A Review of Post-harvest Milk Losses in Tanzania's Milk Sector: Lessons from Production to Consumption

***Lugamara, C.B. [1,2], J.K. Urassa[3], and G.D. Massawe[3]**

[1]Department of Development and Strategic Studies, Sokoine University of Agriculture, P.O. Box 3024, Morogoro, Tanzania
[2]Department of Livestock Production and Marketing Development, Ministry of Livestock and Fisheries, P.O. Box 2870, Dodoma, Tanzania
[3]Department of Policy, Planning and Management, Sokoine University of Agriculture, P.O. Box 3035, Morogoro, Tanzania

*Corresponding author's email: *charleslugamara@gmail.com*

Abstract

Tanzania has engaged in various policies, strategies and programmes in order to increase production, processing and marketing infrastructure for milk and milk products and minimise animal product losses. However, not much is known in relation to post-harvest milk losses. Therefore, the review paper aims to establish from empirical literature the extent of Tanzania's post-harvest milk losses and the causes in relation to efforts made by the government to minimise the same. To achieve the above, the authors used various databases to locate documents reporting on Tanzania's post-harvest milk losses whereby 1605 documents were identified and screened remaining with 82 that were deemed relevant. Thereafter, an assessment of the 82 documents led to only 12 being included in the critical review, with ten being dropped due to either being similar or using the same data. Therefore, in the end, only two documents are captured in this paper. Generally, the review shows that there is insufficient empirical information on Tanzania's post-harvest milk losses with the most recent study having been conducted almost 19 years ago. In addition, the study's scope was quite limited, covering a sample of 66 respondents and a narrow geographical coverage of only three regions (i.e. Coast, Dar es Salaam and Morogoro). Furthermore, the study used the rapid appraisal approach. Therefore, there is a need for disaggregated information on Tanzania's extent of post-harvest milk losses at various nodes of the milk value chain so as to inform policy makers and other stakeholders interested in curbing the same.

Keywords: Milk losses, milk supply chain, post-harvest losses.

Introduction

According to the 2019 world report of the Population Prospects, the projection of population growth globally is on increase from 7.7 billion people in 2019 to the expected 9.7 billion people in 2050 with an average growth rate of 10% by 2030 and 26% by 2050 (UN, 2019). The population growth in sub-Saharan Africa (SSA) is expected to increase from 1.1 billion people in 2019 to 2.1 billion people in 2050 (UN, 2019). The above population growth projected suggests more future food demand including milk. Therefore, there is a need for concerted efforts to minimize, among others, post-harvest milk losses so as to increase the supply and stability of dairy products as part of the general food security measures. In addition, doing the above will reduce socio-economic costs associated with post-harvest[1] food losses in various countries (FAO, 2011, 2019; FAO & LEI, 2015). Moreover, the number of the world's hungry population remains unacceptably high as an estimated 820 million people are hungry globally (FAO *et al.,* 2019), and 13.8% produce for human use is lost from the post-harvest

[1] *Post-harvest, as defined by FAO (2018), is the duration starting immediately after the initial stage of production and extends to when the product is ready for utilization. Therefore, this study considers post-harvest to be the chain immediate after milking to the stage when the milk is ready for consumption.*

stage before reaching the retails (FAO, 2019). In addition, of the 13.8% of global food lost, 12% is of animal products (milk included) (FAO, 2019). Other reports show that, annually, about 1.3 billion tonnes (one-third) of the global food produce meant for people's consumption got lost or wasted due to contamination or spillage or spoilage along the whole food distribution channels (FAO, 2011).

Furthermore, out of the global food losses and waste estimated above, 3%, 7%, 8%, 12% and 17% are dairy products lost at production, post-harvest, processing, distribution and consumption levels respectively (FAO, 2011). In SSA, the estimated milk losses are 6% at the production level, 17% during post-harvest handling and 25% during storage (FAO, 2011). Therefore, various studies argue that post-harvest loss reduction operations are of paramount socio-economic importance and that if this is properly integrated in various development strategies, farmers and communities can be more economical than concentrating on extra production (ADB & FAO, 2011; Bechoff *et al.,* 2019; Lipinski *et al.,* 2013; Sawicka, 2019). Besides, Aulakh *et al.* (2013); FAO (2019) and Nanda *et al.* (2012) argue that minimising food losses or preserving produced food enhances its availability for domestic consumption (ensures food security[2]) and serves economic purposes. Therefore, understanding post-harvest milk losses is of great importance as part of efforts of ending hunger, raising income and improving food security in poor and lower middle income countries, Tanzania included.

Tanzania has formulated various policies, strategies and programmes to reduce losses along the milk value chain. For example, the Tanzania Livestock Policy of 2006 aims at improving livestock production and productivity by reducing animal and animal product losses (harvest and post-harvest) (URT, 2006). Similarly, Tanzania's 2010 Livestock Sector Development Strategy insists on national food security by investing in massive production, well established markets and processing infrastructures for livestock harvests in the process of fulfilling the nutrition requirements at the national level (URT, 2010). In addition, Tanzania's 2011 Livestock Sector Development Programme aims at enhancing food stability, increasing income of the livestock stakeholders, improving livestock products' marketing systems and infrastructure for animal products (URT, 2011). Furthermore, Tanzania Livestock Master Plan 2016/17–2021/22 insists on additional dairy investments and value addition through processing to ensure a stable market for fresh milk (URT, 2017a).

Moreover, the Ministry of Livestock and Fisheries (MLF), through the Tanzania Dairy Board (TDB) and Private Sector Desk (PSD), has created an enabling environment and built the capacity of milk collectors, dairy cooperative unions and milk processors and linked them with financial institutions for easy access to loans so that they may purchase the required facilities/equipment including milk cooling tanks (TDB, 2019, 2021; URT, 2020). Based on the above efforts, Tanzania's livestock industry continues to be a source of livelihood for many Tanzanians. For example, out of 7.8 million Tanzanian households involved in agricultural activities, 33% deal with both crops and animal production, while only 2% are involved in livestock keeping (NBS, 2021). Moreover, the total number of cattle in Tanzania increased from 30.5 million (of which 1.1 million were improved dairy cattle) in 2017/18 (URT, 2017b) to 33.9 million cattle in 2019/20 (NBS, 2021); the annual milk production increased from 1.7 billion litres in 2007/08 to 3.1 billion litres in 2020/21 (NBS, 2021).

Furthermore, literature (URT, 2020) shows that despite the availability of potential livestock resources in Tanzania, the dairy industry's contribution is low (about one-third of the 7.4% livestock industry's contribution) to the country's Gross Domestic Product (GDP) (URT, 2020). Moreover, in the early 2020s, there were 96 operating milk processing plants/ industries with a capacity of processing 711,400 litres per day though the actual processing was quite minimal (26% per day) (URT, 2021). This suggests a milk supply deficit in Tanzania. In

[2] *The World Food Summit of 1996 defined food security as "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FA, 1996).*

addition, milk importation varied yearly; for example, in the year 2011/12, Tanzania imported 106 million litres of milk with a value of 53.4 billion TZS and in 2020/21 the importation from various countries was about 5.3 million litres of milk (Liquid Milk Equivalent - LME) with the total value of 12 billion TZS. Therefore, this suggests a milk supply deficit within the country. Similarly, the rate of milk consumption nationally was 55 litres per capita (TDB, 2021), which is quite low, compared to the recommended 200 litres per capita as per FAO standards. The low milk consumption rate may be due to a number of factors, one of which is low milk supply as an outcome of un-prevented milk harvest and post-harvest losses, thus high price of milk which the poor may not afford (Mbwambo, 2015).

Despite the Tanzanian government's efforts meant to transform the milk sector by increasing production and marketing systems of the milk, little is known on the extent of milk loss in the country. Therefore, the review aimed to establish from the literature the extent of post-harvest milk losses in Tanzania, the causes of the losses, and suggest areas for further studies. Generally, the paper is guided by the following questions: What is Tanzania's current magnitude of post-harvest milk losses? What are the causes of Tanzania's post-harvest milk losses?

Methods

Search Strategy

A systematic review of journal articles and other publications from international institutions and consortia such as the Food and Agriculture Organization of the United Nations (FAO) and Consultative Group on International Agricultural Research (CGIAR) on post-harvest milk losses in SSA was done. In addition, to enable a wider access to published documents, various keywords (Table 1) were used in databases such as ScienceDirect, Emeralds, PubMed, Research4Life E-resources (AGORA and HINARI); Multidisciplinary Resources (such as African Journal Online - AJOL, LibHub, and Taylor & Francis Journals); and Google Scholar and Google search engines. The searching of journal and other publications was restricted to Tanzania, sub-Saharan Africa and Africa. Moreover, the search was restricted to the years of publication between 2000 and 2022 in order to have coverage of at least 20 years reviewing materials.

Selection of the Reviewed Documents

One of the challenges in undertaking this review was to ensure that analytical conclusions were legitimate, given that it is difficult to analyse a large number of articles or publications. Therefore, for this review, a detailed analysis of two documents (Technical paper and Synthesis Report) which were selected from the list of accessed reading materials, based on the extent to which an article or publication fitted in with the key theme relating to post-harvest milk loses in Tanzania, was adopted. Moreover, a document's relevance for selection was ensured by screening the titles and a review of the abstracts and full articles. However, articles that did not meet the selection criteria were excluded from a critical review of the same. Some of the reasons for exclusion included irrelevant titles, duplication, wrong geographical coverage (not conducted in Tanzania), theses/dissertations using similar data used in other publications, and articles/documents not reporting extent of milk losses (Figure 1).

Results and Discussion

The extent of post-harvest milk losses in Tanzania

Out of 12 full assessed articles, only two articles, Lore *et al.* (2005) and FAO (2004) cited in ACF (2014), were relevant to the Tanzanian context (Table 2). Lore *et al.* (2005) conducted a rapid appraisal in July 2003 to collect data on milk losses along the milk supply chain (from producer to retailer) using a structured questionnaire and a checklist. In addition, at least three representatives of each milk supply chain actor were interviewed in the three covered regions (i.e. Coast, Dar es Salaam and Morogoro), and the selected points included a milk shed which is believed to be dominated by pastoralists and smallholder farmers (Lore *et al.,* 2005). Further to the above, milk losses in Tanzania are high at the farm level (quantified at 6.5% of which spoilage and spillage accounted for 6.3%; while forced consumption was

Table 1: Database/search engine and key words used

Sn.	Database/ Search Engine	KEY WORDS	Results
1	ScienceDirect	"post-harvest losses" AND "Milk" AND "sub Saharan Africa"	96
2	Emeralds	"post-harvest losses" AND "Milk" AND "sub Saharan Africa"	11
3	PubMed	((("sub Saharan"[tw] OR "sub Saharan Africa"[tw] OR "Africa sub Saharan"[tw] OR "Africa"[tw] OR "African"[tw] OR "East Africa"[tw] OR "Tanzania"[tw] OR "Tanzanian"[tw])) AND ((Post-harvest [mesh] OR Post-harvests OR Harvests OR Harvest*, After-harvests OR post-harvest loss OR post-harvest losses OR after-harvest loss OR After-harvest losses OR post harvesting OR after harvesting OR farm products))) AND ((Milk loss[mesh] OR Milk, loss OR milk losses OR milk lost OR milk, lost))	18
4	Research4Life E-resources	((“post-harvest milk losses") OR (“milk losses”)) AND (("sub Saharan") OR ("sub Saharan Africa") OR ("sub Saharan Africa") OR ("Africa sub Saharan") OR (Africa) OR ("East Africa") OR (Tanzania))	10
5	Google Scholar	"Post-Harvest" "Milk Losses" "Food Security" and "Sub-Saharan Africa".	102
6	Google search	"Post-Harvest" "Milk Losses" "Food Security" and "Sub-Saharan Africa".	742
7	African Journal online (AJOL)	post-harvest milk losses in Africa	524
8	LibHub	Post-harvest milk losses in Tanzania	2
9	Taylor & Francis Journals	post-harvest milk losses in Africa	100

Source: Adapted from Wafeu *et al.* (2017)

about 0.2%). Other losses were reported at the collection centres and processing plants where milk is routinely chilled. The spoilage losses at these two levels were 0.44% and 1.5%, respectively. At retailers, losses were 0.7% due to spillage and 0.62% due to spoilage (Lore *et al.,* 2005). In addition, FAO (2004) as cited in ACF (2014) reported that about 59.5 million litres of milk, approximately 16% and 25% of total dairy production, is lost annually in Tanzania being during the dry and wet seasons respectively due to spoilage and waste. However, ACF (2014) did not exhaust much on the methodology (study design and sample size) used by FAO (2004) to generate the results.

Causes of post-harvest milk losses in Tanzania

In Tanzania, milk losses occur at all the nodes of the milk supply chain whereby the nodes face similar or different causes of loss. According to Lore *et al.* (2005), spillage, spoilage and forced consumption at the farm level are due to a lack of market and poor roads; spoilage at the collection centres and the processing plants is due to electricity failure; while spillage and spoilage at the retail level are due to electricity failure and lack of market (Table 2). The above results are supported by Bingi and Tondel (2015) that milk losses in the East African region due to spoilage is a threat in the dairy supply chain facing many actors, whereby its impacts is evidenced by low income

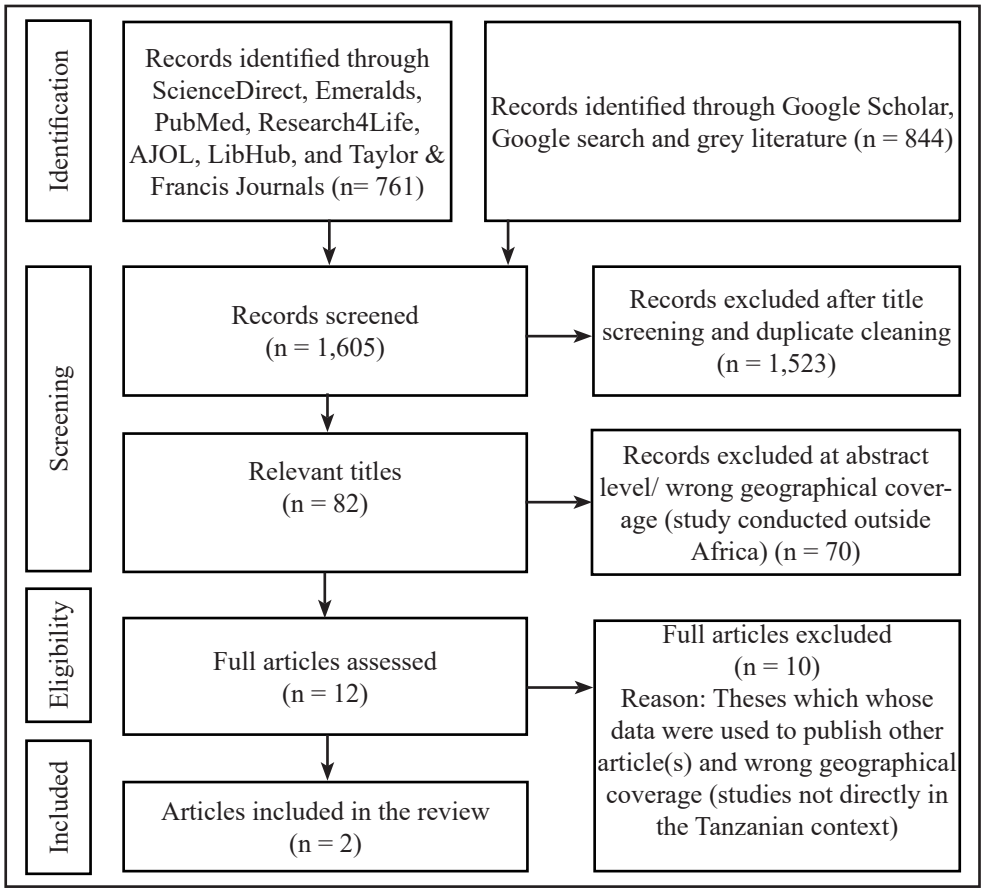

Figure 1: Flow diagram for selection and exclusion of the documents for review

Table 2: Summary of studies reporting post-harvest milk losses in Tanzania

Author (year)	Document type	Country	Study design	Sampling frame	Sample size	Extent of milk losses	Causes of post-harvest milk losses
FAO (2004) cited in ACF (2014)	Technical paper	Tanzania	-	-	-	16% dry season	Spoilage and waste
						25% wet season	Spoilage and waste
Lore *et al.* (2005)	Synthesis Report	Tanzania	Rapid appraisal	Farms	15-66 respondents	6.5% (6.3% spillage and spoilage; and 0.2% forced consumption)	Lack of market and poor roads
				Collection centres		0.44% spoilage	Electricity failure
				Processing plants		1.5% spoilage	Electricity failure
				Retailers		0.7% spillage and 0.62% spoilage	Electricity failure and lack of market

and minimal milk supply. Post-harvest milk losses in the area of production (households and farms), especially during the rainy season, lead to most of the large urban centres being dependent on dairy products imported from outside East Africa, particularly during the dry season (Häsler *et al.,* 2019; Omore *et al.,* 2016 Further to the above, Häsler et al. (2019) argue that only a very small proportion of milk-producing households have stability on accessing electricity, which is an important factor in post-harvest losses. Generally, cold storage at the household level is crucial in limiting microbial growth for the majority of rural producers and consumers. Moreover, some milk collection centres, especially those without stable electricity supplies, often do not accept evening milk delivered to them the next day due to the low quality, hence a higher likelihood of postharvest losses. Generally, post-harvest milk losses deny smallholder farming households the much-needed income for their socio-economic development. In addition, the losses also lead to many households at urban centres failing to access affordable milk, hence the likelihood of affecting their food and nutritional security.

Research Gap

The review has shown that there's a real dearth of knowledge on Tanzania's current situation of post-harvest milk losses. For example, the latest study on such losses is one by FAO (2004) as cited in ACF (2014) and Lore *et al.* (2005), which was conducted almost 19 years ago. In addition, the study's sample size was small (i.e. 66 respondents), and its geographical coverage was also narrow, i.e. it only covered the three regions of Coast, Dar es Salaam and Morogoro. In addition, it involved a rapid appraisal nature of the study (Lore *et al.,* 2005). Other documents (Bingi and Tondel, 2015 and Häsler *et al.,* 2019) cover Tanzania's milk production, but not much was reported about post-harvest milk losses. In addition, only two studies/reports out of the 1,605 identified documents that were screened and assessed somehow captured Tanzania's post-harvest milk losses in relevant detail. Furthermore, there have been a lot of economic reforms in the country from which one would expect a major improvement in operations along the country's milk value chain. Hence, the need for further studies to provide a good understanding of post-harvest milk losses and their associated socio-economic costs occurs.

Conclusions and Area for Future Research

Based on the aim of this review, it is concluded that there is existence of milk losses in Tanzania, mainly by spoilage, forced consumption and/or spillage. The most reported causes of milk losses are inadequate market, poor roads to the market places and electricity failure at the storage points. The existing information was collected many years ago (about 19 years) and covered a sample of 66 respondents from Morogoro, Dar es Salaam and Coast regions) (Lore *et al.,* 2005). It is further concluded that much has been done favouring milk production and market system as stipulated in various policies, strategies and programmes, but no current information in relation to Tanzania's post-harvest milk losses. The lesson learnt is that despite the number of livestock increasing annually, the rate of milk consumption is low (55 litres per person per year), compared to the amount recommended by FAO of 200 litres per person per year. The low milk consumption rate may be due to a number of factors, one of which is low milk supply as a result of un-prevented milk harvest and post-harvest losses. Therefore, there is a need for a more rigorous study (field research) to explore progress made following Tanzania's government efforts to reduce livestock product losses as stipulated in various policies, strategies and programmes. The above will help to properly inform policymakers and other stakeholders interested in improving the well-being of those involved in the milk value chain, especially smallholder livestock keepers. Moreover, future researchers need to come up with disaggregated information on the implications of post-harvest milk losses among different actors along the milk value chain, in particular the extent of milk losses at various supply chain nodes, the causes and the socio-economic implications of the losses. This could save much of Tanzania's foreign currency used to import milk and milk products, hence channelling the same to other priority areas for

the country's socio-economic development.

Acknowledgments

The authors acknowledge technical assistance received from Sokoine University of Agriculture (SUA), Morogoro, Tanzania and the research money received from the Ministry of Livestock and Fisheries, Dodoma, Tanzania, for supporting the study on which this article is based.

Conflicts of Interest: No conflict of interest declared by the Authors

References

ACF (Action contre la Faim) (2014). Post-Harvest Losses and Strategies to Reduce Them. Technical paper on Post-Harvest Losses, Action Contre la Faim (ACF). (25pp. [https://www.actioncontrelafaim.org/wp-content/uploads/2018/01/technical_paper_phl__.pdf] Site visited on 16/04/2022.

ADB and FAO (African Development Bank and Food and Agriculture Organization of the United Nations). Continental Programme on Post-harvest Losses (PHL) Reduction Rapid Needs Assessment – Working Document – Ghana. 101pp.

Aulakh, J., Regmi, A., Fulton, J., & Alexander, C. (2013). Estimating post-harvest food losses: Developing a consistent global estimation framework. In: Proceedings of the Agricultural & Applied Economics Association's 2013 AAEA & CAES joint annual meeting, Washington, DC, USA, 4–6 August 2013.

Bechoff, A., Mayanja, S., S., Mvumi, B., Nyanga, L., Ngwenyama, P., Tanya Stathers, Apurba Shee, Mario Ferruzzi, Hawi Debelo, Julia de Bruyn, Sarah Arnold, Corinne Rumney, & Keith Tomlins. (2019). The NUTRI-P-LOSS (Nutritional Postharvest Loss) methodology: A guide for researchers and practitioners. 25pp.

Bingi, S and Tonde, F. (2015). Recent Developments in the Dairy Sector in Eastern Africa towards a Regional Policy Framework for Value Chain Development. Briefing Note No. 78, European Centre for Development Policy Management (ECDPM). [https://ecdpm.org/wp-content/uploads/BN-on-dairy-sector-in-EA_final1.pdf] site visited on 14/4/2022.

FAO (Food and Agriculture Organization of the United Nations) (1996). The Rome declaration on world food security. Population and Development Review 22, 807–809.

FAO (Food and Agriculture Organization of the United Nations) (2011). Global food losses and food waste: Extent, causes and prevention; study conducted for the International Congress Save Food! at Interpack, Düsseldorf, Germany. FAO. 38pp

FAO (Food and Agriculture Organization of the United Nations) (2018). Guidelines on the measurement of harvest and post-harvest losses: Recommendations on the design of a harvest and post-harvest loss statistics system for food grains (cereals and pulses). Rome. 137pp.

FAO (Food and Agriculture Organization of the United Nations) (2019). The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction. FAO. 182pp.

FAO, FAO, IFAD, UNICEF, WFP & WHO (Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, United Nations Children's Fund, World Food Programme and World Health Organization) (2019). The State of Food Security and Nutrition in the World 2019. Safeguarding against economic slowdowns and downturns. Rome. 212pp.

FAO & LEI (Food and Agriculture Organization of the United Nations & LEI) (2015). Potential impacts on sub-Saharan Africa of reducing food loss and waste in the European Union—A focus on food prices and price transmission effects. Rome, Italy. 64pp.

Häsler, B., Msalya, G., Roesel, K., Fornace, K., Eltholth, K., Sikira, A, Kurwijila, L, Rushton, J, & Grace, D. (2019). Using participatory rural appraisal to investigate food production, nutrition and safety in the Tanzanian dairy value chain. Global Food Security 20 (2019) 122–131. https://doi.org/10.1016/j.gfs.2019.01.006

Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R., & Searchinger, T. (2013). Installment 2 of "Creating a sustainable food future" reducing food loss and waste. Working paper. World Resource Institute, Washington, DC. 40pp.

Lore, T., Omore, A., & Staal, S. (2005). Types, levels and causes of post-harvest milk and dairy losses in sub-Saharan Africa and the Near East: Phase two synthesis report. ILRI. 40 pp. http://hdl.handle.net/10568/3741.

Mbwambo, N. (2015). Market Assessment of Dairy Industry In Tanzania: SFOAP Inception Workshop: 13th January , 2015 , Blue Pear L Hotel, Ubungo Plaza.

Nanda, S.K., Vishwakarma, R.K., Bathla, H.V. L., Rai, A., & Chandra, P. (2012). Harvest and post-harvest losses of major crops and livestock produce in India. All India Coordinated Research Project on Post-Harvest Technology (ICAR), Luthiana. 149pp.

NBS (National Bureau of Statistics) (2021, August). National Sample Census of Agriculture 2019/20—National Report. [https://www.nbs.go.tz/index.php/en/census-surveys/agriculture-statistics/661-2019-20-national-sample-census-of-agriculture-main-report] site visited on 01/09/2021.

Omore, A., Twine, E., Kanyuuru, C., and Kidoido, M. (2016). Maziwa Zaidi Theory of Change: Context and 'start point'. 29pp. http://livestockfish.cgiar.org.

Sawicka, B. (2019). Post-harvest Losses of Agricultural Produce. In: W. Leal Filho *et al.* (Eds.) Zero Hunger. Springer. [DOI: 10.1007/978-3-319-69626-3_40-1] Site visited on 14/11/2020.

TDB (Tanzania Dairy Board) (2019). Tanzania Milk Sector Status 2018/19. Dar es Salaam, Tanzania. 52pp.

TDB (Tanzania Dairy Board) (2021). Tanzania Dairy Board Achievements Report for the year 2005/06 to 2020/21. Dodoma, Tanzania. 25pp.

UN (United Nations) (2019). World Population Prospects 2019, Volume II: Demographic Profiles (ST/ESA/SER.A/427). 1238pp.

URT (United Republic of Tanzania) (2006). National Livestock Policy 2006. Ministry of Livestock and Fisheries Development. 53pp.

URT (United Republic of Tanzania) (2010). Livestock Sector Development Strategy. Ministry of Livestock and Fisheries Development. Dar es Salaam, Tanzania. 90pp.

URT (United Republic of Tanzania) (2011). Livestock Sector Development Programme. Ministry of Livestock and Fisheries Development. 123pp.

URT (United Republic of Tanzania) (2017a). Tanzania Livestock Master Plan 2017/18 – 2021/22. Dar es salaam, Tanzania. 146pp.

URT (United Republic of Tanzania) (2017b). Tanzania Livestock Sector Analysis 2016/17-2031/32. Dar es salaam, Tanzania. 150pp.

URT (United Republic of Tanzania) (2020). The Minister of Livestock and Fisheries Hon. Luhaga Joelson Mpina (MP) Speech on the Expected Expenditure financial year 2020/21 of the Ministry of Livestock and Fisheries. Ministry of Livestock and Fisheries. 323pp.

URT (United Republic of Tanzania) (2021). The Minister of Livestock and Fisheries Hon. Mashimba Ndaki (MP) Speech on the Expected Expenditure financial year 2021/22 of the Ministry of Livestock and Fisheries. Ministry of Livestock and Fisheries. 257pp.

Wafeu, G.S., Tankeu, A.T., Endomba, F.T.A., Nansseu, J.R., Kaze, A.D., Bigna, J.J., & Noubiap, J.J. (2017). Prevalence and associated factors of active smoking among individuals living with hypertension and/or diabetes in Africa: A systematic review and meta-analysis protocol. BMJ Open, 7(10), e015444. https://doi.org/10.1136/bmjopen-2016-015444