Agricultura, Sociedad y Desarrollo

MORTALITY DUE TO MODERN DISEASES AS A FUNCTION OF CONSUMPTION OF ULTRA-PROCESSED PRODUCTS: THE CASE OF MEXICO

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ABSTRACT

Modern diseases occupy the first places as cause of death in Mexico due to changes in the food consumption habits and lifestyles of the population. This study measures and projects the impact of per capita consumption of ultra-processed products on mortality from modern illnesses such as diabetes, cancer, and heart disease through first-order differential equations. It is estimated that by 2030, with data from 1960-2014 for a population of 135 million inhabitants, the per capita consumption of ultra-processed products will be 295 kg and the mortality from modern diseases will be 363 people for every 100 thousand inhabitants. With data from 2000-2014, the per capita consumption of ultra-processed products will be 300 kg and the mortality 421 people. The impact on the mortality rate in Mexico by 2030 from consuming ultra-processed products will continue rising if the per capita consumption of these products is not intervened to prevent these diseases.

Keywords: ultra-processed foods, first-order differential equations, non-transmissible chronic diseases, obesity, public health.

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INTRODUCTION

In recent decades, population growth and social dynamics in developing countries such as Mexico have led to an increase in the socioeconomic gap and therefore the food gap. On the one hand, the booming middle class struggles between the consumption of healthy products and the consumption of ultra-processed products (UPs), which are easy to prepare and affordable; on the other hand, low-income families allocate a higher percentage of their income to their diet, but they tend to be the ones that consume the most junk food or UPs as they seek low prices (Instituto Nacional de Estadística Geografía e Informática [INEGI], 2021).

In 2018, Mexican people destined on average $3,731 monthly to expenditure in foods and beverages, which were distributed as follows: 75.3% for foods considered healthy (including the expenditure in fruits and vegetables) and 12.7% for unhealthy foods, primarily PUs. The northern region in Mexico allotted 14.9% to purchase unhealthy foods, and the southern region allotted 13% of the total expenditure. It should be mentioned that when it comes to rural and urban population, the first allots 78.3% of its monthly expenditure to healthy foods and 14.6% to unhealthy, while the urban population allots 74.4% of the expenditure to healthy foods and 12.1% to unhealthy (INEGI, 2021).

This food dynamic, in addition to the low physical activity and higher sedentarism of the population, has led to chronic diseases (non-contagious) related to bad dietary habits, which have obesity as a risk factor, such as type 2 diabetes, high blood pressure, dyslipidemias, heart diseases, sleep apnea, and cancer to become the main causes of death in people older than 40 years (Barrera-Cruz *et al*., 2013; Secretaría de Salud [SS], 2020).

In the last 20 years, non-transmissible chronic diseases have advanced to occupy the first places as general causes of death; heart diseases, malignant tumors, and mellitus diabetes occupied the 1st, 2nd and 3rd place, respectively. This is due mainly to the change in lifestyle, both in the diet and in physical activity, and to establishing programs for prevention and control of infectious diseases (Instituto Nacional de Salud Pública [INSP], 2020).

In 2019, the National Institute of Statistics and Geography (*Instituto Nacional de Estadística y Geografía*, INEGI, 2020) pointed out that 88.8% of deaths in Mexico are because of diseases and problems related to health. The main diseases that caused mortality in Mexico are modern illnesses like diabetes mellitus, cancer and heart diseases, and they have increased to worrying levels. In 1960 the number of annual deaths from this cause was 187 thousand people, in 2019 it reached 349 thousand people, and in 2021 it reached 456 thousand people, at an annual average rate of 1.5% during this period; however, from 2019 to 2021, the average annual growth rate was 14.3%. It should be clarified that, in 2021, the main cause of death was COVID-19 (INEGI, 2022).

Something to highlight is that the population considered as adult in Mexico is the one most affected by diseases like diabetes, with higher proportion of the disease in women (11.4%) than in men (9.1%), and the group of older than 60 years being the one most affected. For its part, high arterial blood pressure affects age groups from 20 years old, with the same trend seen in the distribution of the disease between men and women, the latter being the most affected (INSP, 2020).

Studies argue that this increase in the population's mortality is due to a radical change in the diet (Moreno-Altamirano *et al*., 2014; Gómez and Velázquez, 2019). Previously, the Mexican diet was based on corn, bean, chili pepper, squash, vegetables and seasonal fruit, but since the 1950s the per capita consumption of flours (bread, cookies), red meat (beef and pork), egg, milk, chicken, vegetable oils (safflower, palm, corn), sugar (soft drinks and candy), and salt present in all processed and home-made products has increased constantly (Brambila *et al*., 2018; SS, 2020).

The Pan American Health Organization (OPS, 2015) points out that the problem of an increase in mortality from modern diseases (MMD) is due to the increase in per capita consumption of UPs (Monteiro, 2010; Popkin, 2020). The director of the Food Orientation Center (FOC Nutrition) and member of the Campaing "Without corn there is no country", stated that Mexico is the country with highest per capita consumption of UPs in Latin America, at 214 kg (Gómez, 2021).

Scientific literature relates the consumption of UPs with modern diseases. Kim *et al*. (2019) report for the United States of America, from a sample of 11,898 people, that the consumption of UPs increased by 71% the risk of having cardiovascular problems.

de Deus Mendoca *et al*. (2017) report for Spain a high incidence of high blood pressure. Sandoval-Insausti *et al*. (2020) associate it with obesity in older adults.

Britton *et al*. (2013), Kim *et al*. (2019), and Rico-Campà *et al*. (2019) also report the relationship of these modern diseases with mortality. They conclude that the consumption of UPs increases the risk of diseases such as diabetes, cancer, heart diseases, and therefore mortality. Matos *et al*. (2021) report that in Latin America, particularly in Mexico and Chile, this problem is increasing. Marrón-Ponce *et al*. (2019) studied the case of Mexico and reached the same conclusion: that the consumption of UPs increases the risk of contracting modern diseases. Rico-Campà *et al*. (2019) reported for Spain, in a long-term study with different socioeconomic variables, that the consumption of daily portions of UPs increases the risk of dying from modern diseases by 68% and in an additional portion the probability increases by 18%. Monteiro and Cannon (2012) conducted studies of impact from the consumption of UPs in health and nutrition in several countries such as Brazil, Canada and Chile, with the same result from damage.

Facing this context, the objective of this study is to measure and project to 2030 the impact of per capita consumption of UPs on MMD such as diabetes, cancer and heart diseases through first-order differential equations for every 100 thousand inhabitants. The hypothesis is that the consumption of UPs has a direct positive relation with MMD, and the implicit recommendation is that their consumption should be reduced.

METHODOLOGY

Data

The study is prospective and observational, based on secondary sources of information, and focalized for the population in Mexico. The MMD data such as diabetes, cancer, heart diseases and population were obtained from INEGI (2016), the World Health Organization (OMS, 2016), the Ministry of Health (SS, 2016), and they were expressed in deaths for every 100 thousand inhabitants. The per capita consumption of UPs was estimated based on the WHO (OPS, 2015) for the period 2000 to 2013 (Table 1).

To broaden the series of per capita consumption of UPs from 1960 to 1999 and 2014, an average indicator ϕ (equation 2) was estimated, which related the per capita consumption of UPs with the per capita consumption of sugar, wheat and oils that are the main inputs for the elaboration of these products. These data were obtained from the databases of the Food and Agriculture Organization of the United Nations (FAOSTAT, 2021).

$$\phi(t) = \frac{u_t}{az_t + tr_t + ac_t} \tag{1}$$

$$\phi = \frac{\sum \phi_t}{t} = \overline{\phi(t)} \tag{2}$$

Table 1. MMD and per capita consumption of UPs, 1960-2014.

Year	M_t	u_t
1960	49.55	75.37
1961	49.15	76.85
1962	49.32	78.36
…	…	…
2000	110.66	164.30
…	…	…
2012	149.02	209.00
2013	152.52	212.20
2014	156.19	216.37

Where M_t: MMD (every 100 thousand inhabitants); u_t: *per capita* consumption of UPs, kg.
Source: prepared by the authors with information from FAOSTAT (2021), INEGI (2016), OMS (2016), OPS (2015) and SS (2016).

where u_r: *per capita* consumption of UPs, kg; az_t: *per capita* consumption of sugar and fructose, kg; tr_t: *per capita* consumption of wheat, kg; ac_t: *per capita* consumption of safflower, colza, sunflower, corn, olive, palm and soy oils, kg; $\phi(t)$: rate of per capita consumption. $\phi=\overline{\phi(t)}$ average indicator; $(\Sigma\phi)$: sum of the per capita consumption of UPs, including per capita consumption of sugar, wheat and oils, kg; (Σt): sum of the years considered.

Model

The dynamic behavior between MMD and consumption of UPs was modelled through a first-order differential equation proposed by Gandolfo (2010).

$$\frac{dM_t}{dt} + rM_t = bu_t \tag{3}$$

$$\frac{du_t}{dt} = iu_t \tag{4}$$

In which M_t: MMD for every 100 thousand inhabitants in the year t, people; dM_t/dt: annual increase of MMD, people; r: continuous annual average growth rate of the MMD; b: parameter estimated; u_t: *per capita* consumption of UPs, kg; du_t/dt: annual increase of consumption of UPs, kg; i: continuous average annual growth rate of UPs; t: time, years. Equation 5 estimated the complementary solution,

$$\frac{dM_t}{dt} + rM_t = 0$$

$$\int \frac{1}{M_t}\frac{dM_t}{dt}dt = \int -r dt$$

$$e^{\ln M_t} = e^{-rt}e^{c} = Ar^{-rt} \tag{5}$$

And equation 6 evaluated the particular solution,

$$\frac{dM_t}{dt} = 0$$

$$rM_t = bu_t$$

$$M_t = \frac{b}{r}u_t \tag{6}$$

The value of A was obtained with t=0 and the value of M_t in the initial year.
Equation 7 estimated the total solution that included the sum of the complementary solution plus the particular solution of equation 3 and 4 (Gandolfo, 2010).

$$M_t = \left[M_0 - \frac{b}{r}u_t \right] e^{-rt} + \frac{b}{r}u_t \tag{7}$$

where:

$$u_t = u_0 e^{it} \tag{8}$$

Total solution of the period 1960-2014

The parameter b was obtained from clearing equation (3) in discrete time for each year and the average was estimated.

$$b(t) = \left(M_t - M_{t-1} + rM_t \right) \left(\frac{1}{u_t} \right); \underline{b(t)} = b \tag{9}$$

Equation (10) projected the MMD to 2030 with data from the period 1960-2014.

$$M_t = \left[49.55 - \frac{0.0298}{0.0205}u_t \right] e^{-0.025t} + \frac{0.0298}{0.0205}u_t \tag{10}$$

$$u_t = 75.37e^{0.0195t} \tag{11}$$

where t=0, 1, 2,…, 69, 70 (from 1960 to 2030).

Total solution of the period 2000-2014

Equation (12) projected the MMD to 2030 with data from the period 2000-2014.

$$M_t = \left[110.66 - \frac{0.0331}{0.0231}u_t\right]e^{-0.0231t} + \frac{0.0331}{0.0231}u_t \quad (12)$$

$$u_t = 164.30e^{0.0197t} \quad (13)$$

where t=0, 1, 2,…, 29, 30 (from 2000 to 2030).

The complementary solutions for both periods tend to be zero, because $e^{-0.025t}$ and $e^{-0.0231t}$ tends to be zero in time. Thus, the MMD depends on the consumption of ultra-processed products, u_t.

RESULTS AND DISCUSSION

The trend of MMD is to increase. The rate of MMD and the rate of UPs were higher in the period 2000-2014, compared to the period 1960-2014 (Table 2). In recent years, the MMD rate has increased because of the consumption of UPs. In populations of 173 countries, including Mexico, it was found that a high consumption in sugar levels and sweeteners have a higher correlation in diabetes rates (Basu *et al.*, 2013), and, in addition, diets rich in fats, sodium and with low fiber contribute to a higher propensity to contract cancer (Consuelo and Glaves, 2020). The PAHO (OPS, 2021) found that there is a direct relationship between the consumption of UPs and non-transmissible diseases such as obesity, diabetes, hypertension, cancer and dyslipidemias which are the main causes of mortality in the Americas.

Results indicate that with the projection for the year 2030 based on a total estimated population of 135 million inhabitants in Mexico, the per capita consumption of UPs in relation to the period 1960-2014 is expected to be equivalent to 295 kg, and the MMD will reach 363 people for every 100 thousand inhabitants. For the period 2000-2014, the per capita consumption of UPs will be around 300 kg and the MMD of 421 people for every 100 thousand inhabitants. López-Torres and López-Alcaraz (2022) found that

Table 2. Average annual growth rate of the MMD, UPs and average indicator of per capita consumption of UPs.

Period	1960-2014	2000-2014
r	2.05 %	2.31 %
b	2.98 %	3.31 %
i	1.95 %	1.97 %
ϕ	1.579	1.538

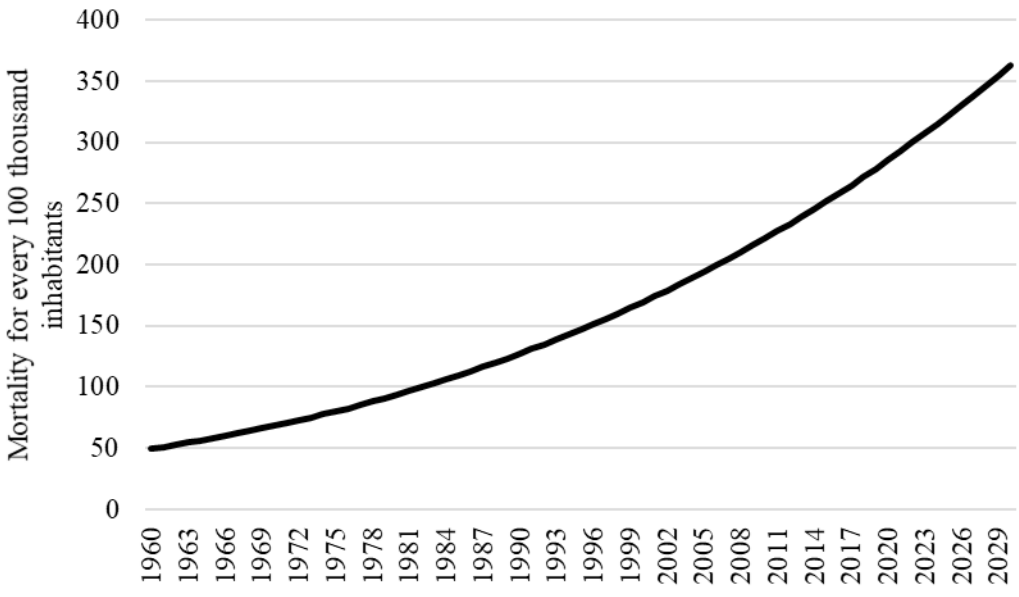
Where r: continuous average annual growth rate of the MMD; b: parameter estimated; i: continuous average annual growth rate of UPs; ϕ: average indicator of per capita consumption of UPs, including per capita consumption of sugar, wheat and oils.
Source: prepared by the authors.

during the period of 2000 to 2013, the per capita consumption of UPs reached a rate of 26.7% (from 102.3 to 129.6 kg per person) in the region of Latin America (LA), and in Mexico it was 212.2 kg per capita in the same period.

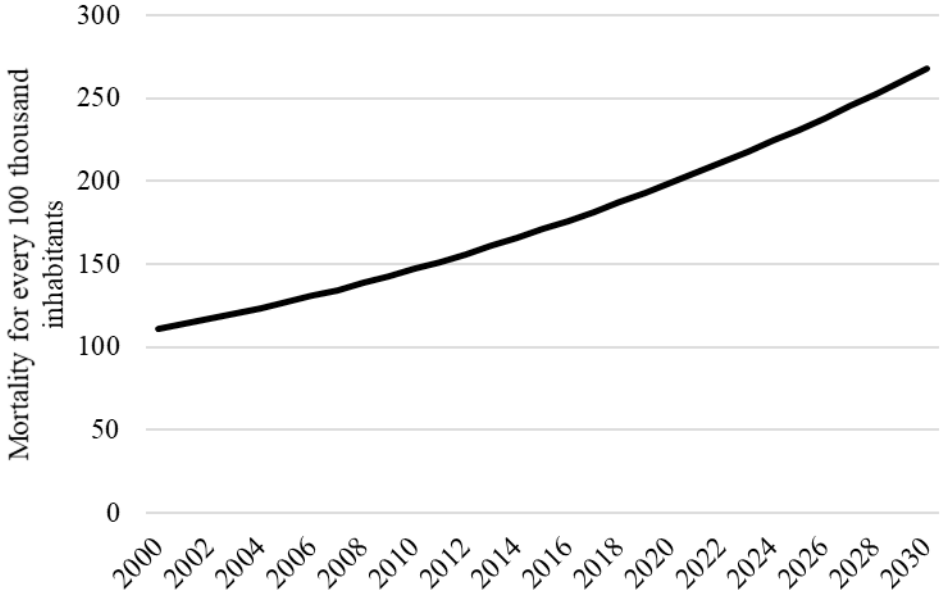
In Figure 1, the MMD is projected until 2030 in function of the consumption of UPs and its trend in time with data from the period 1960-2014 and in Figure 2 it is projected with data from the period 2000-3014. Both figures show the direct relation between consumption of UPs and MMD with an increasing trend.

With data from the Federal Consumer Affairs Office (*Procuraduría Federal del Consumidor*, PROFECO, 2022), it was estimated that if a person is taken as reference who consumes a 500 mL soft drink, one 150 g pachage of cookies, and one 250 g package of potato chips daily, the annual consumption would be equivalent to 329 kg, corresponding to 1,631 kcal daily; if this is extrapolated to the total of the population, it will have an effect on a MMD of 478 people for every 100 thousand inhabitants. In 2014, it was 156 people who died with a consumption of 216 kg. López-Torres and López-Alcaraz (2022) and OPS (2019) point out that from the period 2009 to 2014, there was an increase of 408 to 441 kcal per capita daily, which is equivalent to an increase of 8.3% during the period for LA. In Mexico, it represented 522 kcal per capita daily.

The results projected allowed to forecast the behavior of the MMD caused by the consumption of UPs if precautionary measures over the consumption of these products are not established. In this sense, the population's health problem impacts the health system because it increases the costs of healthcare for a sick population and therefore



Source: prepared by the authors with results from the total equation, 1960-2014.
Figure 1. Projection of the MMD util 2030, with data from the period 1960-2014 (for every 100 thousand inhabitants).



Source: prepared by the authors with results from the total equation, 2000-2014.
Figure 2. Projection of the MMD until 2030, with data from the period 2000-2014 (for every 100 thousand inhabitants).

financially destabilizes the institutions in charge of health. In 2017, Torres and Rojas (2018) estimated that the costs associated from diseases with overweight represented 150 million pesos and just to treat diabetes, the expenditure represented between 70 and 90% of the total programmable expense in health.

Given the implications of these results, it would be advisable that in order to reduce the consumption of UPs, work should be done in a joint strategy that involves institutions from government, industry and society to revert the damages caused by their consumption. This strategy should integrate lines of action to reduce the consumption through sanctions and taxes on the UPs, and to promote healthy foods, among others. In addition, it would be convenient to check periodically on the popuation, primarily younger than 18 years, to prevent problems of obesity and diabetes. Royo-Bordonada *et al.* (2019) propose five interventions to prevent obesity and the main non-transmissible diseases, such as: a) to regulate advertising of UPs; b) to promote the consumption of healthy foods; c) to apply a tax of at least 20% on sugary beverages and to charge less taxes on healthy foods; d) to regulate labeling; and e) to review agreements to reformulate with the food industry.

In Mexico, efforts have been made to reduce and avoid the consumption of UPs through frontal nutritional labeling signaled by the NOM-051-SCFI/SSAI-2010 of the Ministry of Economy (SE, 2020) and taxes have been applied on sugary beverages (Colchero *et al.*, 2017); however, although advances have been made, there is still room to generate strategies to promote the consumption of healthy, nutritional foods that are affordable for the population in general, so that the health benefits are reflected in the long term.

CONCLUSIONS

The consumption of ultra-processed foods shows a clear increasing trend and if the per capita consumption of these products is not intervened (reduced), the impact in mortality from modern diseases will increase by 2030, but in addition, the expenditure in public health to care for a population with various health problems will also increase. The implications of this study lead to highlight the establishment of public policy strategies that tend to reduce the consumption of ultra-processed products, such as the imposition of rigurous taxes, regulation of labeling, advertising, and the promotion of consumption of healthy products through information campaigns or incentives for their production to combat the mortality from modern diseases related to the consumption of ultra-processed products in benefit of the Mexican society.

For future studies, it is necessary to have updated information about mortality data from modern diseases and from statistics of per capita consumption of ultra-processed products; and to narrow them down by regions of the country, by urban and rural areas, and by age groups, as well as considering the lifestype and the physical activity of the population.

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