Turkish Journal of Agriculture - Food Science and Technology, 11(8): 1269-1275, 2023
DOI: https://doi.org/10.24925/turjaf.v11i8.1269-1275.5558

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

A Production Analysis of Dry Onion Powder from the Water Perspective

Oyelayo Ajamu Oyedele[1,a,*], Olusegun Adeoti[1b], Funke Florence Akinola[1,c].

[1]*The Federal Polytechnic, Ado-Ekiti, Department of Agricultural and Bio-Environmental Engineering, Ekiti State, Nigeria*
[*]*Corresponding author*

ARTICLE INFO

Research Article

Received : 04-10-2022
Accepted : 14-05-2023

Keywords:
Dry onion powder
Production analysis
Dry onion
Water use
Water footprint assessment

ABSTRACT

Nigeria's dry onion production amounted to 1.38× 10^6 metric tonnes (t) in 2020. Roughly 50% of yearly production do not reach the table. An option lies in converting fresh dry onions to dry onion powder to mitigate postharvest losses. This study explores the possibility of producing dry onion powder from fresh dry onions using a pre-tested locally fabricated direct-mode solar tent dryer. The outcome of processing revealed a product yield of 8.09%, while there was no statistically significant difference between the measured proximate contents of powder and fresh dry onions ($t(28)=0.04$, $p=0.97$, two-tailed; eta square=5.71 × 10^{-5}). Overall, the production of dry onion powder was not water neutral. About 4.5 cubic metres (m^3) of freshwater per tonne of cleaned onions were needed during processing. Dry onion powder production (from field to table) freshwater use amounted to 31879.6 m^3/t. Converting 40 - 60% of national average dry onion production (2000-2020) to dry onion powder would consume 14.05 - 21.08 × 10^9 m^3 of Nigeria's freshwater. This study affirms that dry onion powder production is technically feasible and can help to minimise dry onion production postharvest losses in Nigeria.

[a] *segilayo4real@yahoo.com* *https://orcid.org/0000-0002-4863-5983*
[b] *olusegunadeoti@yahoo.co.uk* *https://orcid.org/0000-0001-6692-9064*
[c] *funkeakinola93@gmail.com* *https://orcid.org/0000-0002-6472-2788*

Introduction

Documented studies on dry onion powder production in Nigeria is scarce. Compared with Egypt (Akinfenwa, 2020), Nigeria is not a known player in the onion powder export markets. Also at the domestic market, there is an absence of locally made dry onion powders. Nigeria is a dry onions producing country. Its production amounted to 1.38 x 10^6 metric tonnes (t) in 2020 (Figure 1), representing 1.32% of world production. Roughly 50% of yearly production do not get to the table (Ministry of Foreign Affairs, 2021; World Vegetable Center, 2022). Crop drying, an aspect of crop processing, is one of the feasible options to minimising postharvest losses. It primarily helps to inhibit microorganism growth and reproduction and enhance crop storage life. Crop drying entails crop moisture removal to a safe storage moisture content, with minimal damage to crop nutrients. Both natural (for example, open sun drying) and artificial (for example, mechanical dryers) methods can be used to dry agricultural crops. Therefore, the production of dry onion powder entails moisture or free water removal from the fresh dry onions, with initial moisture contents typically > 80% wet basis (wb) (Dantata, 2014; Armand et al., 2018; Mitra et al., 2011; Sasongko et al., 2020), and can be up to 90.3% (Seifu et al., 2018).

This study illustrates the processing steps involved, and estimates the amount of water required, to produce dry onion powder in Nigeria. Although there are no standard drying methods (Bamba et al., 2020), examples of methods that can be used to produce onion powders include freeze-drying, flow drying, vacuum-shelf drying, and dehydration (Akinfenwa, 2020), or according to Mitra et al (2011) could also include fluidized bed drying, solar drying, convective air drying, vacuum microwave drying, osmotic drying, and infrared drying. In this study, a pre-tested locally fabricated natural convection solar tent dryer was used to dry the onions in order to obtain a high-quality product. Nigeria's mean daily solar insolation varies from 3.5 in the coastal areas of the south to 7.0 kilowatt-hour/square metre (kWh/m^2) in the arid regions of the north (Federal Ministry of Science and Technology (FMST), 2014a, 2014b). The average daily sunshine hour is from 4 to 9 hours (h), increasing from the south to the north (FMST, 2014a).

This study draws on the water footprint assessment to estimate the amount of water required to produce dry onion powder in Nigeria. The assessment sums the amount of water used over the production and/or consumption steps of a good or service (Adeoti et al., 2021a). Many studies have applied the accounting model to estimate the amount of water required or consumed in the manufacture of a product. Examples include pasta and pizza (Aldaya and Hoekstra, 2010), gari (Adeoti et al., 2009), soy milk and soy burger (Ercin et al., 2011), and Gazpacho, a chilled vegetable soup (Ibáñez et al., 2017). The outcome of this study will benefit intending entrepreneurs wishing to invest in dry onion powder production in Nigeria, and other stakeholders in the dry onion markets (for example, policy makers, water managers, supermarkets, food industries, etc) to understand the amount of pressure dry onion powder production exerts on Nigeria's freshwater resource, towards increasing the productivity of water use.

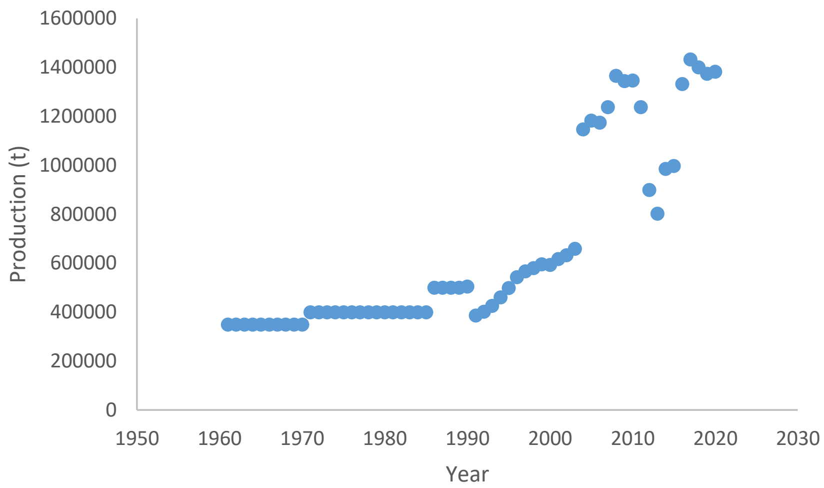

Figure 1. Fresh dry onion production in Nigeria (1961- 2020)
(Data source: Food and Agriculture Organisation of the United Nations (FAO), 2022)

Table 1. Some important parameters where data were measured

S/No.	Parameter	Equipment used
1.	Mass (of sample, and losses)	Electric weighing balance (model: XY2000C)
2.	Temperature (inside tent dryer)	Digital thermometer
3.	Relative humidity (inside tent dryer)	Digital humidity meter
4.	Volume (of water)	Graduated plastic bucket

Data and Analyses

Data

This study draws on both primary and secondary data sources to realise its ambition. Primary data were collected on the source product, resulting product, losses, and amount of water needed during processing. A sack of fresh dry onion bulbs weighing 14.82 kg was purchased from a local market in Ado Ekiti, Ekiti State, Nigeria on Monday, 8 November 2021. The bulbs were cleaned (entailing the removal of the dry skin, roots, damaged, or rotten bulbs, etc), washed, sun dried (to remove water on the surface of the onions), chopped, dried in a solar tent dryer of 7.0 cubic metres (m^3) capacity from Wednesday, 10 to Monday, 15 November 2021, and milled in batches using the QBL-15L40 home blender. Some important parameters where data were assembled are illustrated in Table 1. Drying in the solar tent dryer was monitored between 8.00 am and 5.00 pm. Temperature and relative humidity measurements inside the dryer were taken daily at an interval of 1 h. On the 6th day, packing for milling started from 12.00 noon, to allow for a better milling. The total drying time in the natural convection direct-mode solar tent dryer was 49 h.

For the moisture content (MC) determination in wet basis (wb), 5.0 g of sample were collected and dried in an incubator (model: DNP-9032) at 55 ^{0}C until constant mass was reached. Equation 1 was used to measure the MC $_{(wb)}$ in%.

$$MC_{(wb)}\% = \frac{m_i - m_f}{m_i} \times 100 \quad (1)$$

Where, m_f = final mass (kg), and m_i = initial mass (kg)

Both the initial mass and the final mass of the sample were measured to calculate the product yield (Equation 2), while the initial mass (before tent drying) and the resulting mass (after tent drying) were measured to determine the total amount of moisture loss and to calculate the average drying rate during the day (Equation 3).

$$\text{Product yield (\%)} = \frac{\beta}{\gamma} \times 100 \quad (2)$$

Where, β = mass of the resulting product (kg), and γ = mass of the source product (kg)

$$\text{Drying rate} = \frac{\varphi}{\tau} \text{ (kg/h)} \quad (3)$$

Where, φ = the amount of moisture loss (kg), and τ = time duration during the day (h)

The proximate contents (ash, crude fat, fibre, protein, and carbohydrate) of fresh and powder were determined using standard test methods. Financial constraints influenced the choice of proximate contents for analysis. After milling no attempts were made to carry out the granulometric analysis as well as the sensory evaluation of the resulting onion powder. Data on the amount of water consumed during the field-level cultivation of dry onions in Nigeria were obtained from the literature (see Adeoti et al., 2021a). Data on Nigeria's dry onion production were obtained from the FAO database.

Analyses

The collected primary data (on dry onion processing parameters, temperature and relative humidity, $MC_{(wb)}$, and proximate contents) were entered into the Microsoft Excel Worksheets. Descriptive tests were carried out using Microsoft Excel 2013. The independent-samples t-test was used to show whether there is a statistically significant difference between the proximate contents of fresh dry onion and dry onion powder, using IBM SPSS Statistics version 22. An alpha (α) value of 0.05 was used for the test of significance. For the MC determination in wet basis (wb), the number of samples, n = 4.

This study followed the Water Footprint Network (WFN) methodology to estimate the amount of water required in the production of dry onion powder. Although there are two approaches in the literature (ISO - 14046 and WFN assessment), Kim and Kim (2019) have argued for the use of the WFN methodology for agricultural-related studies. The production of dry onion powder from fresh dry onion follows a sequence of production stages with different effects on freshwater resource. Dry onion processing has two major effects on freshwater resource: a) the abstraction of surface and/or subsurface water sources (also referred to as blue water) to process the bulbs into powder, and b) the water required to dilute the processing return waste flows to safe limits when discharged into freshwater bodies (also called the grey water requirement). In this study, the grey water requirement was ignored because of the possibility of wastewater treatment in-situ before being discharged into the environment or recycled. Nonetheless, the initial process water requirement was used in the computation of the dry onion powder production water use. Data on source and resulting product were used to determine the product fraction (pf) per processing step, measured as the ratio of the resulting product to the source product (Adeoti, 2010). In the analysis, the water use of the resulting product (in m^3/t) was calculated by dividing the water use of the source product with the pf. This accounted for why the water use of the resulting product became larger than that of the source product. Since dry onion powder production requires process water, that is, water for onion washing, the blue water required (in m^3/t of source product) was added to the source product water use before evaluating the water use of the resulting product (in accordance with the methodology described in Chapagain and Hoekstra, 2010). In this study, the total amount of water use in the production of dry onion powder was estimated as the addition of field-level water use and processing water use (direct and indirect).

At the national level, the average total amount of water required to produce dry onion powder was computed by multiplying the water use of dry onion powder production (as obtained in this study) with the national average dry onions produced in Nigeria between 2000 and 2020 (t/year).

Results and Discussion

172 fresh dry onion bulbs, measuring 14.82 kg, 90.12 ± 1.84% $MC_{(wb)}$, with mean mass (and standard deviation) amounting to 86.18 ± 25.0 grammes (g) per bulb (range: 36.8 - 177.4 g) were processed. The dry onion powder production flow process is illustrated in Figure 1. The final mass of the resulting dry onion powder and the $MC_{(wb)}$ were 1.20 kg and 9.44%, respectively. The product yield translated to 8.09% of fresh dry onions, without excluding losses due to handling, removal of unwanted materials, and others. The total amount of moisture loss over the drying period was 12.11 kg. This indicates that from fresh dry onions to dry onion powder, there were mass reductions. Therefore, to produce 1.0 kg of dry onion powder (at 9.44% $MC_{(wb)}$), about 12.36 kg of fresh dry onions would be needed. This has implications for estimating the amount of fresh dry onions that would be required by processors in the production, marketing, and pricing of dry onion powder. The volume of water used in the processing steps amounted to 4.48 m^3 per t of cleaned onions. This volume did not account for water for equipment cleaning pre and post processing operations.

In terms of temperature and relative humidity profiles, the mean (and standard deviation) and maximum temperatures for inside the tent dryer during the day were 31.60 ± 3.03 and 38.9 °C, respectively. In the case of relative humidity, the values were 52.0 ± 10.8 and 81%, respectively. Ado Ekiti has mean annual minimum and maximum temperature of 20.1 and 30.1 °C, respectively (Adeoti et al., 2021b). Figure 2 illustrates two sample plots of temperature and relative humidity inside the solar tent dryer during day time. The variations between ambient and inside tent dryer were as a result of the conversion of solar energy and the evaporation process. Compared with the ambient, the chopped onions were dried at 11.5 to 18.8 °C above the mean annual minimum temperature. Ayensu and Asiedu-Bondzie (1986) observed that for agricultural crops drying could be maintained at temperatures between 10 and 15 °C above the ambient temperatures. For powders (including those obtained from bulbs), the Codex Alimentarius Commission of the Food and Agriculture Organisation of the United Nations has specified a maximum moisture content of 12.0%. The value obtained in this study, 9.44%, was well below the maximum limit. Onion powder moisture contents below 9.44% have also been reported in the literature (Mitra et al., 2011; Seifu et al., 2018; Sangwan et al., 2010). The average drying rate over the drying period was 0.25 kg of water evaporated per h. By design, the direct-mode solar tent dryer was a partially closed system to allow for natural ventilation, with no air preheater. Both the angled roof and the walls of the drying chamber were transparent, while the chopped onions being dried served as the main absorber. No attempts were made to assemble data on the air speed inside the solar tent dryer. However, Ado Ekiti mean wind speed varies from 2.3 to 4.1 m/s (Ajayi et al., 2014).

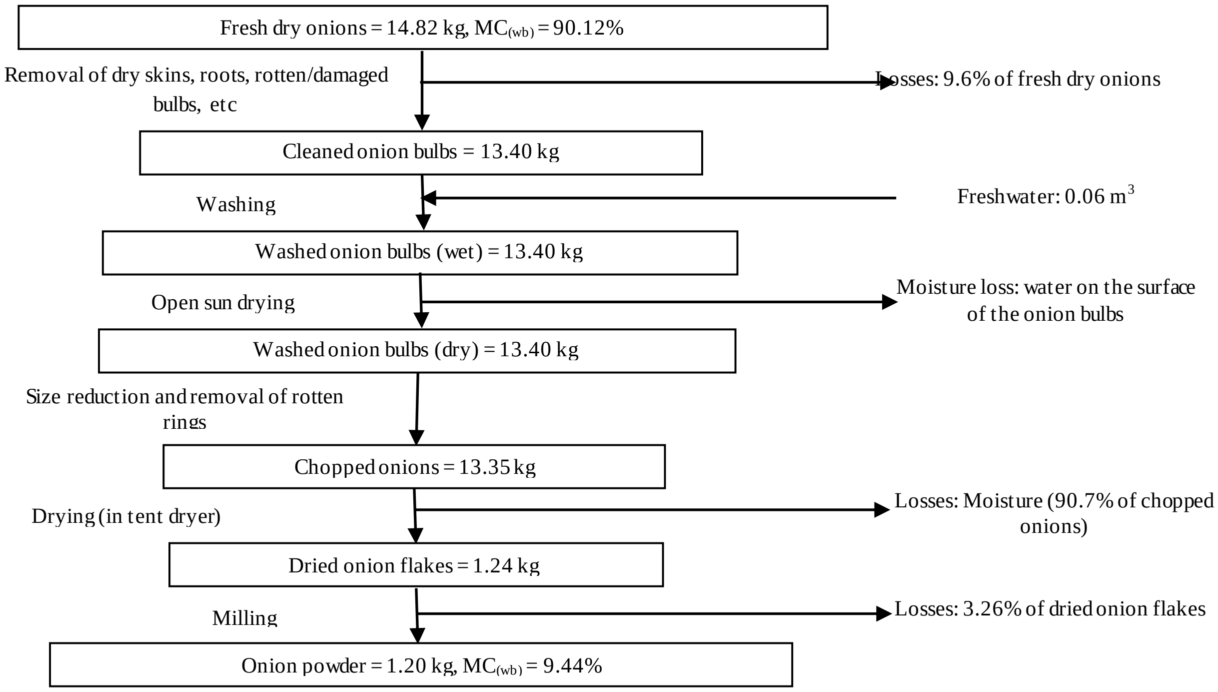

Figure 1. Onion powder production flow process (manual method)

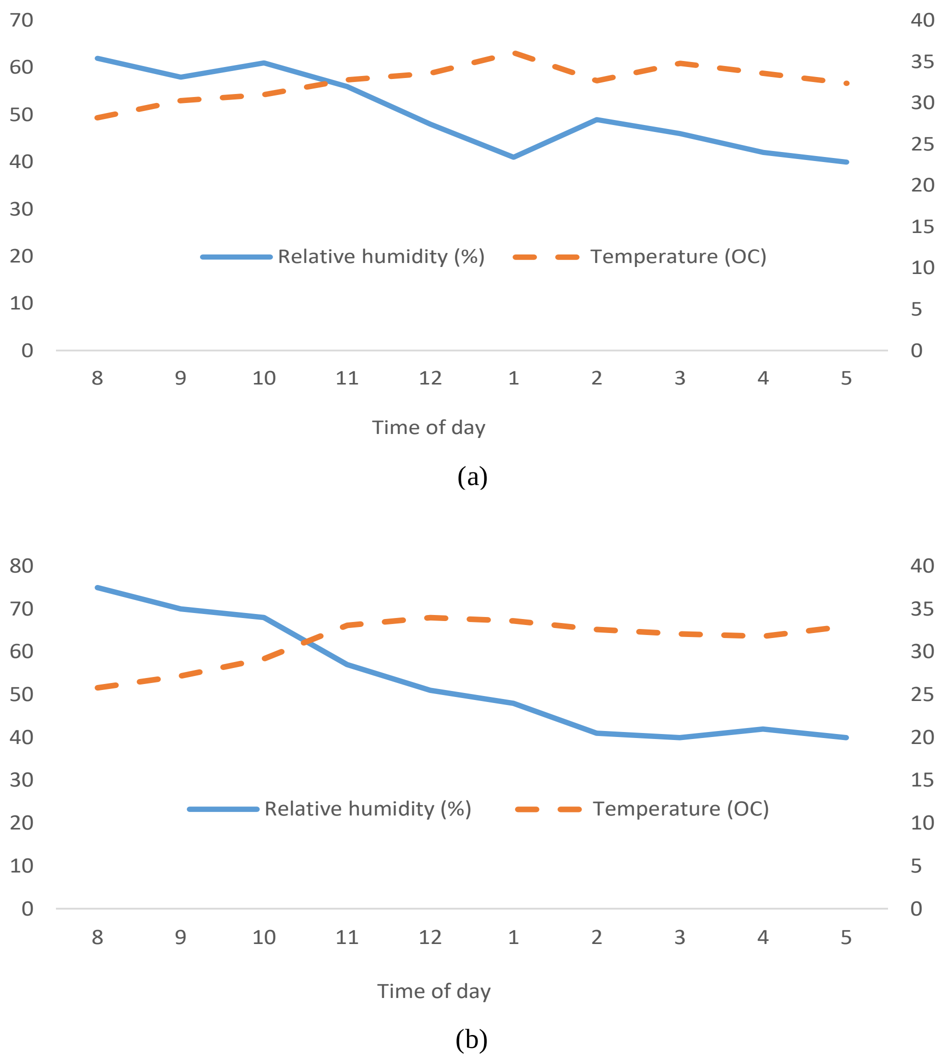

Figure 2. Temperature and relative humidity profiles inside the solar tent dryer for (a) day 1, and (b) day 5

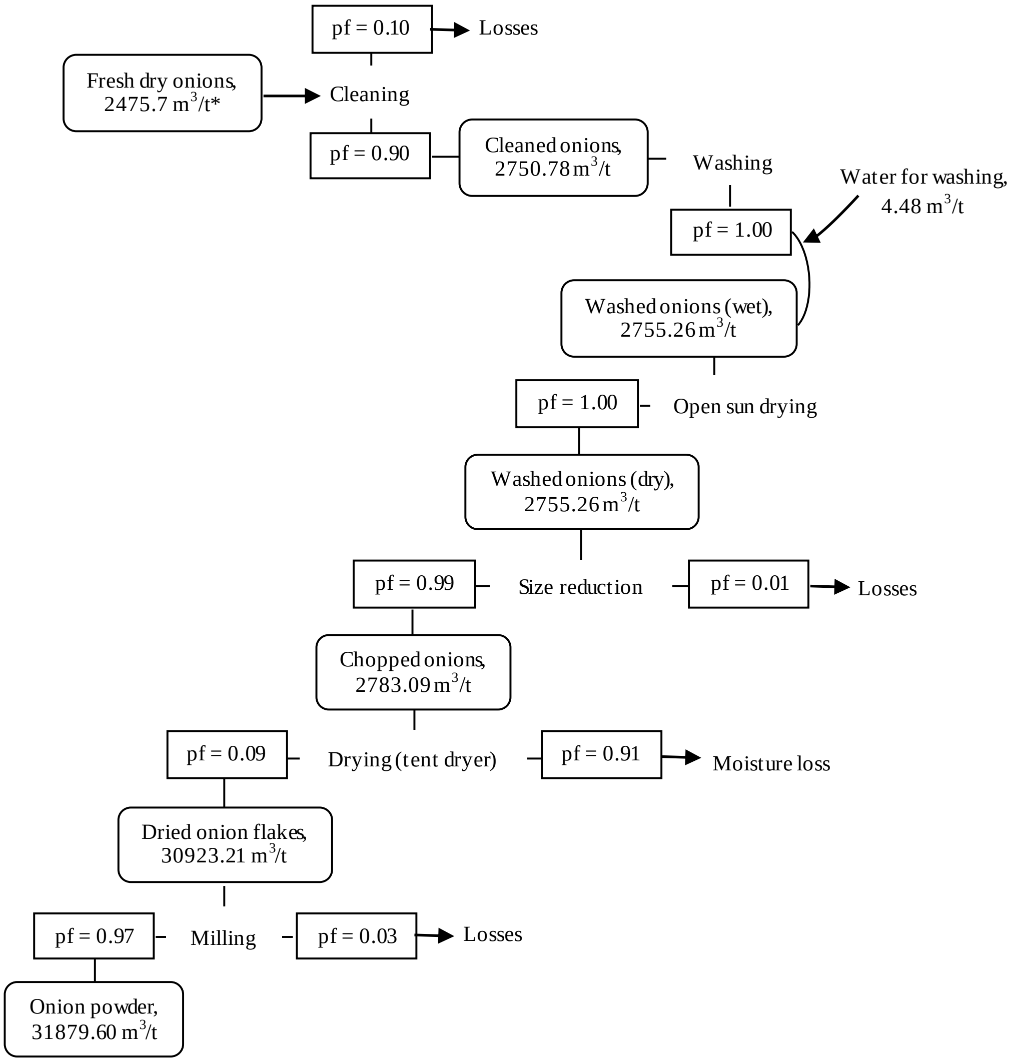

Figure 3. Processing tree for onion powder production, indicating the product fraction (pf) and the water use per processing step

*National average obtained from Adeoti et al. (2021a); out of which 97.16% is blue, 0.77% green, and 2.07% grey

Drawing on the results of the processing analysis (Figure 1), the estimated amount of water use in the production of one t of dry onion powder (from field to table) in Nigeria was 31879.6 m^3 (Figure 3). This amounted to 244.27 m^3 of green, 30977.10 m^3 blue, and 658.23 m^3 grey. Documented studies reporting the water use of onion powders were hard to find. Looking at the Jalgaon district, India, the study of International Finance Corporation (IFC) (2010) reported the water use of onion powder to be 2704 m^3/t. From a water viewpoint, the value obtained in this study was relatively higher. Three major factors could be held responsible: a) the relatively high field-level water use of fresh dry onions production in Nigeria. The report of IFC (2010) had considered onions cropped under the use of micro-irrigation systems, while the study of Adeoti et al. (2021a) had considered onions cropped under open field conditions in Nigeria; b) the processing losses (for example, cleaning, moisture, and handling losses, etc). Compared with Figure 3, the report of IFC (2010) was silent on processing losses, with little consideration for the use of the pf in the computation of the water use of the onion powder production in line with the WFN methodology; and c) the moisture content of the powder. In the IFC (2010) report, the resulting moisture content of the onion powder was 14.8%, relatively higher than 9.44% obtained in this study. The drier the dried onion flakes becomes, the higher the water use (see Figures 1 and 3). Nonetheless, this study has shown that it is technically feasible to produce dry onion powder from fresh dry onions in Nigeria, using a locally suited technology, a solar tent dryer. This has implications for equipment and machine fabricators and the industrialisation of onion powder production in Nigeria and elsewhere.

Since the production of dry onion powder is not water neutral, converting 40 - 60% of national average dry onion production (2000 - 2020), amounting to $1.10 \pm 0.29 \times 10^6$ t (FAO, 2022), would require between 14.05 and 21.08×10^9 m^3 of freshwater per annum. Already the field-level production of 40 - 60% of fresh dry onions would have consumed $1.09 - 1.64 \times 10^9$ m^3 of freshwater per annum, leaving the balance for the processing aspect. It should be highlighted that during processing (from chopped onions to dried onion flakes), about 907.16 t of moisture per t of chopped onions were evaporated. This moisture may not likely return (as precipitation) to the river basins where the onion powders were produced. However, in terms of the water use rate, a ratio of dry onion powder production water use to Nigeria's freshwater potential estimated at

375.1 x 10^9 m^3/year (FRN, 2014), this would amount to between 3.75 and 5.62%. This represents the amount of pressure dry onion powder production derived from 40 - 60% of national average dry onions cultivated in Nigeria will exert on Nigeria's freshwater resource. To what extent will this contribute to freshwater scarcity in Nigeria would require future investigations.

The results of the measured proximate contents of fresh dry onions and dry onion powder are illustrated in Figure 4. The independent-samples t-test carried out to compare the mean values for dry onion powder and fresh dry onions revealed that there was no significant difference in mean value for dry onion powder (m = 18.60, SD = 31.16) and fresh dry onions (m = 18.19, SD = 18.93; t (28) = 0.04, p = 0.97, two-tailed). The magnitude of the differences in the means (mean difference = 0.41, 95% CI: –18.88 to 19.69) was very small (eta squared = 5.71 x 10^{-5}). This suggests that the use of the direct-mode solar tent dryer to dry the fresh dry onions had minimal effects on the measured proximate contents of the dry onion powder. Nonetheless, how a direct-mode solar tent dryer would affect the nutritional contents of onion powder under commercial production merits future research. To assist, this study can serve as a useful guide.

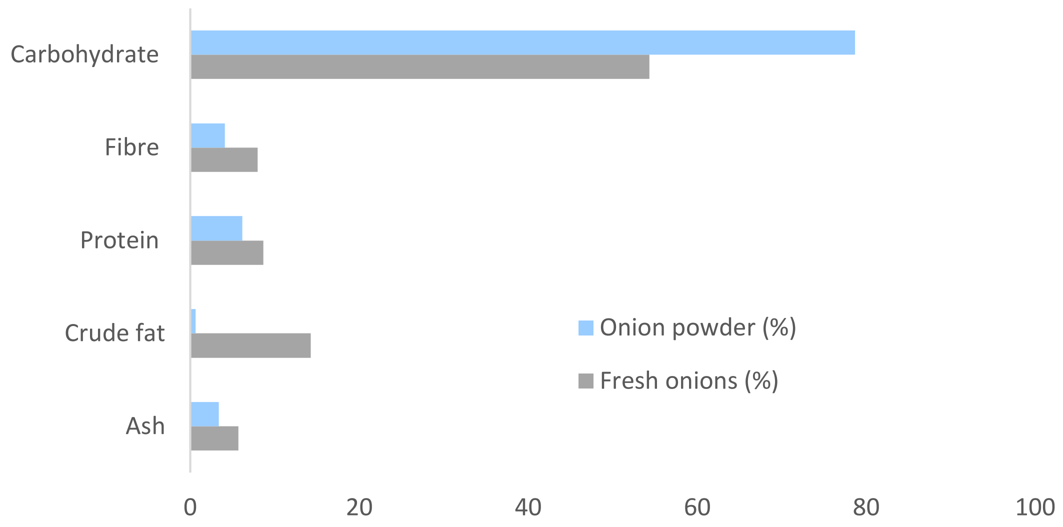

Figure 4. The measured proximate contents of fresh and dry onion powder (n = 3)

Limitation

Despite its industrial applicability, this study has some limitations which merit discussion. First, it follows a manual processing approach. Thus, processing losses may be higher. Processing losses is positively associated with water use. Second, the sample was left inside the solar tent dryer over the period of drying. Being a partially closed structure, there might be a possibility of rewetting during the night. Below certain MC thresholds, dried agricultural crops may exhibit some hygroscopic properties. Third, although there were no rains during the drying period, no tests were carried out to show any microorganism contamination. Since dry onion powders are meant for food and with the possibility of rewetting, this makes the tests to be very crucial. Lastly, this is a small scale test, with only one processing test run. For commercial purposes, a larger capacity direct-mode solar tent dryer may be needed, requiring that its performance be evaluated. Although only the proximate contents were purposively selected and evaluated in this study, future investigations should check for any variations between the anti-nutrients, vitamins, sensory, functional, and elemental (or mineral) properties of fresh and powder. For the tests of significance (α = 0.05), the independent-samples t-test could be useful.

Conclusions

This study concludes with some certainty that dry onion powder production is technically feasible in Nigeria and can serve as a means to minimising dry onion production postharvest losses in Nigeria. Notwithstanding its limitations, the study has shown that dry onion powder production in Nigeria is not water neutral. A tonne of dry onion powder would need about 31879.6 m^3 of freshwater for its production (from field to table). At the national level, converting 40 - 60% of national average dry onion production (2000 - 2020) to powder would consume between 14.05 and 21.08 x 10^9 m^3 of freshwater per annum. In terms of the water use rate, this would amount to between 3.75 and 5.62%. Further studies are needed to understand the contribution of this pressure to freshwater scarcity in Nigeria. In terms of its practical application, the outcome of this study can help a) to contribute to reduction in fresh dry onion production postharvest losses in Nigeria, b) to stimulate the processing and industrialisation of dry onion powder production in Nigeria, and c) water managers, policy makers, dry onion farmers, and food processors to take socially robust decisions on freshwater governance and management in Nigeria.

Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Adeoti O. 2010. Water use impact of ethanol at a gasoline substitution ratio of 5% from cassava in Nigeria. Biomass and Bioenergy 34(7): 985-992, doi:10.1016/j.biombioe.2010.02.006

Adeoti O, Akinola FF, Ogundare SA, Awe BS. 2021b. Freshwater requirement to attain open-defecation-free status in Nigeria by 2025. J Water Sanit Hyg Dev. 11.1, doi:10.2166/washdev.2020.135

Adeoti O, Ayelegun TA, Oyewole BA. 2009. Impact of gari consumption on the water resource of Nigeria. Afr. J. Biotechnol. 8(25): 7283-7289

Adeoti O, Oyedele OA, Yusuf A. 2021a. The water footprint of dry onion production in Nigeria. Water Resour Ind. 25, 100147, doi:10.1016/j.wri.2021.100147

Ajayi OO, Fagbenle RO, Katende J, Ndambuki JM, Omole DO, Badejo AA. 2014. Wind energy study and energy cost of wind electricity generation in Nigeria: Past and recent results and a case study for south west Nigeria. Energies 7: 8508-8534, doi:10.3390/en7128508

Akinfenwa G. 2020. Harnessing onion powder potential for consumption, export. The Guardian Newspapers (Nigeria) Online. https://guardian.ng/features/harnessing-on ionpowder-potential-for-consumption-export/ (accessed 4 June 2022)

Aldaya MM, Hoekstra AY. 2010. The water needed for Italians to eat pasta and pizza. Agric. Syst. 103: 351-360, doi:10.1016/j.agsy.2010.03.004

Armand AB, Scher J, Aboubakar, Augustin G, Roger P, Montet D, Moses MC. 2018. Effect of three drying methods on the physicochemical composition of three varieties of onion (Allium cepa L). Journal of Food Sciences Nutrition 1(2):17-24

Ayensu A, Asiedu-Bondzie V. 1986. Solar drying with convective self-flow and energy storage. Solar & Wind Technology 3(4): 273-279

Bamba SBB, Komenan ACA, Kouassi KKP, Soro D. 2020. Effects of onion bulb processing conditions on drying characteristics, physicochemical and functional properties profile of onion (Allium cepa L.) powder. J Food Sci. 85(10): 3345-3354.

Chapagain AK, Hoekstra AY. 2010. The blue, green and grey water footprint of rice from production and consumption perspectives. Ecol. Econ. 70(4): 749 - 758, doi:10.1016/j.ecolecon.2010.11.012

Dantata IJ. 2014. Bulb moisture, ash and dry matter contents of onion provenances in Northern Bauchi, Nigeria. Asian J Appl Sci. 2(3): 368-374

Ercin AE, Aldaya MM, Hoekstra AY. 2011. The water footprint of soy milk and soy burger and equivalent animal products. Ecol Indic. 18: 392-402, doi:10.1016/j.ecolind.2011.12.009

FAO. 2022. Crops and livestock products. https://www.fao.org/faostat/en/#data/QCL (accessed Saturday, 4 June 2022)

FMST. 2014a. Draft National Renewable Energy and Energy Efficiency Policy (NREEEP). Energy Commission of Nigeria, Abuja

FMST. 2014b. National Energy Masterplan (draft revised edition). Energy Commission of Nigeria, Abuja

FRN. 2014. The project for review and update of Nigeria national water resources master plan, volume 4 – National water resources master plan 2013. Federal Ministry of Water Resources, Abuja

Ibáñez GR, Ruíz JMM, Sánchez MIR, López JLC. 2017. A corporate water footprint case study: The production of Gazpacho, a chilled vegetable soup. Water Resour Ind. 17: 34-42, doi:10.1016/j.wri.2017.04.001

IFC. 2010. Water footprint assessments: Dehydrated onion products micro-irrigation systems. Jain Irrigation Systems Ltd., India

Kim I, Kim K-S. 2019. Estimation of Water Footprint for Major Agricultural and Livestock Products in Korea. Sustainability 11, 2980, doi:10.3390/su11102980

Ministry of Foreign Affairs. 2021. Food loss in Nigeria - Value chain analysis (VCA) of tomato, onion, chilli value chains. https://www.rvo.nl/sites/default/files/2021/02/Report-Food-Loss-in-Nigeria.pdf (accessed 4 June 2022)

Mitra J, Shrivastava SL, Rao PS. 2011. Onion dehydration: a review. J Food Sci Technol. 49(3): 267-277, doi:10.1007/s13197-011-0369-1

Sangwan A, Kawatra A, Sehgal S. 2010. Nutritional evaluation of onion powder dried using different drying methods. J Dairying Foods & H.S. 29(2): 151-153

Sasongko SB, Hadiyanto H, Djaeni M, Perdanianti AM, Utari FD. 2020. Effects of drying temperature and relative humidity on the quality of dried onion slice. Heliyon 6, e04338, doi:10.1016/j.heliyon.2020.e04338

Seifu M, Tola YB, Mohammed A, Astatkie T. 2018. Effect of variety and drying temperature on physicochemical quality, functional property, and sensory acceptability of dried onion powder. Food Sci Nutr. 6: 1641-1649, doi:10.1002/fsn3.707

World Vegetable Center. 2022. Increasing production and reducing postharvest losses of onion in Nigeria. https://avrdc.org/increasing-production-and-reducingpostharvest-losses-of-onion-in-nigeria/ (accessed 4 June 2022)