegetal Products	Average Dietary Energy Supply Adequacy	**0.036**	**5.641**	**0.000**	0.653
Per Capita Supply Total (KCal/Day) Animal Products	Average Dietary Energy Supply Adequacy	0.003	0.240	0.810	0.030
Per Capita Supply Proteins (g/Day) Vegetal Products	Average Dietary Energy Supply Adequacy	**-0.618**	**-4.181**	**0.000**	-0.484
Per Capita Supply Proteins (g/Day) Animal Products	Average Dietary Energy Supply Adequacy	-0.093	-0.655	0.512	-0.076
Per Capita Supply Fat (g/Day) Vegetal Products	Average Dietary Energy Supply Adequacy	-0.044	-0.703	0.482	-0.084
Per Capita Supply Fat (g/Day) Animal Products	Average Dietary Energy Supply Adequacy	0.251	1.122	0.262	0.150
Losses Vegetal Products	Prevalence of Undernourishment	-0.004	-0.109	0.913	-0.005
Losses Animal Products	Prevalence of Undernourishment	**0.236**	**2.095**	**0.036**	0.110

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Independent variable	Dependent variable	Unstandardized coefficient	*z*-statistics	*p*-value	Standardized coefficient
Per Capita Supply Total (Kg/Year) Vegetal Products	Prevalence of Undernourishment	-0.003	-1.594	0.111	-0.060
Per Capita Supply Total (Kg/Year) Animal Products	Prevalence of Undernourishment	-0.001	-0.389	0.697	-0.017
Per Capita Supply Total (KCal/Day) Vegetal Products	Prevalence of Undernourishment	**-0.017**	**-24.964**	**0.000**	-0.908
Per Capita Supply Total (KCal/Day) Animal Products	Prevalence of Undernourishment	**-0.011**	**-7.987**	**0.000**	-0.309
Per Capita Supply Proteins (g/Day) Vegetal Products	Prevalence of Undernourishment	0.012	0.745	0.456	0.027
Per Capita Supply Proteins (g/Day) Animal Products	Prevalence of Undernourishment	**-0.041**	**-2.727**	**0.006**	-0.100
Per Capita Supply Fat (g/Day) Vegetal Products	Prevalence of Undernourishment	**0.031**	**4.788**	**0.000**	0.180
Per Capita Supply Fat (g/Day) Animal Products	Prevalence of Undernourishment	**-0.078**	**-3.336**	**0.000**	-0.140
Losses Vegetal Products	Per Capita Supply Total (Kg/Year) Vegetal Products	5.273	1.238	0.216	0.273
Losses Animal Products	Per Capita Supply Total (Kg/Year) Animal Products	**15.460**	**2.684**	**0.007**	0.535
Losses Vegetal Products	Per Capita Supply Total (KCal/Day) Vegetal Products	-1.920	-0.163	0.870	-0.038
Losses Animal Products	Per Capita Supply Total (KCal/Day) Animal Products	20.490	1.551	0.121	0.343
Losses Vegetal Products	Per Capita Supply Proteins (g/Day) Vegetal Products	0.104	0.202	0.840	0.048
Losses Animal Products	Per Capita Supply Proteins (g/Day) Animal Products	0.564	0.469	0.639	0.107
Losses Vegetal Products	Per Capita Supply Fat (g/Day) Vegetal Products	-1.387	-1.146	0.252	-0.261
Losses Animal Products	Per Capita Supply Fat (g/Day) Animal Products	**1.924**	**2.450**	**0.014**	0.500

Results and Discussion

Obtained statistically significant relationships are presented in Fig. 2.

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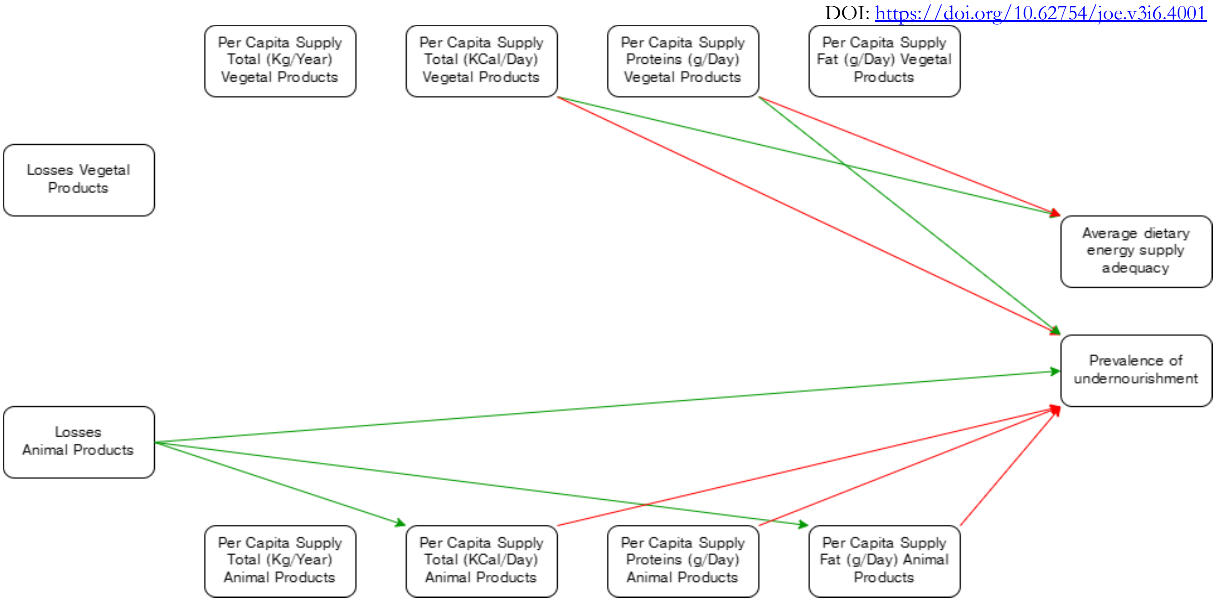

Fig.2. Relationships Identified Through the Mediation Analysis

From the revealed relations in Fig. 2, several conclusions can be drawn:

Losses Vegetal Products does not influence either directly or indirectly on the two dependent variables;

Losses Animal Products influences both directly and indirectly on Prevalence of undernourishment:

Direct relationship is positive – greater Losses Animal Products leads to a higher Prevalence of undernourishment, which coincides with preliminary expectations;

Indirect relationships are mediated by Per Capita Supply Total (KCal/Day) Animal Products and Per Capita Supply Fat (g/Day) Animal Products:

The relationships between Losses Animal Products and the mediator variables are positive – greater losses lead to greater per capita supply. This contradicts preliminary expectations that greater losses will lead to a smaller per capita supply;

The relationships between per capita supply and Prevalence of undernourishment are negative – larger per capita supply leads to a smaller Prevalence of undernourishment, which coincides with preliminary expectations;

Some of the mediator variables have an independent influence on the dependent variables:

Per Capita Supply Total (KCal/Day) Vegetal Products affects both Average dietary energy supply adequacy and Prevalence of undernourishment:

The relationship between Per Capita Supply Total (KCal/Day) Vegetal Products and Average dietary energy supply adequacy is positive – greater Per Capita Supply Total (KCal/Day) Vegetal Products leads to greater Average dietary energy supply adequacy, which coincides with preliminary expectations;

The relationship between Per Capita Supply Total (KCal/Day) Vegetal Products and Prevalence of undernourishment is negative – larger Per Capita Supply Total (KCal/Day) Vegetal Products leads to lower Prevalence of undernourishment, which coincides with preliminary expectations;

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Per Capita Supply Proteins (g/Day) Vegetal Products affects both Average dietary energy supply adequacy and Prevalence of undernourishment:

The relationship between Per Capita Supply Proteins (g/Day) Vegetal Products and Average dietary energy supply adequacy is negative – higher Per Capita Supply Proteins (g/Day) Vegetal Products leads to lower Average dietary energy supply adequacy. This contradicts preliminary expectations that greater Per Capita Supply Proteins (g/Day) Vegetal Products will lead to greater Average dietary energy supply adequacy;

The relationship between Per Capita Supply Proteins (g/Day) Vegetal Products and Prevalence of undernourishment is positive – greater Per Capita Supply Proteins (g/Day) Vegetal Products leads to higher Prevalence of undernourishment. This contradicts the preliminary expectations that greater Per Capita Supply Proteins (g/Day) Vegetal Products will lead to a lower Prevalence of undernourishment;

Per Capita Supply Total (KCal/Day) Animal Products affects the Prevalence of undernourishment. The relationship is negative – larger Per Capita Supply Proteins (g/Day) Animal Products leads to lower Prevalence of undernourishment, which coincides with preliminary expectations;

Some of the mediator variables do not influence the dependent variables – Per Capita Supply Total (Kg/Year) Vegetal Products, Per Capita Supply Total (Kg/Year) Animal Products and Per Capita Supply Fat (g/Day) Vegetal Products.

Conclussion

In the study, two indicators were used as a measure of population nutrition: Average adequacy of food energy supply and prevalence of malnutrition. Data from food balances and from food security and nutrition were used. The data refer to the period 2000-2021.

The specific indicators we used to measure food losses, per capita supply, and population nutrition lead to the specification of the main hypothesis. Simultaneous equation modeling (SEM) was used to model these relationships and for data processing. After evaluating the model, the following conclusions were drawn:

• Plant product losses do not directly or indirectly affect the two dependent variables;

• Losses Animal products directly and indirectly affect the prevalence of malnutrition.

It is concluded that the relationships between animal product losses and the mediator variables are positive – greater losses lead to greater per capita supply. The relationships between supply per capita and prevalence of malnutrition are negative – higher supply per capita leads to lower prevalence of malnutrition.

The conclusion drawn is that Losses Vegetal Products does not influence either directly or indirectly on the nutrition of the Bulgarian population; Losses Animal Products influences both directly and indirectly on Prevalence of Undernourishment. Direct relationship is positive – greater Losses Animal Products leads to a higher Prevalence of Undernourishment. Indirect relationship is mediated by Per Capita Supply Fat (g/Day) Animal Products; the relationship between Losses Animal Products and the mediator variable is positive – greater losses lead to greater per capita supply; the relationship between per capita supply and Prevalence of Under-nourishment is negative – larger per capita supply leads to a smaller Prevalence of Undernourishment.

Some of the mediation variables have an independent influence on the dependent variables, which we have already discussed. And some of the mediator variables do not influence the dependent variables.

Author Contributions

All authors contributed to the study design, data collection and manuscript preparation. The role(s) that each author undertook should be reflected in this section. This section affirms that each credited author has had a significant contribution to the article.

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Data Availability

The data source is the Food and Agriculture Organization (FAO). Data from Food Balances and from Food Security and Nutrition were used. https://www.fao.org/faostat/en/#data).

Conflict of Interest

All authors disclosed no any conflict of interest.

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