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VULNERABILITY OF THE CHICKEN MEAT MARKET TO CHANGES IN THE PRICE OF FEED GRAINS

Alvaro **Nochebuena-Molina**[1], José Alberto **García-Salazar**[1*]

[1]Colegio de Postgraduados Campus Montecillo. Posgrado en Socioeconomía, Estadística e Informática-Economía. Carretera México-Texcoco km 36.5, Montecillo, Texcoco, State of Mexico, Mexico. C. P. 56264.
* Author for correspondence: jsalazar@colpos.mx

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ABSTRACT

In the past three decades, the chicken (*Gallus gallus domesticus* L.) meat market has been favored by the commercial liberation established in the Free Trade Agreement, since the growth in production of this product was largely due to the supply of inputs used to feed cattle, such as maize and soybeans, based on imports at low costs from the USA. This situation could be reversed in the future, since the dependence on grains determines if the cattle markets are vulnerable to international exogenous changes. The aim of this investigation was to determine the effects of an increase in the price of feed grains on the chicken meat market in Mexico using a spatial equilibrium model for 2021. Results indicate that, in the year of analysis, chicken meat production, imports, and consumption were 3669 and 4419 thousand Mg, respectively. A 60 % increase in the price of feed grains would have considerable effects on the chicken meat market, since production would decrease by 390 thousand Mg and imports would increase by 363 thousand Mg. Due to these changes, consumption would only decrease by 27 thousand Mg, an expected result in a market open to international trade such as chicken meat. Due to the negative effects on the production and increase in imports, it is recommended for the government to take all necessary measures to reduce the dependence on feed grains demanded by the livestock sector, since an increase in the international price would make it difficult to guarantee the supply of such inputs.

Keywords: Free Trade Agreement, food dependence, production, imports, spatial equilibrium model.

INTRODUCTION

Ever since the North American Free Trade Agreement (NAFTA, now known as the T-MEC), the livestock sector dedicated to the production of meats has been one of the most dynamic sectors in Mexico's economy. Between 1994 and 2021, the production of chicken, beef, and pork grew by 225.8, 56.1, and 93.9 %, respectively. In the same period, chicken meat production increased from 1126 to 3669 thousand Mg, beef from 1365 to 2131 thousand Mg, and pork from 873 to 1693 thousand Mg (SIAP, 2023).

Despite the increase in production, meat imports carried out by Mexico presented a similar behavior, influenced by the commercial liberation established in the agreement. From 1994 to 2021, chicken meat imports increased from 124 to 813 thousand Mg, beef imports from 122 to 173 thousand Mg, and pork imports from 251 to 1275 thousand Mg (ABPA, 2022; COMECARNE, 2022; FAO, 2023a; National Customs Directorate of Chile, 2023; USITC, 2023). As in the case of production, the above data indicate a strong growth in external purchases of 554.9, 41.9, and 407.9 % for chicken, beef, and pork, respectively.

As a result of the growth in production and imports, the demand for all three types of meats grew. From 1994 to 2021, the growth experienced by the National Apparent Consumption (NAC) was 258.7 % for chicken meat, 33.9 % for beef, and 142.9 % for pork. In this period, chicken meat consumption went from 1248 to 4475 thousand Mg, beef consumption from 1485 to 1989 thousand Mg, and pork from 1118 to 2716 thousand Mg (ABPA, 2022; COMECARNE, 2022; FAO, 2023a; National Customs Directorate of Chile, 2023; USITC, 2023). The highest growth was found in chicken meat, which was positioned as the most important in terms of the preferences of meat consumers.

These trends show the positive effects of NAFTA on meat producers and consumers, since the strong production growth during the 1994–2021 period was a consequence of low international prices in maize and soybean, the main inputs used in the production of chicken feed, which allowed prices to be reduced. The increase in production allowed for a greater consumption of meat. Feed costs are the main expense in meat production: for chicken meat, they represent up to 62 % of total costs (UNA, 2022); for pork, between 63.6 and 86.6 % (Hernández-Cruz *et al*., 2019); and for beef, between 75 and 80 % (Castro-Samano *et al.*, 2019). The balanced feed used in the production of chicken meat is a mixture of maize (or sorghum), which provides energy, and soybean, which provides protein. Fats, oils, vitamins, and supplements are also used. Maize and sorghum are substitute goods in the production of balanced feed (OECD, 2018).

In 2021, 38.7 million Mg of raw material were used for the production of balanced feed in Mexico, out of which 17.6, 8.6, and 4.2 million Mg correspond to maize, soybean, and sorghum, respectively (CONAFAB, 2022). The greatest use of these crops was a consequence of the dynamic observed in the market variables, influenced by the commercial liberalization. From 1994 to 2021, maize production increased from 18 236 to 27 503 thousand Mg; sorghum production from 3701 to 4370 thousand Mg, and soybean production decreased from 523 to 288 thousand Mg (SIAP, 2023). These data represent a growth rate of 50.8, 18.1, and -44.9 % for these crops, respectively.

The real international prices (in 2010 USD Mg^{-1}) of these products in 1994 were 128.49, 124.09, and 300.88 for maize, sorghum, and soybean, whereas in 2021, their real prices were USD 237.24, 198.41, and 533.20 per Mg, respectively (World Bank, 2023). In this period, maize imports increased significantly from 2747 to 17 396 thousand Mg, representing a growth of 533.4 %. The same trend was observed with soybean imports, which grew 84.1 %, from 2497 to 4597 thousand Mg. In regard to sorghum, imports fell

from 3475 to 66 thousand Mg, representing a decrease of almost 100 % (FAO, 2023a). In the period, maize consumption increased 113.9 %, from 20 946 to 44 802 thousand Mg, and soybean consumption grew 61.8 %, from 3019 to 4885 thousand Mg. Due to the greatest use of maize in diets as a source of energy, the consumption of sorghum decreased by 38.2 %, from 7176 to 4436 thousand Mg.

The production and import behavior of feed grains determined a change in the structure of the demand exerted by livestock farming. During the 2010–2020 period, the amount of maize used as feed for cattle increased from 11.78 to 20.07 million Mg, displaying an increase of 8.3 million Mg and a growth of 70.4 %. Sorghum presented an opposite behavior, since in 2010, the amount of this product used in the balanced food industry was 8.8 million Mg, whereas for 2020, 4.8 million Mg were used, representing 3.9 million Mg less than in 2010 (FAO, 2023b).

The above change was a consequence of several factors. The first was the reduction in the price of maize in relation to the price of sorghum. Although at the beginning of NAFTA the maize/sorghum price ratio was 1.04, by 2021 this ratio was 0.96, indicating that the price of maize decreased faster than the price of sorghum (World Bank, 2023). The second factor that determined the change in the structure of feed grain demand was the removal of the prohibition on the use of maize for cattle consumption. According to data from the US Department of Agriculture (USDA, 2022), prices are expected to resume their downward tendency shown until before the COVID-19 pandemic and the armed conflict between Russia and Ukraine. By 2024, maize, sorghum, and soybean prices were expected to be USD 169.33, 167.37, and 372.49 per Mg, respectively. Due to this, the maize/sorghum ratio for 2022 was expected to be 1.02, and by 2023 and 2024, 1.01, which implies that the price of maize is expected to rise faster than that of sorghum, implying that the price of the balanced feed for fattening chicken will increase its price, affecting this industry.

In the last three decades, Mexican feed grain food policies have taken advantage of international prices in the world market, allowing an increased percentage of the consumption to be supplied with imports. In the case of maize, in 1994, the food dependence index was 13.1 %, whereas by 2021, it had increased to 38.8 %. In the case of soybean, the dependency index changed from 82.7 to 94.1 %. In the case of maize, the data on the food dependency index is aggregated and takes into account human, industrial, and livestock consumption; if only livestock consumption alone were considered, the issue of food dependency would be greater.

The evolution of the dependency index reflects the policy followed since 1994 to ensure the consumption of forage grains. In order to take advantage of low international prices, the country has preferred to supply consumption with imports. From an economic point of view, this could be justified in an international environment of low international prices, as was the case since 1994; however, should the international market change and international prices rise in the future, the country must make an effort to increase production and depend less on imports. Should there be an increase in the international price of maize and soybean, the cost of the balanced feed would

rise, resulting in an increase in retail price and a decrease in chicken meat production, requiring the import of more of this product to meet national demand.

Given that chicken meat is widely consumed by Mexicans, the most produced in the country, and its production cost depends on the price of the grains used in the feed (maize and soybean), the aim of this investigation was to determine the effects of an increase in the price of feed grains on the chicken meat market in Mexico using a spatial equilibrium model for 2021. The main hypothesis considers that, should the prices of maize and soybean increase, chicken meat production costs would increase, resulting in a reduction in national production of chicken meat and an increase in imports to meet internal demand.

MATERIALS AND METHODS

Chicken producing and consuming regions

Twelve chicken-producing and consuming regions were considered, based on their geographic location and production importance: 1) Northwest (Nayarit, Sinaloa, and Sonora), 2) Baja California Peninsula (Baja California and Baja California Sur), 3) North (Chihuahua, Coahuila, and Durango), 4) Northeast and Center North (Nuevo León, San Luis Potosí, Tamaulipas, and Zacatecas), 5) Aguascalientes, 6) West (Jalisco and Colima), 7) Bajío (Michoacán and Guanajuato), 8) Querétaro, 9) Center (Mexico City, Hidalgo, State of Mexico, Morelos, Puebla, and Tlaxcala), 10) Gulf (Tabasco and Veracruz), 11) South (Chiapas, Guerrero, and Oaxaca), and 12) Yucatán Peninsula (Campeche, Quintana Roo, and Yucatán).

The cities taken as references to calculate the transportation costs were Culiacán, Tijuana, Torreón, Monterrey, Guadalajara, Guanajuato, Querétaro, Mexico City, Veracruz, Tuxtla Gutiérrez, and Mérida. The seven points of entry of the imports (m) were defined based on information from USITC (2023), and they are Ciudad Juárez, Nuevo Laredo, Port of Veracruz, Progreso, Nogales, Tijuana, and Manzanillo.

A spatial equilibrium model was formulated, which included variables of the chicken meat market. Considering d consumer regions and s production regions, the functions of supply and demand are:

$$P_d = \lambda_d + \omega_d Y_d$$

$$P_s = \upsilon_s + \kappa_s PRAB_s + \eta_s X_s$$

where P_d is the retail price of chicken meat in d, λ_d is the intercept of the demand function in d, w_d is the slope of the demand function in d, Y_d is the amount of chicken meat consumed in d, Ps is the chicken meat producer price in s, υ_s is the intercept of the supply function in s, η_s is the slope of the supply function in s, X_s is the amount of chicken meat produced in s, κ_s is the coefficient that relates the price of feed and the chicken meat producer price in s, and $PRABs$ is the real price of feed in s.

$$MaxNSP = \sum_{d=1}^{12}\left[\lambda_d Y_d + \frac{1}{2} w_d Y_d^2\right] - \sum_{s=1}^{12}\left[v_s + k_s PRAB_s + \frac{1}{2}\eta_s X_s^2\right] - \sum_{m=1}^{7}[P_m X_m] - \sum_{s=1}^{12}\sum_{d=1}^{12}[t_{sd} X_{sd}] - \sum_{m=1}^{7}\sum_{d=1}^{7}[t_{md} X_{md}]$$

The empirical formulation of the model was based on Takayama and Judge (1971). The target function of the model maximizes the Net Social Payoff (NSP), which is the area under the demand curve minus the area under the supply curve minus the value of imports and minus transportation costs. Considering s (s=1, 2, …, 12) chicken meat producing regions, d (d=1, 2, …, 12) consumer regions, and m (m=1, 2, …, 7) points of entry of the imports, the objective function is:

The target function is subject to the following restrictions:

$$\sum_{s=1}^{12}[X_{sd}] + \sum_{m=1}^{7} X_{md} \geq Y_d \quad (1)$$

$$\sum_{s=1}^{12} X_{sd} \leq X_s \quad (2)$$

$$\sum_{m=1}^{7} X_{md} \leq X_m \quad (3)$$

$$\sum_{s=1}^{12} X_s + \sum_{m=1}^{7} X_m = \sum_{j=1}^{12} Y_j \quad (4)$$

$$Y_d, X_s, X_{sd}, X_{md} \geq 0 \quad (5)$$

where P_m is the international price of chicken meat imported by m, X_m is the amount of chicken meat imported by m, t_{sd} is the cost of transporting one Mg of chicken meat from s to d, X_{sd} is the amount of chicken meat sent from s to d, t_{md} is the cost of transporting from m to d, and X_{md} is the amount of chicken meat sent from m to d.

Equation 1 establishes that the amount of chicken meat sent from the producing regions *s* to the consumer region *d* plus the amount of chicken meat sent from entry points *m* to consumer region *d* must be greater than or equal to the consumption in region *d*. Equation 2 establishes that the amount of chicken meat sent from producing region *s* to consumer regions *d* must be less than, or equal, to the amount of chicken meat produced in region *s*. Equation 3 establishes that the amount of chicken meat sent from entry points *m* to consumer regions *d* must be lower than, or equal, to the total amount of imported chicken meat. Equation 4 indicates the balance in the chicken meat market. Finally, Equation 5 establishes the conditions of non-negativity of the model.

The model was validated by comparing the base model estimates to observed data on production, consumption, imports, and retail prices. The base model must estimate values for the mentioned variables that are 10 % lower or higher than those observed in 2021. After obtaining the base model, three scenarios were tested, which included price increases of 20, 40, and 60 % for the balanced feed. Hypothetical increases in PRAB between 20 and 60% were used since, according to the OECD-FAO (2022), the international price of maize in 2021 was 50 % of the price expected in 2020. This increase was caused by a decrease in grain supply, an increase in demand, uncertainty caused by global trade policy, weather-related maize production in South America, an increase in production costs, and China's large volume of imports. Likewise, the nominal price of soybean increased by 40 % due to an increase in demand (mainly in China) and a slight reduction in the supply as a consequence of adverse weather conditions in South America that impacted their yield.

Information sources and analysis

The information used in the model corresponds to the period from January to December 2021. The functions of supply and demand were obtained using information on production, consumption, prices for the producer, retail price for the consumer, and demand price elasticities. The elasticities that relate chicken meat with the price of balanced feed were obtained from Nochebuena-Molina *et al*. (2023), and the price elasticity of the demand was obtained from Vázquez-Alvarado and Martínez-Damián (2015).

Chicken meat production data was obtained from the SIAP (2023), whereas the price of the balanced feed was obtained from the National Market Information and Integration System (SNIIM, 2023). The regional chicken meat consumption was obtained as follows: a) The national production of meat was added to the imports to obtain the National Apparent Consumption (NAC), without considering exports since they are very low; b) The NAC of chicken meat was used by the National Population Council (CONAPO, 2023) to obtain the national per capita consumption of chicken meat for 2021; c) The regional consumption of chicken meat was obtained by multiplying the national per capita consumption by the consumption of each state (CONAPO, 2023). The costs of transportation from producing regions and points of entry to the

consumer regions were calculated using the software GlobalMap (2023), using the cities of reference mentioned earlier and the customs entry points for imports as origins and destinations.

The retail price to the consumers of the different regions was calculated using the price per Mg of chicken meat in the nearest entry point to the consumer region. Because the largest amount of imported chicken meat comes from the USA (83.86 %), the unit value of this product (USD per Mg) was used to obtain the price of a Mg of chicken meat at the different points of entry (USITC, 2023). The international price in USD was multiplied by the average 2021 exchange rate. The previous cost was added to the 2.7 % entry expenses if the chicken was brought into the country by land or 3.4 % if it entered by sea (García-Salazar and Williams, 2004), and the financial cost of importing the chicken using the average six-month LIBOR rate reported for 2021 by the Bank of Mexico (BANXICO, 2023).

The price for producers was calculated using the following procedure: a) The retail price for the consumer calculated earlier was taken; b) Using data on the retail price of chicken meat reported by the National Statistics and Geography Institute (INEGI, 2023) and the mean rural price paid to the chicken meat producer reported by the SIAP (2023), a margin was calculated between the price for the consumer and the price for the farmer; c) The retail price obtained for the consumer was discounted the previously mentioned percentage to obtain the estimated price to the producer. Given that the analysis carried out is for a specific year (2021), it was not necessary to calculate real prices; therefore, the prices for the consumer and the producer used in the model were nominal.

Chicken meat imports were obtained from official sources of the countries that exported this product to Mexico in 2021 (USITC, 2023; National Customs Directorate of Chile, 2023; ABPA, 2022). The solution of the model was obtained using the General Algebraic Modeling Systems programming language (GAMS Development Corporation, 2023).

RESULTS AND DISCUSSION

The observed values of the main variables of the chicken meat market in Mexico (Table 1) show that, in 2021, production, consumption, and imports were 3.7, 4.5, and 0.8 million Mg, respectively. The average retail price for the consumer was MXN 44 637 per Mg. Production was concentrated in six regions, representing 69 % of the country's production. In the case of consumption, three regions demand 52.3 % of chicken meat in Mexico. The results of the model validation (Table 1) showed that the difference between the data observed and the data estimated by the model is lower than ±10 %, so it is assumed that the base model can be used to generate scenarios.

Nationwide, the model overestimates consumption and production by 0.8 and 1.2 %, and underestimates imports and the retail price for the consumer by 0.8 and 4.7 %, respectively. The base model overestimates the consumption in the North, Center, and South regions by 0.7, 1.2, and 1.4 %. In production, the model underestimates

Table 1. Validation of the spatial equilibrium model of the gutted chicken meat market in Mexico for year 2021.

Region	Situation observed	Base model	Change	%
	Regional consumption (Mg)			
Northwest	264 047	266 511	2464	0.9
Baja California Peninsula	156 757	156 370	-387	-0.2
North	312 122	314 420	2298	0.7
Northeast and Center North	484 013	485 471	1458	0.3
Aguascalientes	50 505	51 007	502	1
West	322 744	326 435	3691	1.1
Bajío	387 041	389 896	2855	0.7
Querétaro	80 600	81 883	1283	1.6
Center	1 384 857	1 401 296	16 439	1.2
Gulf	388 768	386 304	-2464	-0.6
South	474 209	480 799	6590	1.4
Yucatan Peninsula	175 908	176 965	1057	0.6
National	4 481 573	4 517 357	35 784	0.8
	Regional production (Mg)			
Northwest	218 486	220 553	2067	0.9
Baja California Peninsula	1902	2052	150	7.9
North	370 984	355 909	-15 075	-4.1
Norheast and Center North	184 616	178 300	-6316	-3.4
Aguascalientes	405 465	434 736	29 271	7.2
West	431 779	436 209	4430	1.0
Bajío	289 376	301 511	12 135	4.2
Querétaro	371 332	405 268	33 936	9.1
Center	468 236	450 333	-17 903	-3.8
Gulf	481 954	472 422	-9532	-2.0
South	247 334	264 380	17 046	6.9
Yucatán Peninsula	197 087	189 381	-7706	-3.9
National	3 668 551	3 711 054	42 503	1.2
	Imports (Mg)			
National	813 022	806 305	-6717	-0.8
	Retail price (MXN per Mg)			
Northwest	58 291	55 959	-2332	-4.0
Baja California Peninsula	46 648	46 648	0	0.0
North	47 977	45 099	-2879	-6.0
Northeast and Center North	45 258	45 258	0	0.0
Aguascalientes	36 854	34 274	-2580	-7.0
West	45 707	41 136	-4571	-10.0
Bajío	42 465	39 493	-2972	-7.0
Querétaro	48 860	43 974	-4886	-10.0
Center	51 838	49 246	-2592	-5.0
Gulf	43 894	43 894	0	0.0
South	53 371	50 702	-2669	-5.0
Yucatán Peninsula	41 195	39 959	-1236	-3.0
Average	46 863	44 637	-2226	-4.8

the amount of this meat produced in the North and Center regions (4.1 and 3.8 %, respectively), whereas it overestimates it in the South (6.9 %). Regarding the retail price, the model underestimates it by 6, 5, and 5 %, respectively.

The scenario for a rise in the price of feed grains (maize and soybean) showed that a 20 % increase in the price of balanced feed would lead to a reduction in the production of chicken meat by 117 thousand Mg, which would represent a decrease of 3.2 % compared to the production of the base model, and the reduction would take place in all regions. Due to the commercial opening considered in the model, imports would experience a rise of 103 thousand Mg, which represents an increase of 12.8 % compared to the value estimated by the base model (Table 2).

Changes in production and imports would have an effect on consumption. Due to the increase in imports, which would compensate part of the decrease in production, the consumption of chicken meat would only decrease by 14 thousand Mg, distributed in 8 out of 12 regions considered, which represents a 0.3 % reduction in regard to the consumption estimated by the base model.

Increases of over 20 % in the price of feed grain would have greater effects on the chicken meat market. If the price of balanced feed were to increase by 60 %, the production of the meat in question would fall by 390 thousand Mg, which would represent a 10.5 % decrease in regard to the production of the base model. Imports, on the one hand, would increase by 363 thousand Mg. As a consequence of these changes, consumption would decrease by 27 thousand Mg, only 0.6 % less than the consumption estimated by the base model.

The results indicate a considerable effect on the production of chicken meat and a low effect on the consumption. This situation is a result of commercial liberalization established in trade agreements, which allows for the supply of consumption with imports when domestic production is declining. In fact, the change in price of balanced feed would have an effect on the retail price for consumers. In the first scenario, the retail price would display an increase of MXN 908.6 per Mg, which represents an increase in the retail price of 2 % compared to the price observed in the base model.

In light of an increase of the *PRAB* by 60 %, the amount of chicken meat produced nationwide would decrease by 10.5 %. This means that, should the *PRAB* increase, there would be a reduction in the production of chicken meat less than proportional to the increase in the *PRAB*. This result is consistent with those obtained by other authors (Rebollar-Rebollar *et al*., 2019a, 2019b; Ramírez-González *et al*., 2003). The strong dependence of livestock consumption on the inputs used in animal feed could pose significant risks for the future. As imports of forage grains account for a larger share of consumption, the market for these products becomes more vulnerable to exogenous changes taking place in the global market (Valencia-Romero *et al*., 2019; Moreno-Sáenz *et al*., 2016).

There are arguments to justify a probable increase in the international price of feed grains. The prices of cereals have displayed a volatile behavior due to the effects of the world supply chain caused by Covid-19, the Russia-Ukraine conflict, constant

Table 2. Effects of a rise in the price of feed grains on the chicken meat market in Mexico for year 2021 according to the spatial equilibrium model.

Region	Base model	Increase in price by:			Change by:		
		20 %	40 %	60 %	20 %	40 %	60 %
		Consumption (Mg)					
Northwest	266 511	265 501	264 808	264 628	-0.4	-0.6	-0.7
Baja California Peninsula	156 370	156 370	156 370	156 370	0.0	0.0	0.0
North	314 420	314 420	314 420	314 420	0.0	0.0	0.0
Northeast and Center North	485 471	485 471	485 471	485 471	0.0	0.0	0.0
Aguascalientes	51 007	50 703	50 494	50 406	-0.6	-1.0	-1.2
West	326 435	324 871	323 798	323 347	-0.5	-0.8	-0.9
Bajío	389 896	387 876	386 489	385 905	-0.5	-0.9	-1.0
Querétaro	81 883	81 517	81 265	81 159	-0.4	-0.8	-0.9
Center	1 401 296	1 395 328	1 391 229	1 389 506	-0.4	-0.7	-0.8
Gulf	386 304	386 304	386 304	386 304	0.0	0.0	0.0
South	480 799	478 809	477 443	476 868	-0.4	-0.7	-0.8
Yucatán Peninsula	176 965	176 014	176 014	176 014	-0.5	-0.5	-0.5
National	4 517 357	4 503 184	4 494 105	4 490 398	-0.3	-0.5	-0.6
		Production (Mg)					
Northwest	220 553	213 098	205 105	196 235	-3.4	-7.0	-11.0
Baja California Peninsula	2052	1972	1892	1812	-3.9	-7.8	-11.7
North	355 909	340 330	324 750	309 171	-4.4	-8.8	-13.1
Northeast and Center North	178 300	170 546	162 792	155 038	-4.3	-8.7	-13.0
Aguascalientes	434 736	424 928	412 858	397 913	-2.3	-5.0	-8.5
West	436 209	424 273	410 395	394 048	-2.7	-5.9	-9.7
Bajío	301 511	292 488	282 484	271 233	-2.9	-6.3	-10.0
Querétaro	405 268	394 661	382 493	368 337	-2.6	-5.6	-9.1
Center	450 333	434 819	418 005	399 540	-3.4	-7.2	-11.3
Gulf	472 422	457 228	440 454	421 671	-3.2	-6.8	-10.7
South	264 380	256 121	247 195	237 421	-3.1	-6.5	-10.2
Yucatán Peninsula	189 381	183 301	176 534	168 891	-3.2	-6.8	-10.8
National	3 711 054	3 593 765	3 464 957	3 321 310	-3.2	-6.6	-10.5
		Imports (Mg)					
National	806 305	909 420	1 029 145	1 169 087	12.8	27.6	45
		Retail price (MXN per Mg)					
Northwest	55 960	57 040	57 942	58 176	1.9	3.5	4.0
Baja California Peninsula	46 648	46 648	46 648	46 648	0.0	0.0	0.0
North	45 099	44 908	44 908	44 908	-0.4	-0.4	-0.4
Northeast and Center North	45 258	45 258	45 258	45 258	0.0	0.0	0.0
Aguascalientes	34 275	35 755	36 657	37 036	4.3	7.0	8.1
West	41 136	42 471	43 373	43 752	3.2	5.4	6.4
Bajío	39 493	40 879	41 781	42 160	3.5	5.8	6.8
Querétaro	43 974	45 290	46 192	46 571	3.0	5.0	5.9
Center	49 247	50 698	51 600	51 979	2.9	4.8	5.5
Gulf	43 894	44 035	44 035	44 035	0.3	0.3	0.3
South	50 703	52 230	53 132	53 511	3.0	4.8	5.5
Yucatán Peninsula	39 959	41 336	41 336	41 336	3.4	3.4	3.4
Average	44 637	45 546	46 072	46 281	2.0	3.2	3.7

change in yield, the increase in the costs of fertilizers and transportation, as well as a macroeconomic environment of high inflation (OECD-FAO, 2022). Due to uncertainty in South America in terms of maize production, the rise in production costs, and the large amount of maize imported by China, the OECD-FAO (2022) indicate that, in 2021, the international price of grain was 50 % higher than the previous year. These factors and the growing exposure to extreme weather phenomena, such as droughts and floods in producing countries, have caused a reduction in the price of maize, leading to volatility in international prices.

In the case of soybean, the OECD-FAO (2022) mention that, in 2021, there was an increase of over 40 % in the nominal price of this product, going from USD 406.64 per Mg in 2020 to USD 583.32 per Mg in 2021. The following factors may cause an increase in the international price of soybean for the following years: a) Extreme weather phenomena that affect the yield, a scenario already seen in 2021; b) Ukraine is an important soybean exporter; therefore, the conflict would reduce world supply, leading to a rise in the price of this legume.

There are arguments in favor of reducing the dependency on feed grain imports. The results of the programming model indicate that an increase in the price of balanced feed would have a negative effect on the chicken meat market, even in a scenario of trade liberalization. On the one hand, the production of chicken meat would decrease, which would have undesirable effects on its use in the agricultural industry, and, on the other hand, imports would increase, leading to an increase in the amount of foreign currency spent on purchases abroad.

Regarding the feed grain markets, there is a risk of a possible increase in the international price of maize. If this situation were to arise, a large amount of foreign currency would be spent to ensure the availability of maize in order to achieve food security (García-Salazar *et al*., 2023). The United Nations (UN, 2022) mentions that, if the world price of food imports was to increase, importing countries could face difficulties affording such a rise, which could lead to importing countries with fewer economic resources not being able to deal with the rise in international prices and seeing their access to imported food jeopardized.

The OECD-FAO (2022) and USDA (2022) forecast that maize and soybean prices will pick up the downward trend they had been presenting before the Covid-19 pandemic. Unpredictable events, such as the pandemic, the Russia-Ukraine conflict, and adverse weather phenomena that affect countries that produce these crops, would cause a reduction in their supply, which, combined with a growing demand, would generate a rise in international prices, as in 2021. According to data from the World Bank (2023), from 2020 to 2021, the international price of maize went from USD 169.02 to 237.24 per Mg in 2020, experiencing an increase of 40.4 %. Soybean went from an international price of USD 415.36 to 533.20 per Mg, which represented an increase of 28.4 %.

CONCLUSIONS

Since the implementation of the North American Free Trade Agreement (NAFTA), chicken meat has become a popular choice among Mexicans. The increase in production was due to a decrease in production costs, which was only made possible by the commercial liberalization agreed upon in NAFTA, which allowed the use of cheaper inputs in balanced feed mixes. The balanced feed has maize and soybean as its main inputs, which the country must import in large quantities to meet the demands of the livestock sector. Import growth has increased food dependency on maize and soybeans, making these markets more vulnerable to exogenous international changes. In the time in which NAFTA has been effective, the supply of the consumption of feed grains used has been based on food dependence and has taken advantage of low international grain prices in the world market. However, this situation could be reverted in the future. The results of the programming model used in this investigation indicate that an increase of 60 % in the price of feed grain would have a considerable effect on production and imports. In a liberalized economy like the chicken meat market, the effect on consumption and retail prices would be less pronounced.

It is recommended that public policies be developed and implemented to encourage domestic maize and soybean production in order to reduce reliance on imports, thereby reducing the risk of exogenous changes in these crops, which could lead to an increase in the cost of chicken meat production. It is also recommended that public policies be designed and implemented to encourage more chicken meat production, such as those aimed at researching and developing genetic chicken varieties with better feed conversion.

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