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Influence of food losses on the negative effects of the nutrition of the population in Bulgaria

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Abstract

A third of all food produced globally by weight is lost or wasted between farm and fork – that's more than 1 billion tonnes. Converted into calories, this equates to 24% of the world's food supplies. Food loss refers to loss at or near the farm and in the supply chain. For the present study, it is important to know the losses of agricultural products that occur between the level at which production is recorded and the household, i.e., storage and transportation. The prevalence of overweight and obesity is emerging as a problem in Bulgarian society as well. Revealing the relationship between food loss from agricultural products and the prevalence of obesity is the aim of the study. The data source is the Food and Agriculture Organization (FAO). Data from Food Balances and from Food Security and Nutrition were used. The data refer to the period 2000–2021. For per capita supply, all four FAO indicators were used: Food supply quantity (kg/capita/year), Food supply (kcal/capita/day), Protein supply quantity (g/capita/day), Fat supply quantity (g/capita/day), separately for vegetal and animal products. One indicator was used as a measure of population nutrition: Prevalence of obesity in the adult population (18 years and older). For the last indicator, there is data only for the period 2000–2016, so our analysis is limited to this period. The main hypothesis is that food losses affect the per capita supply, which in turn affects the nutrition of the population and the prevalence of obesity. A simultaneous equations model (SEM) was used to model these relationships and process data. After evaluation of the SEM model, the following results were obtained: Losses of vegetal products directly influence the prevalence of obesity in the adult population (18 years and older). The relationship is negative – greater losses of vegetal products lead to a lower prevalence of obesity in the adult population (18 years and older), which coincides with preliminary expectations. Losses of animal products indirectly influence the prevalence of obesity in the adult population (18 years and older). The relationship is mediated by food supply (kcal/capita/day). The relationship between losses of animal products and the mediator variable is 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 relationship between per capita supply and the prevalence of obesity in the adult population (18 years and older) is positive; larger per capita supply leads to a higher prevalence of obesity in the adult population, which coincides with preliminary expectations. Some of the mediator variables have an independent influence on the dependent variables.

Keywords: Food losses, Mediation analysis, Population nutrition, SEM, Obesity.

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1. Introduction

In 2022, 2.5 billion adults aged 18 and older were overweight, including more than 890 million adults living with obesity. This accounts for 43% of adults aged 18 and over (43% of men and 44% of women) who are overweight; an increase from 1990, when 25% of adults aged 18 and over were overweight. The prevalence of overweight varied by region, from 31% in the WHO South-East Asia and African Regions to 67% in the Americas.

A new study released by the Lancet [1] shows that, in 2022, more than 1 billion people worldwide were living with obesity. WHO contributed to the data collection and analysis of this study? Globally, obesity among adults has more than doubled since 1990 and has quadrupled among children and adolescents (5 to 19 years of age). The data also indicate that 43% of adults were overweight in 2022. The study further reveals that, although the rates of undernutrition have decreased, it remains a public health challenge in many regions, particularly in South-East Asia and sub-Saharan Africa. Countries with the highest combined rates of underweight and obesity in 2022 included island nations in the Pacific and the Caribbean, as well as those in the Middle East and North Africa.

Obesity is a major public health problem that contributes to an increased prevalence of chronic diseases [2, 3]. Obesity is a complex, multifactorial disease, and in the European Region of the World Health Organization, almost 60% of people are obese. The prevalence of obesity has been rising worldwide, and Bulgaria is no exception [4].

In the country, no studies have been conducted to link food losses of agricultural origin (vegetal and animal) with the nutrition of the population. Ivanova et al. [5] examined the prevalence of overweight and obesity by gender and income among adults in Sofia, Bulgaria. Publications of the European Observatory on Health Systems and Policies, as well as those of the WHO, exist in the literature.

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. Waste from both edible and inedible parts of the commodity occurring in the household is also excluded.

Although estimates of loss vary depending on location and handling system [6], about one-third of food produced for human consumption is spoiled or wasted [7, 8]. In developing countries, most losses occur between the farm and the consumer, while in developed countries, a similar percentage of food is wasted by the final purchaser [9].

2. Materials and Methods

2.1. 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) [10]. The data refer to the period 2000-2021. Food losses are calculated separately for vegetable and animal products. First, the food losses of individual vegetal and animal products, measured in million metric tons, are summed up. The resulting losses are then divided by the domestic supply total. In this way, food losses are expressed as percentages that are comparable across different years.

For per capita supply, all four FAO indicators were used:

(i) Food supply quantity (kg/capita/year);
(ii) Food supply (kcal/capita/day);
(iii) Protein supply quantity (g/capita/day);
(iv) Fat supply quantity (g/capita/day).

These indicators are available separately for vegetal and animal products.

One indicator was used as a measure of the prevalence of obesity:

(v) Prevalence of obesity in the adult population (18 years and older)

For the last indicator, there is data only for the period 2000-2016, so our analysis is limited to this period.

The main hypothesis is that food losses affect per capita supply, which in turn influences the nutrition of the population and the prevalence of obesity. The rationale for this hypothesis is as follows:

(i)According to the Food Balance, Domestic Supply Total is the sum of Domestic Utilization as Food, Processing, Feed, Seed, Losses, Other Uses (non-food), Tourist Consumption, and Residuals. This means that when food losses increase as a percentage of the Domestic Supply Total, other forms of domestic utilization are expected to decrease also as a percentage of the Domestic Supply Total.

(ii) 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;

(iii)When per capita supply decreases, then the ability for population nutrition will decrease;

(iv)When the ability for population nutrition decreases, then the prevalence of obesity will also decrease.

2.2. Methods

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

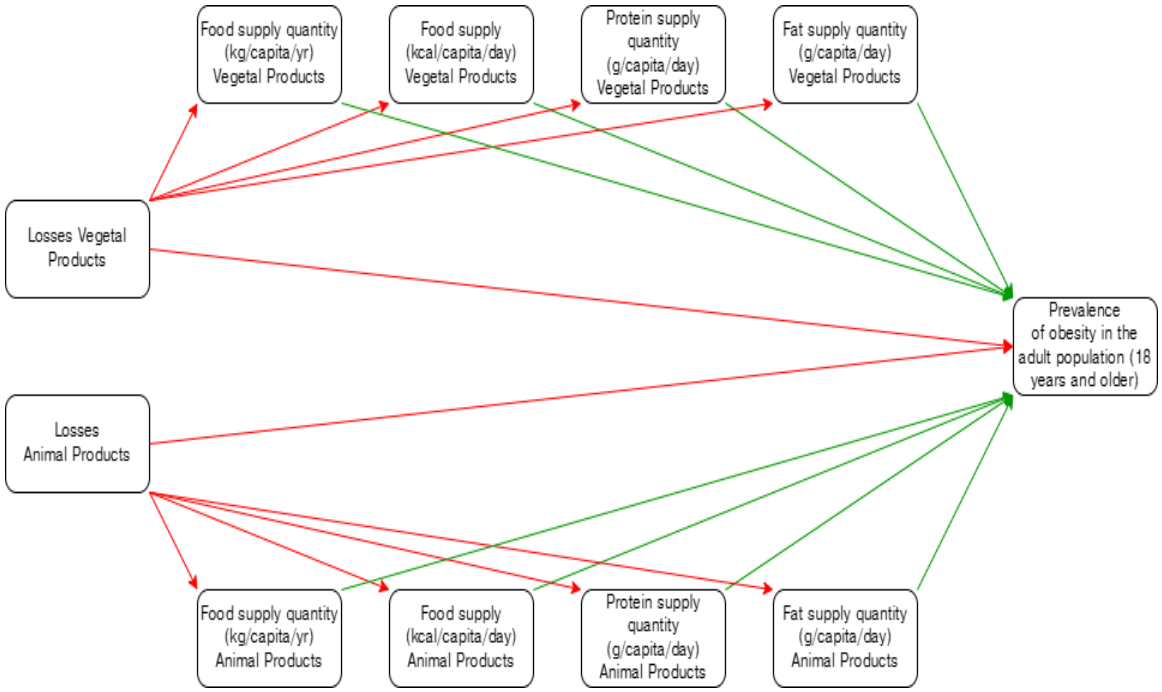

Figure 1.
Concretization of the main hypothesis.

Simultaneous equations model (SEM) was used to model these relationships. Following Martin et al. [11] SEM is 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:

$$\begin{cases} \hat{Y} = a + \sum_{i=1}^{2} b_i X_i + \sum_{i=1}^{2}\sum_{j=1}^{4} c_{ij} M_{ij} \\ \widehat{M}_{1j} = a_{1j} + b_{1j} X_1 \ (j = 1,2,3,4) \\ \widehat{M}_{2j} = a_{2j} + b_{2j} X_2 \ (j = 1,2,3,4) \end{cases}$$

Where:

Y is Prevalence of obesity in the adult population (18 years and older);

X_1 are Losses of Vegetal Products;

X_2 are Losses of Animal Products;

M_{1j} are per capita supply of vegetable products.

M_{2j} are per capita supply of animal products.

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

3. Results

However, few longitudinal data are available on the prevalence of overweight and obesity in Bulgaria, especially with respect to income [10]. There is limited data on the prevalence of obesity in Bulgaria, but there is information on losses from agricultural products. Moreover, the only reports of BMI in adults in Bulgaria come from clinical trials of limited size and scope [12, 13]. The agricultural product-food-obesity link is being investigated for the first time. The reciprocity that occurs in the course of this relationship is extremely important. It is important to know the losses of agricultural products that occur between the level at which production is recorded and the household, i.e., storage and transportation. Much

attention has been given in the literature to losses of agricultural products occurring before and during harvest [14]. In our data, they are excluded.

Before the application of SEM, a stationarity test for the time series was conducted. The Augmented Dickey-Fuller (ADF) test was used for this purpose (Table 1), which is the most popular and most commonly used Unit Root test.

Table 1.
Augmented Dickey-Fuller test*.

Variable	Level – intercept		First differences – intercept	
	Test statistics	*p*-value	Test statistics	*p*-value
Losses of Vegetal Products	-4.91	0.001		
Losses of Animal Products	-5.17	0.001		
Food supply quantity (kg/capita/year) Vegetal Products	-2.40	0.154	-5.32	0.001
Food supply quantity (kg/capita/year) Animal Products	-1.07	0.708	-5.64	0.000
Food supply (kcal/capita/day) Vegetal Products	-2.31	0.177	-5.91	0.000
Food supply (kcal/capita/day) Animal Products	1.39	0.998	-4.70	0.002
Protein supply quantity (g/capita/day) Vegetal Products	-2.43	0.146	-4.81	0.001
Protein supply quantity (g/capita/day) Animal Products	0.22	0.967	-5.32	0.000
Fat supply quantity (g/capita/day) Vegetal Products	-2.75	0.085	-3.51	0.019
Fat supply quantity (g/capita/day) Animal Products	1.60	0.999	-3.48	0.020
Prevalence of obesity in the adult population (18 years and older)	3.10	1.000	-3.52	0.022

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

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

(i) The time series of Losses Vegetal Products and Losses Animal Products are stationary;

(ii) The time series of the prevalence of obesity in the adult population (18 years and older), food supply quantity (kg/capita/year) for vegetal products, food supply quantity (kg/capita/year) for animal products, food supply (kcal/capita/day) for vegetal products, food supply (kcal/capita/day) for animal products, protein supply quantity (g/capita/day) for vegetal products, protein supply quantity (g/capita/day) for animal products, fat supply quantity (g/capita/day) for vegetal products, and fat supply quantity (g/capita/day) for animal products are non-stationary. However, the time series of the first differences is stationary. Therefore, the first differences are used in the analysis.

After evaluation of the SEM model, the following results were obtained (Table 2):

Table 2.
Estimations of coefficients of SEM.

Independent variable	Dependent variable	Unstandardized coefficient	*z*-statistics	*p*-value
Losses of Vegetal Products	Prevalence of obesity in the adult population (18 years and older)	-0.028	-4.000	0.000
Losses of Animal Products	Prevalence of obesity in the adult population (18 years and older)	-0.007	-0.227	0.821
Food supply quantity (kg/capita/year) Vegetal Products	Prevalence of obesity in the adult population (18 years and older)	-2.235×10^{-4}	-0.724	0.469
Food supply quantity (kg/capita/year) Animal Products	Prevalence of obesity in the adult population (18 years and older)	0.001	1.669	0.095
Food supply (kcal/capita/day) Vegetal Products	Prevalence of obesity in the adult population (18 years and older)	8.269×10^{-4}	4.909	0.000
Food supply (kcal/capita/day) Animal Products	Prevalence of obesity in the adult population (18 years and older)	0.003	8.754	0.000
Protein supply quantity (g/capita/day) Vegetal Products	Prevalence of obesity in the adult population (18 years and older)	-0.019	-4.397	0.000
Protein supply quantity (g/capita/day) Animal Products	Prevalence of obesity in the adult population (18 years and older)	-0.008	-2.216	0.027
Fat supply quantity (g/capita/day) Vegetal Products	Prevalence of obesity in the adult population (18 years and older)	-0.004	-1.294	0.196
Fat supply quantity (g/capita/day) Animal Products	Prevalence of obesity in the adult population (18 years and older)	-0.018	-3.522	0.000
Losses of Vegetal Products	Food supply quantity (kg/capita/year) Vegetal Products	-3.305	-0.621	0.535

Independent variable	Dependent variable	Unstandardized coefficient	*z*-statistics	*p*-value
Losses Animal Products	Food supply quantity (kg/capita/year) Animal Products	20.324	3.994	0.000
Losses Vegetal Products	Food supply (kcal/capita/day) Vegetal Products	1.845	0.189	0.850
Losses Animal Products	Food supply (kcal/capita/day) Animal Products	25.959	1.994	0.046
Losses Vegetal Products	Protein supply quantity (g/capita/day) Vegetal Products	-0.088	-0.226	0.821
Losses Animal Products	Protein supply quantity (g/capita/day) Animal Products	1.688	1.415	0.157
Losses Vegetal Products	Fat supply quantity (g/capita/day) Vegetal Products	-0.761	-1.334	0.182
Losses Animal Products	Fat supply quantity (g/capita/day) Animal Products	1.624	1.799	0.072

Obtained statistically significant relationships are presented in Figure 2.

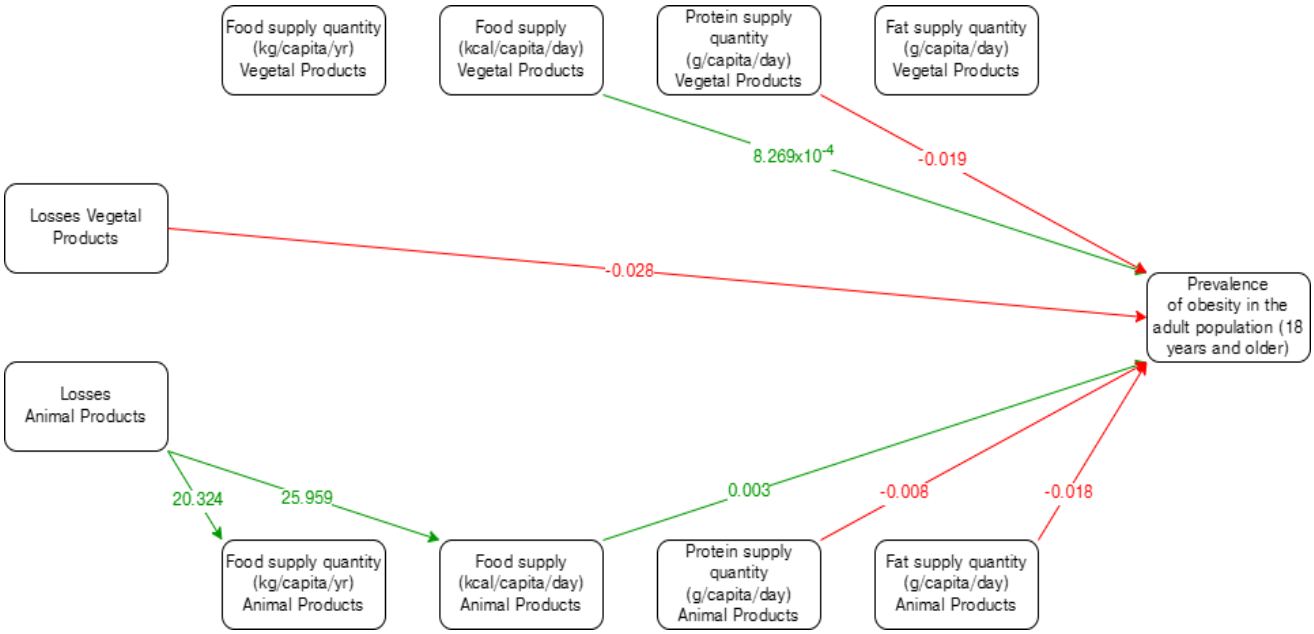

Figure 2.
Statistically significant relationships were identified through the SEM.

From the revealed relationships in Figure 2, several conclusions can be drawn:

(i) Losses Vegetal Products influence directly on Prevalence of obesity in the adult population (18 years and older). The relationship is negative – greater Losses Vegetal Products leads to a lower Prevalence of obesity in the adult population (18 years and older) ($z = -4.000, p = 0.000$), which coincides with preliminary expectations;

(ii) Losses in Animal Products indirectly influence the prevalence of obesity in the adult population (18 years and older). The relationship is mediated by the food supply (kcal/capita/day) of vegetal products.

(i)The relationship between Losses, Animal Products, and the mediator variable is positive; greater losses lead to a greater per capita supply ($z = 1.994, p = 0.046$). This contradicts preliminary expectations that greater losses will lead to a smaller per capita supply;

(ii) The relationship between per capita supply and prevalence of obesity in the adult population (18 years and older) is positive; larger per capita supply leads to a higher prevalence of obesity in the adult population (18 years and older), which coincides with preliminary expectations;

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

(i) Food supply (kcal/capita/day) Vegetal Products affects the Prevalence of obesity in the adult population (18 years and older). The relationship is positive – greater Food supply (kcal/capita/day) Vegetal Products leads to greater Prevalence of obesity in the adult population (18 years and older) ($z = 4.909, p = 0.000$), which coincides with preliminary expectations;

(ii) Protein supply quantity (g/capita/day) from vegetal products affects the prevalence of obesity in the adult population (18 years and older) ($z = -4.397, p = 0.000$).. The relationship is negative: higher protein supply quantity (g/capita/day) from vegetal products leads to a lower prevalence of obesity in this population. This contradicts preliminary

expectations that greater protein supply quantity (g/capita/day) from vegetal products would lead to a higher prevalence of obesity in the adult population (18 years and older);

(iii) Protein supply quantity (g/capita/day) from animal products affects the prevalence of obesity in the adult population (18 years and older). The relationship is negative – larger Protein supply quantity (g/capita/day) Animal Products leads to lower Prevalence of obesity in the adult population (18 years and older) ($z = -2.216, p = 0.027$). This contradicts preliminary expectations that greater Protein supply quantity (g/capita/day) Animal Products will lead to greater Prevalence of obesity in the adult population (18 years and older).

(iv) Fat supply quantity (g/capita/day) of animal products affects the prevalence of obesity in the adult population (18 years and older). The relationship is negative: a larger fat supply quantity of animal products leads to a lower prevalence of obesity in this population ($z = -3.522, p = 0.000$). This contradicts preliminary expectations that a greater Fat supply quantity (g/capita/day) of Animal Products will lead to a higher Prevalence of obesity in the adult population (18 years and older). Some mediator variables do not influence the dependent variables: Food supply quantity (kg/capita/year) of Vegetal Products, Fat supply quantity (g/capita/day) of Vegetal Products, and Food supply quantity (kg/capita/year) of Animal Products.

(iv) Losses in animal products influence the food supply quantity (kg/capita/year) of animal products. The relationship is positive – higher losses in animal products lead to a higher food supply quantity (kg/capita/year) of animal products (z=3.994, p=0.000). This contradicts preliminary expectations that greater losses of animal products will lead to a lower food supply quantity (kg/capita/year) of animal products.

4. Discussion

There are three possible explanations why, when the percentage of Losses increases, the per capita supply also increases. To have a balance, Domestic supply = Domestic Utilization. In turn, Domestic Utilization = Food + Processing + Feed + Seed + Losses + Other uses (non-food) + Tourist consumption + Residuals. Then, if Domestic supply = Domestic Utilization = 100%, then increasing the percentage of Losses will reduce the total percentage of all other collectables. But:

(i) The percentage of Food is one of these other collectibles, but this percentage may also increase due to the decrease in the total percentage of other collectibles.

(ii) Even if the percentage of Food decreases, it is possible that Domestic Utilization in the corresponding year is so large in natural units of measurement that the smaller percentage of Food leads to a larger volume in natural units of measurement.

(iii) Per capita supply is obtained by dividing food in natural units of measurement by the population in the corresponding year. The population of Bulgaria decreases throughout the period, so per capita supply can only increase if the numerator (food) remains constant or increases, while the denominator (population) decreases. References are maintained.

So, although contrary to preliminary expectations, it is possible that the percentage of losses is increasing, and at the same time, the per capita supply is also increasing.

Possible explanation for the negative relationships between protein supply quantity (g/capita/day) vegetal products, protein supply quantity (g/capita/day) animal products, and fat supply quantity (g/capita/day) animal products, on the one hand, and prevalence of obesity in the adult population (18 years and older), on the other hand, is related not to the quantity but to the quality of proteins and fats. It is possible that a higher amount of high-quality protein and fat does not lead to the prevalence of obesity, as does a lower amount of protein and fat, but of poorer quality.

5. Conclusions

The conclusion drawn is that the relationship between losses of vegetal products and the prevalence of obesity in the adult population (18 years and older) is direct and negative; greater losses lead to a higher prevalence of obesity in the adult population (18 years and older).

Losses in animal products indirectly influence the prevalence of obesity in the adult population (18 years and older). The relationship is mediated by the food supply (kcal/capita/day) of vegetal products.

(i) The relationship between Losses Animal Products and the mediator variable is positive – greater losses lead to greater per capita supply;

(ii) The relationship between per capita supply and prevalence of obesity in the adult population (18 years and older) is positive; larger per capita supply leads to a higher prevalence of obesity in the adult population (18 years and older).

As a result, the relationship between Losses in Animal Products and the Prevalence of obesity in the adult population (18 years and older) is positive, which contradicts preliminary expectations. Possible reasons for this contradiction have already been discussed.

Some of the mediating variables have an independent influence on the dependent variables, which we have already discussed.

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