Introduction

Many people in the world today face food insecurity. In a survey by the Food and Agriculture Organization of the United Nations of 20 middle to low-income nations; on average 72 percent of households faced moderate or severe food-insecurity. This percentage is up 12 percent from the previous year. Many of those surveyed expressed that the Sars-CoV-2 pandemic exacerbated the problem. World hunger increased in 2020, after remaining relatively unchanged for the past five years. [1]

Along with food insecurity, many people, especially in low-income nations, experience malnutrition. An investigation on maternal and child undernutrition in low to middle income countries described the main complications of undernutrition being fetal growth restriction, suboptimum breastfeeding, stunting, wasting. Stunted growth of children younger than 5 years old globally affected at least 165 million children in 2011 and wasting affected at least 52 million children. Comprehensively, undernutrition resulted in a total of 3.1 million child deaths in 2011, equivalent to 45% of all child deaths in 2011.[2]

To address these global issues the United Nations established seventeen worldwide sustainable development goals to meet by 2030. The second goal being the ambitious goal of ending worldwide hunger and achieving food security. Considering current events the United Nations released a statement in their latest annual report on food security stating, "Well before the COVID-19 pandemic, we were already not on track to ending world hunger and malnutrition in all its forms by 2030. Now, the pandemic has made this goal significantly more challenging." [1]

Four crops accounted for half of all global production in 2018: sugar cane, maize, rice, and wheat. Rice was the 3rd most produce crop accounting for 9 percent of the total global production for primary crops.[3] This report aims to put the world's food supply into perspective with *Oryza sativa* (rice), a food staple for many people around the world. The report will focus on aspects of food security and total nutritional contents of rice. Calculations have been made to quantify the total number of grains of rice produced in one year along with associated metrics relating to food security and nutrition.

Results

To begin the calculation quantification of two key figures are obtained from the literature. The first quantity is the total global rice production each year. Data supplied by the latest United Nations Food and Agricultural Report on Rice Production established the world rice production in 2017 to be 759.6 million tonnes, unprocessed. On a milled basis the yield is equivalent to 503.9 million tonnes.[4] Data is obtained from a record provided from each specific country. When countries fail to report data, data is obtained from commodity-specific trade publications. When neither are provided, the data is imputed. The official data source does not make mention of estimates relating to uncertainty.[5] In this case the report will utilize the first constant milled basis figure approximated to 500 million tonnes:

$$R_{m} \sim 500\ million\ tonnes \quad \text{(Constant 1)}^{[4]}$$

The second constant is the mass of one grain of rice. A previous study produced a dataset utilizing 474 grains of rice from 59 different species of rice. Of note the rice is whole grain (brown rice). The second constant provides the resulting grain mass:

$$G_{m} = \frac{22.2\ mg}{grain\ of\ rice} \pm \frac{0.31\ mg}{grain\ of\ rice} \text{ with 95\% confidence (Constant 2)}^{[6]}$$

The first calculation takes the two established constants to provide the total number of grains of rice. The following equation is used:

$$G_{Total} = \frac{R_{m}}{G_{m}} \quad \text{(Equation 1)}$$

Prior to equation 1 input rice mass (R_m) [C1] was converted to milligrams to calculate total grains of rice (G_{Total}). First rice mass was converted to kilograms using the conversion factor of 10^3. Rice mass is then converted to milligrams by a factor of 10^6:

$$R_{m} = 5.0x10^{8}\ tonnes\ rice * \frac{1x10^{3}\ Kg\ rice}{1\ tonne\ rice} * \frac{1x10^{6}\ mg\ rice}{1\ Kg\ rice}$$

$$R_{m} = 5.0\ x\ 10^{17}\ mg$$

Using equation 1 and with unit-converted rice mass[C1] and grain mass[C2], total grains of rice in the 2017 harvest were calculated:

$$G_{Total} = \frac{(5.0\ x\ 10^{17}\ mg)}{(\frac{22.2\ mg}{grain\ of\ rice})}$$

$$\boldsymbol{G_{Total} = 2.3\ x\ 10^{16}\ grains\ of\ rice}$$

The next calculation of total calories relies on the following equation which multiplied rice mass[C1] by the rice per gram calorie ratio:

$$C_{Total} = R_m * R_c \qquad \text{(Equation 2)}$$

Prior to equation 2 input rice mass (R_m) [C1] was converted to grams using the conversion factor of 10^6:

$$R_m = 5.0x10^8\ tonnes\ rice * \frac{1x10^6\ g\ rice}{1\ tonne\ rice}$$

$$R_m = 5.0\ x\ 10^{14}\ g\ rice$$

Using equation 2 we can calculate total calories:

$$C_{Total} = (5.0\ x\ 10^{14}\ g) * \frac{679\ calories}{185\ g}\ \text{[7]}$$

$$\boldsymbol{C_{Total} = 1.8\ x\ 10^{15}\ calories}$$

Total rice grains and total calories have now been calculated. The next portion of the results focuses on key nutrient totals adapted from the investigation of malnutrition[2]. Rice key nutrition equation takes rice mass[C1] and multiplies by nutrient ratio defined as follows:

$$Nu_{Total} = R_m * Nu_r \quad \text{(Equation 3)}$$

Before calculating nutrition totals, rice mass[C1] is converted to grams as was previously calculated with the output: $R_m = 5.0\ x\ 10^{14}$ g rice. Inputting key nutrient ratios for calcium, iron, zinc, vitamin A, and vitamin D we calculate the total mass of key nutrients in a single harvest year[EQ3]:

$$\textbf{\textit{Calcium}}$$

$$Nu_{\ Total} = \ (5.0\ x\ 10^{14}\ g\ rice) * (\frac{16.6\ mg\ Calcium}{185\ g\ rice})[\mathbf{7}]$$

$$Nu_{\ Total} = \ 4.5\ x\ 10^{13}\ mg\ Calcium$$

$$\textbf{\textit{Iron}}$$

$$Nu_{\ Total} = \ (5.0\ x\ 10^{14}\ g\ rice) * (\frac{2.39\ mg\ Iron}{185\ g\ rice})[\mathbf{7}]$$

$$Nu_{\ Total} = \ 6.5\ x\ 10^{12}\ mg\ Iron$$

$$\textbf{\textit{Zinc}}$$

$$Nu_{\ Total} = \ (5.0\ x\ 10^{14}\ g\ rice) * (\frac{3.94\ mg\ Zinc}{185\ g\ rice})[\mathbf{7}]$$

$$Nu_{\ Total} = \ 1.1\ x\ 10^{13}\ mg\ Zinc$$

$$\textbf{\textit{Vitamin A}}$$

$$Nu_{\ Total} = \ (5.0\ x\ 10^{14}\ g\ rice) * (\frac{0\ mg\ Vitamin\ A}{185\ g\ rice})\ [\mathbf{7}]$$

$$Nu_{\ Total} = \ 0\ mg\ Vitamin\ A$$

$$\textbf{\textit{Vitamin D}}$$

$$Nu_{\ Total} = \ (5.0\ x\ 10^{14}\ g\ rice) * (\frac{0\ mg\ Vitamin\ D}{185\ g\ rice})[\mathbf{7}]$$

$$Nu_{\ Total} = \ 0\ mg\ Vitamin\ D$$

For the final portion of calculations food supply and nutrients per person are calculated. The following constant for world population is provided for proceeding calculations:

$$P_W = \ 7.75\ x\ 10^9\ people \quad \text{(Constant 3)}^{[\mathbf{8}]}$$

To calculate the total days of food provided for each person from a total year's harvest the following equation is presented, with C_{RDA} equating to daily recommended calories:

$$F_{\ Days} = \ \frac{\frac{C_{\ Total}}{P_W}}{C_{\ RDA}} \quad \text{(Equation 4)}$$

Inputting previously calculated values of total calories (C_{Total}) and Constant 3 along with the daily recommended calories adapted from a reference study:

$$F_{Days} = \frac{\frac{(1.8\ x\ 10^{15}\ calories)}{(7.75\ x\ 10^{9}\ people)}}{(\frac{2000\ calories}{day})\ [\mathbf{9}]}$$

$$\boldsymbol{F_{Days} \approx \quad 116\ days\ of\ food\ per\ person}$$

With food supply calculated the final calculation is based on the following equation for nutrients per person with a slightly modified version of Equation 4:

$$Nu_{Days} = \frac{\frac{Nu_{Total}}{P_W}}{Nu_{RDA}} \quad \text{(Equation 5)}$$

Inputting each previously calculated nutrient calcium, iron, zinc, vitamin A, and vitamin D the total days of nutrition from rice are calculated**[Eq5]**:

$$\boldsymbol{Calcium}$$

$$Nu_{Days} = \frac{\frac{(4.5\ x\ 10^{13}\ mg\ Calcium)}{(7.75\ x\ 10^{9}\ people)}}{(\frac{1{,}000\ mg}{day})\ [\mathbf{10}]}$$

$$\boldsymbol{Nu_{Days} \approx \quad 6\ days\ of\ Calcium\ per\ person}$$

$$\boldsymbol{Iron}$$

$$Nu_{Days} = \frac{\frac{(6.5\ x\ 10^{12}\ mg\ Iron)}{(7.75\ x\ 10^{9}\ people)}}{(\frac{12\ mg}{day})\ [\mathbf{10}]}$$

$$\boldsymbol{Nu_{Days} \approx \quad 70\ days\ of\ Iron\ per\ person}$$

$$\boldsymbol{Zinc}$$

$$Nu_{Days} = \frac{\frac{(1.1\ x\ 10^{13}\ mg\ Zinc)}{(7.75\ x\ 10^{9}\ people)}}{(\frac{10\ mg}{day})\ [\mathbf{10}]}$$

$$\boldsymbol{Nu_{Days} \approx \quad 142\ days\ of\ Zinc\ per\ person}$$

$$\boldsymbol{Vitamin\ A}$$

$$Nu_{\ Days} = \frac{\frac{(0\ mg\ Vitamin\ A)}{(7.75\ x\ 10^{9}\ people)}}{(\frac{0.9\ mg}{day})\ [\mathbf{10}]}$$

$$\boldsymbol{Nu_{\ Days} = \ \ 0\ days\ of\ Vitamin\ A\ per\ person}$$

$$\boldsymbol{Vitamin\ D}$$

$$Nu_{\ Days} = \frac{\frac{(0\ mg\ Vitamin\ D)}{(7.75\ x\ 10^{9}\ people)}}{(\frac{0.015\ mg}{day})\ [\mathbf{10}]}$$

$$\boldsymbol{Nu_{\ Days} = \ \ 0\ days\ of\ Vitamin\ D\ per\ person}$$

Discussion

In conclusion there are an estimated 2.3 x 10^{16} grains of rice produced in a year. This figure is a true testament to modern agriculture. Furthermore, rice covers roughly a third of everyone's calorie needs in a year with ~116 days of food per person. For a single food crop, this number suggests that food insecurity is not inherently reliant on production, rather governmental policy, or logistical hurdles.

The previously mentioned study on undernutrition states the most pressing and impactful nutrient deficiencies in low to middle-income nations are calcium, iron, zinc, vitamin A, and vitamin D.**[2]** Results indicate that while rice may have caloric abundance, key nutrients are noticeably lacking. One exception would be quantity of Zinc with a greater ratio per day than calories. There is a notable lack in Calcium (6 days per person) and a complete lack of Vitamin A and Vitamin D. Efforts to remediate the lack of nutrition are ongoing, with promise in Vitamin A enriched rice, dubbed "Golden Rice". Researchers were able to produce genetically modified rice with the most recent iteration providing enough pro-vitamin A to fulfill 55–70% of in the recommended dietary allowance in a single cup of rice. This is a marked difference and is likely to have a meaningful impact on malnutrition in consuming populations.**[11]** Further efforts to improve the nutritional contents of rice, may help to alleviate malnutrition. Tangentially, focus on improving rice yield characteristics may also prove to alleviate food insecurity. Loss of function in a single allele of the *TGW6* gene in rice led to significant yield increases.**[12]**

To further the efforts of this study it may prove useful to calculate these metrics for the top fifty most produced crops on an annual basis to monitor trends in food & nutritional security. Such research may also provide insight on regional nutrition profiles, based on region-dependent food staples. Cognizance of these metrics may also prove useful to identify candidate foods able to be nutritionally enriched.

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