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African Journal of Food Science

Full Length Research Paper

Effect of traditional and hermetic bag storage structures on fungus contamination of stored maize Grain (*Zea mays* L.) in Bako, Western Shoa, Ethiopia

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The experiment was conducted between December 2017 and May 2018 at Bako, Ethiopia to study the effectiveness of traditional (Gombisa, Sack) and Hermetic bag storage structures and storage periods on fungal contamination of stored maize grain on agar plate method. The incidence and frequency of storage fungi was determined at 0, 2, 4 and 6 months of storage periods. The experiment was replicated three times in factorial design. The design was 3×4 in factorial fashion. The treatments were three storage types (Gombisa, sack and Hermetic bag), one variety of maize (Bako hybrid-661) and storage periods (0, 2, 4 and 6) months. The collected data were analyzed statistically using Generalized Linear Model (GLM) procedure of SAS and means that were significantly different were separated using Least Significant Difference (LSD). Fungi were the major causes of deterioration and quality loss on stored maize grains during the storage period. The fungal incidence and frequency significantly different (p<0.05) increased with storage periods. The highest (39.4%) *Fusarium* species incidence was recorded at the last six months of storage. *Fusurium* spp. occurred in Gombisa with the highest 29.9% incidence and 23% frequency, respectively. The highest frequency of *Aspergillus* species 26.7% was recorded in Gombisa whereas the minimum 18% was obtained from Hermetic bag in the six months of storage periods. In this study, *Fusurium* spp. was the most prevailing storage fungi followed by *Aspergillus* spp. As a result of this research, the Hermetic bag was determined to be more appropriate for protecting the stored maize grains from fungal attack during the storage periods and the stored grains have low fungal incidence and frequency until initial to four months. Therefore, gombisa and sack storages were inadequate for protecting stored maize from insect pests and fungal attacks. Overall, the hermetic bag storage can protect insect infestation and fungal development and consequently maintains seed viability and nutritional content during storage without use of insecticides.

Key words: Moisture, temperature, humidity, fungi, storage.

INTRODUCTION

Maize (*Zea mays* L.) is the third most important crop after rice and wheat cultivated in the world and occupying more than 120 million hectares of cropland annually (Marta et al., 2017). In Ethiopia maize is the first most important cereal crop in terms of its production accounting for 26.7% (7.2 million tons) of 87.3% (23.6

million tons) of the cereal production (Binyam and Girma, 2016). Due to its higher caloric and nutritive values, it is a valuable food for human beings as well as good feed for livestock and poultry (Girma et al., 2006). However, the grain suffers from quantitative and qualitative losses during storage. The losses occur mainly due to improper storage (Ishrat and Shahnaz, 2009) and fungi, bacteria, viruses and insects infecting and infesting stored maize grains and causes combined worldwide annual losses of 9.4% (Verga and Teren, 2005). The main storage fungi associated with stored grains includes *Aspergillus* and several *Penicillium* species. Nine fungal species isolated from stored maize were *Aspergillus flavus, Aspergillus nidulans, Fusarium moniliforme, Penicillium* spp. and the different types of fungi from the stored maize (Bosah and Omorusi, 2014; Chattha et al., 2016). Fungi are the second important cause of deterioration and loss of maize next to insects (Ali et al., 2007).

Fungi could cause about 50 to 80% of damage on farmers' stored maize grains during storage if conditions are favorable for their development (Ali et al., 2007). Aflatoxin content was increased in the stored maize grain after 12 months of storage. Fungi affect the quality of grains from the results; there were an increase in fatty acid, reduction in germination, increase its mustiness, production of toxins and finally leading to spoilage of grain in many ways. Regardless of the incidence and frequency of these storage fungi which cause losses to the stored grains of maize in Ethiopia, appropriate studies have not been made. Information on outcome of these fungi inefficiently exists. In future, many studies to be done on the close-fitting of storage maize grains fungal pathogens are required. The present study was initiated with the objective study of the effectiveness of traditional (Gombisa, Sack) and Hermetic bag storage structures in protecting the stored maize grain from fungal infection in Bako district, Oromia region, Ethiopia (Befikadu et al., 2012).

MATERIALS AND METHODS

Description of the study area

This study was conducted at Bako Agricultural Research Center located in East Wollega Zone of the Oromia Regional State, Western Ethiopia at an altitude of 1650 m above sea level (m.a.s.l). Bako lies at 9° 6" north latitude and 370° 9" east longitude in the sub-humid ecology of the country 260 km west of Addis Ababa and 8 km away to the south from the main road to Nekemte. Average annual rainfall at this location is 1237 mm. The rainy season extends from May to October and maximum rain is received in the months of July and August. Agro-ecologically, it has a warm humid climate with mean minimum, maximum and average air temperatures of 15, 30 and 23°C, respectively. The RH minimum, maximum and average of the area is 49, 74.7 and 61.85%, respectively. The major annual and perennial crops of the area include maize, sorghum, teff, noug, hot pepper, haricot bean, sweet potato, mango, banana, and sugar cane in order of importance. The study was conducted for six (6) moths starting from harvesting time in December, 2017 to May, 2018 at Bako National Maize Research Center (Figure 1).

Experimental plan and design

The experiment was arranged in a 3×4 factorial combination with two factors, storage types and storage period in complete randomized design with three (3) replications. Storage types have three levels, that is Gombisa, Sack and Hermetic bag, while storage period have four levels that is 0, 2, 4 and 6 months of storage periods. Data were collected at every two months interval, including at the start of the study making up four levels for the factor storage period.

Experimental materials

The study materials were BH-661 maize of variety harvested in December, 2017 and three types of Gombisa, Sack and Hermetic bag storage structures.

Sampling methods

A total of 90 samples of BH-661 maize variety were collected from each of storage structures periodically starting from the beginning of the storage (0, 2, 4 and 6) months of the storage periods. The samples were taken from the top, middle and bottom of the storage structures. The initial maize samples from each storage structures were taken as a control at the beginning of the storage. Each sample was taken by inserting the spear into the grain mass straight to the maximum depth from the top, middle and the bottom of the storage.

Physical parameters

Moisture content

Grain moisture content was determined by using the AACC (2005) standard procedures of oven dry methods. The grain was dried at a temperature of 105°C for 3 h and after being removed from the oven, it was allowed to cool in a dissector and then weighed. Then, the moisture content was calculated as follows:

$$\text{MC (\%)} = \frac{\text{Weigh initisal of the sample} - \text{Weight after dry}}{\text{Weight of sample after dry}} \times 100$$

Storage temperature and relative humidity

The temperature and relative humdity of the internal and external environment of the storage was measured at an interval of every week by using portable digital thermo-hygrometer (Hanna, HI8564) and measurement was done in the afternoon 3.00 p.m. in the day

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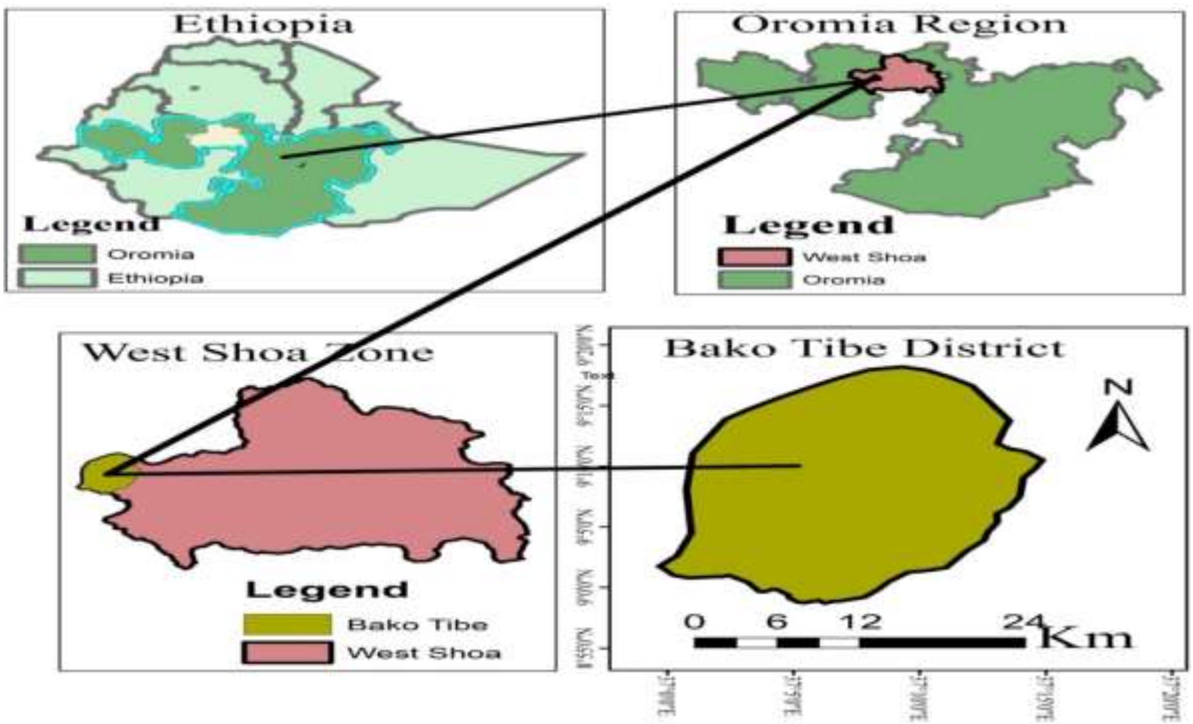

Figure 1. Map of the study area.

(to reduce variations) and at the time three data was taken and its average was recorded. Measurements were taken from the center, side, and top portion of the storage.

Microbial identification

Fungal detection of the stored maize grain

Agar plate method: A sample of stored maize grains with and without surface disinfection was used and 10 grains of each treatment were aseptically placed on potato dextrose agar (PDA) by the method of agar plate according to the procedures used by Binyam and Girma (2016). The laboratory analysis was carried out in the Ambo Plant Protection Research Center mycology laboratory department. Firstly, from each sample, 360 maize grains; in 3 replications of 120 seeds were selected. Initially, freshly harvested seed of BH661 was used and periodically the stored maize grains were used and thoroughly washed with distilled water at each period. From surface disinfected and non-disinfected samples, 10 grains/Petri-dish/plate (9 cm diameter plates) containing potato dextrose agar (PDA) were aseptically placed. The plate that contains fungus was incubated at 26°C for 7 days and after 7 days of incubation, the identification of fungi isolates was done based on: septate, growth rate, color, and morphology of mycelia, conidia and sporulation structures. Then, the isolated fungi were sub-cultured after three days of incubation for purification of the isolate. Finally, incidence of isolation fungi (%) and frequency of isolation of fungi (%) were calculated as follows:

Incidence of fungi: Incidence of fungal infection on each samples was calculated by using the following formula:

$$\text{In } (\%) = \frac{\text{Number of infected grain}}{\textit{total of grain}} X\ 100$$

Isolation frequency (IF): For each fungus, the proportion of samples that yielded its isolates were determined and expressed as percent by using the following formula (Marasas et al., 1988).

$$\text{IF } (\%) = \frac{\text{Number of samples of occurence fungi species}}{\textit{total number of sample}} X\ 100$$

Statistical analysis

All the data collected were subjected to analysis of variance (ANOVA) by using the PROC GLM procedure (SAS institute, 2004) and difference among means was compared by the Least Significant Difference at 5% level of significance (Steel and Torie, 1980). The correlation parameters were examined using Pearson's correlation coefficient using PROC CORR procedure of the SAS software (SAS Institute, 2004).

RESULTS AND DISCUSSION

Relative humidity of the stored maize grain

Mean relative humidity of stored maize grains over the storage periods is shown in Table 1. The initial loading of data of relative humidity for all storages just before being closed was 23.60% which was the same as that of the ambient relative humidity. In the subsequent months, the relative humidity kept on increasing in each storage as well as the ambient and reached 41.80, 37.15, 36.45 and 35.00%, respectively. Befikadu et al. (2012) reported that the average relative humidity ranged from 30.83 to

Table 1. Mean relative humidity of stored maize grains over the storage periods, 2017/2018.

Storage period (Months)	Mean of RH (%)			Mean of ambient RH (%)
	Gombisa	Sack	Hermetic	
ILD	23.60[g]	23.60[g]	23.60[g]	23.60[f]
1	27.75[f]	27.05[f]	26.35[f]	25.0[e]
2	30. 50[e]	30.35[e]	28.50[e]	27.0[d]
3	32.50[d]	33.50[d]	30.70[d]	29.5[c]
4	34. 35[c]	34.50[c]	32.90[c]	32.0[b]
5	36.55[b]	35.10[b]	34.10[b]	32.5[b]
6	41.80[a]	37.15[a]	36.45[a]	35.0[a]
LSD (5%)	1.3	1.0	0.85	0.65
CV (%)	3.5	4.8	2.7	4.8

Mean values of three replicates within each column sharing similar letters were not significantly different by LSD test at P≤0.05. CV: Coefficient of variation, LSD: least significant different, ILD: initial loading date, RH: relative humidity.

Table 2. Mean of grain temperature of stored maize grains over the storage periods, 2017/2018.

Storage period (months)	Mean of temperature (°C)			Mean of ambient temperature (°C)
	Gombisa	Sack	Hermetic bag	
ILD	22.25[f]	22.25[f]	22.25 [b]	22.25[e]
1	23.15[f]	23.10[f]	22.40[b]	25.0d
2	24.95[e]	25.00[e]	24.15[b]	27.0[c]
3	27.30[d]	26.85[d]	26.20[b]	28.0[b]
4	28.95[c]	28.00[c]	27.85[b]	29.5[b]
5	32.80[b]	30.85[b]	29.55[b]	31.0[a]
6	35.65[a]	34.15[a]	33.05[a]	31.05[a]
LSD (5%)	0.9	1.0	0.6	0.8
CV (%)	3.5	4.8	2.7	4.8

Mean values of three replicates within each column sharing similar letters were not significantly different by LSD test at P≤0.05. CV: Coefficient of variation, LSD: least significant different, ILD: initial loading date.

54.67% and 29.33 to 65.17% being recorded inside Gombisa and Sack. Abass et al. (2014) reported that the mean relative humidity maintained inside hermetic storage containers was significantly higher from 72.47 to 75.32% in Manyara sites than in Dodoma sites from 60.02 to 61.68%, but the average relative humidity conditions in polyprolyne bags without treatment in Manyara (62.28%) is similar to the average humidity in Dodoma (58.52%). Likewise, Chattha et al. (2016) stated that the average maximum ambient temperature at 38.07°C; and the mean relative humidity was 78.0% throughout the study period.

Temperature of the stored maize grain

Table 2 shows monthly average temperature data of the three storage types and that of the ambient atmosphere. The initial temperature during the loading of the storages was 22.25°C. The temperature readings continued to increase continuously and reached 35.65, 34.15, 33.05 and 31.05°C for Gombisa, Sack, Hermetic bag and the ambient in the six months. Likewise, Befikadu et al. (2014) reported that the average temperature ranged from 21.30 to 35°C for Gombisa and 16.55 to 28.95°C for Sack, while Marek et al. (2018) reported average values of temperature inside of the floored warehouse to be 21.9°C within the timeframe, with the maximum value of 32.6°C and minimal value of 12.6°C.

Moisture content of the stored maize grain

The average moisture content data of grains stored in the three types of storages for six months are shown in Table 3. The values did not change much after storage periods of one month. As time passed by the moisture contents in

Table 3. Mean moisture content of stored maize grains over the storage periods, 2017/2018.

Storage period (Months)	Mean of grain moisture content (% in dry base)		
	Gombisa	Sack	Hermetic
ILD	10.00[c]	10.00[c]	10.0[c]
1	9.93[c]	10.00[c]	9.30[c]
2	7.40[d]	8.40 [d]	7.80[d]
3	8.36[d]	8.00 [d]	7.50[d]
4	10.50[c]	10.20[c]	9.86[c]
5	11.23[b]	10.46[c]	10.03[c]
6	13.9[a]	11.70[b]	10.70[c]
LSD (5%)	0.53	0.48	0.72
CV (%)	3.4	2.30	2.81

Mean values of three replicates within each column sharing similar letters were not significantly different by LSD test at P≤0.05. CV: Coefficient of variation, LSD: least significant different, ILD: initial loading date.

all three storage types decreased. For instance, the moisture content of samples in Gombisa dropped to 7.40% after two months and that of Sack reduced to 8.40% and of the Hermetic bag to 7.80%. The reduction in moisture content of grains could be loss of moisture to the air in the storage through transpiration (Evaporation). In contrast, Niamketchi et al., 2016, reported that with an individual mean of 9.23 and 9.05% at the beginning (0 month), the moisture contents increased significantly (P<0.001) during the storage period. In the third months, the moisture content of grains in Gombisa increased to 8.36% whereas those in Sack and Hermetic bag continued to drop to 8.00 and 7.50%, respectively. The reduction in moisture content of grains could be loss of moisture to the air in the storage through transpiration (Evaporation). The moisture content of the grains at and after the fourth months showed continued increment reach 13.9, 11.7 and 10.70% at the end of six months storage periods for samples in Gombisa, Sack and Hermetic bag, respectively. These increments could be due to the moisture generated during respiration of the grain and other living things in the storages. However, Befikadu et al. (2012) reported that grain stored in the sacks was different in that the moisture content exhibited increment to 11.08 at 120 days and 11.7 at 180 days of storage time.

Effect of storage type on fungal incidence and frequency of stored maize grain

Interaction effect of storage type with storage periods on fungal incidence and frequency in stored maize grains is shown in Table 6. The values of fungal incidence and frequency are significantly different (p<0.005) to each other with the storage periods (Table 1). No incidence and frequency of *Apergillus* and *Penicillium* spp. was recorded during the initial. Maximum incidence 39.4% of *Fusarium* spp. was recorded in the last six months of storage periods. The highest incidence of *Aspergillus* spp. 21.3% was recorded in the last six months. This might be due to high relative humidity and temperature that hastened the rewetting of the grains and resulted in fungal infection to the grains. Likewise, Kodwo (2015) reported that *Aspergillus flavus* was recorded in Ava and Shade storage structures with the highest occurrence rates of 100 and 86.76%, while Sack and Hermetic storage bags record the least rates of 53.33 and 46.67%, respectively. Regarding to fungal incidence and frequency, Fusurium spp. was recorded in more incidentally and frequently in Gombisa 29.9 and 23.9% the least recorded in Hermetic bag with 20.4 and 16.4%. Similarly, Ng'ang'a et al., 2016, reported in the PICS bags, the incidences of *Aspergillus* (9 - 16%) and *Penicillium* (3 - 6%), respectively.

Effect of storage type on fungal incidence and frequency of stored maize grain

The effects of storage type on fungal incidence and frequency of stored maize grain are shown in Table 4. The highest 29.9% *Fusurium* spp. incidence was recorded in Gombisa whereas the lowest 18% was recorded in Hermetic bag. Minimum value 5.2% of *Aspergillus* spp. incidence was recorded in Hermetic bag. Initially, the frequency of *Aspergillus* and *Penicillium* spp. was 0.0% in all the three storage structures and increased significantly to 15.7 and 4.6%. This might be due to the high relative humidity and temperature that hastened the rewetting of the grains and resulted in fungal infection to the grains. Likewise, Kodwo (2015) reported that *A. flavus* was recorded in Ava and Shade storage structures with the highest occurrence rates of100 and 86.76%, while Sack and Hermetic storage bags scored the least rates of 53.33 and 46.67%, respectively. Regarding of fungal incidence and frequency in storage type, *Fusurium* spp. was recorded more incidentally and frequently in Gombisa as 29.9 and 23.9%; the least recorded in Hermetic bag with the

Table 4. Effect of storage period on fungal incidence and frequency in stored maize grains, 2017/2018.

Storage periods (months)	*Aspergillus* Incidence (%)	*Aspergillus* Frequency (%)	*Fusarium* Incidence (%)	*Fusarium* Frequency (%)	*Penicillium* Incidence (%)	*Penicillium* Frequency (%)
ILD	0.00 ±0.00[d]	0.0 ± 0.00[d]	10.0±0.86[d]	6.3 ± 1.47[d]	0.00±0.00[d]	0.00 ±0.00[d]
2	5.3 ± 3.40[c]	4.7 ± 1.85[c]	16.7±1.54[c]	12.0±1.54[c]	2.6±1.14[c]	1.10 ±1.01[c]
4	11.8 ±1.96[b]	8.4 ± 1.39[b]	27.8±2.47[b]	22.2±1.33[b]	6.9 ± 1.28[b]	4.30 ±2.47[b]
6	21.3 ±1.47[a]	15.9 ± 2.91[a]	39.4±3.96[a]	33.3±2.81[a]	11.7±1.49[a]	8.00 ±1.51[a]
LSD (5%)	2.8	1.9	3.9	3.4	1.3	0.87
CV (%)	28.3	25.3	16.3	17.4	23.5	24.7

Mean values ± standard deviation of three replicates within each column sharing similar letters were not significantly different by LSD test at p≤0.05. CV: Coefficient of variation, LSD: least significant different, ILD: initial loading date.

Table 5. Effect of storage types on fungal incidence and frequency in stored maize grains, 2017/2018.

Storage type	*Aspergillus* Incidence (%)	*Aspergillus* Frequency (%)	*Fusarium* Incidence (%)	*Fusarium* Frequency (%)	*Penicillium* Incidence (%)	*Penicillium* Frequency (%)
Gombisa	15.7 ±1.01[a]	12.6 ± 1.17[a]	29.9±2.50[a]	23.9±2.33[a]	7.7 ± 1.65[a]	4.6 ± 1.13 [a]
Sack	10.4 ±1.33[b]	7.3 ± 0.58 [b]	24.6±2.22[b]	20.2±1.75[b]	5.2 ± 1.14[b]	3.4 ± 1.47 [b]
Hermetic b	5.2 ± 1.12[c]	3.4 ± 0.58[c]	20.4±1.85[c]	16.4±0.58[c]	4.5 ± 0.16[c]	3.1 ± 0.73 [c]
LSD (5%)	2	1.3	2.8	2.4	0.92	0.62

Mean values ± standard deviation of three replicates within each column sharing similar letters were not significantly different by LSD test at p≤0.05. CV: Coefficient of variation, LSD: least significant different, ILD: initial loading date.

incidence and frequency of 20.4 and 16.4%. Similarly, Ng'ang'a al., 2016, reported in the PICS bags, the incidences of *Aspergillus* (9 - 16%) and *Penicillium* (3 - 6%), respectively.

Effect of storage periods on fungal incidence and frequency of stored maize grains

Table 5 shows the effects of storage type on fungal incidence and frequency of stored maize grain. The value of the incidence of *Aspergillus* spp. was 0.0% initially and increased significantly (p<0.05) to 21.3% in the last six months of storage periods. Maximum 39.4% incidence of *Fusurium* spp. was recorded during six months of storage periods. *Fusurium* spp. occurred more frequently 33.3% than *Aspergilus* spp. 15.9% and *Penicillium* spp. 8.0% in the last six months. As the storage period increased, the incidence and frequency of all fungal species increased significantly (p<0.05). This is due to increase of relative humidity in the storage which favors the rewetting of the stored maize grains. The use of Hermetic bag storage structures reduces the fungal infection, since low relative humidity was recorded in the storage and the use of the stored grains before six months of storage periods is better.

Conclusion

High relative humidity favors the rewetting of the stored grains and made the grains to be mouldy. Moisture content and stored maize grains temperature increased progressively with storage periods. Initially, the incidence and frequency of the fungal species was not recorded except for the *Fusurium* spp. with the incidence of 10.0%. The values of fungal incidence and frequency showed significant difference (p<0.005) to each other with the storage periods. Maximum incidence 39.4% of *Fusurium* spp. was recorded in the last six months of storage periods. The highest 29.9% *Fusurium* spp. incidence was recorded in Gombisa whereas the lowest *Fusurium* spp. incidence 18% was recorded in Hermetic bag. *Fusurium* spp. incidence was 21.7% for Gombisa, 15.0% for Sack, 13.0% for Hermetic bag, respectively. Therefore, maize grains should not be stored for more than six months. It is concluded that adoption of improved storage facilities like Hermetic bag storage will reduce maize grain losses, save the resources required for maize grain production, minimizes the maize nutrient quality deteriorations and mycotoxins that causes health risks and ultimately contributes to the improvement of food safety and food security of the region.

CONFLICT OF INTERESTS

The authors have not declared any conflict of Interests.

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Table 6. Interaction effect of storage type with storage periods on fungal incidence and frequency in stored maize grains, 2017/2018.

Storage period (months)	*Aspergilius* incidence (%)			*Aspergilius* frequency (%)		
	Gombisa	Sack	Hermetic	Gombisa	Sack	Hermetic
ILD	0.0 ± 0.00 h	0.0 ± 0.00h	0.0 ± 0.00h	0.0 ± 0.00h	0.00 ±0.00h	0.00±0.00h
2	13.3 ±1.24e	7.3 ± 1.63f	3.6 ± 1.14g	10.3±0.86e	5.0 ± 2.12g	3.7 ±1.66g
4	23.3 ±2.24c	15.0 ±1.46d	14.3±1.86d	16.6±2.32c	11.0 ±1.96d	8.5 ± 1.39f
6	33.3 ±3.08a	28.3±2.99b	26.7±2.32b	26.7 ±2.32b	23.3 ±1.47b	18.0±1.66c
LSD (5%)		2.8			3.4	
CV (%)		16.3			17.4	
	***Fusarium* incidence (%)**			***Fusarium* frequency (%)**		
ILD	10.0±0.86g	10.0±0.86g	10.0±0.86g	6.3 ± 1.47i	6.3 ±1.47i	6.3 ± 1.47i
2	21.7 ±1.47e	15.0± 1.91f	13.0 ±1.91f	15.0±1.91f	11.7±1.96g	9.0±1.46h
4	33.3 ± 2.14c	26.6 ± 2.50d	23.3± 1.75e	26.7 ±.03c	21.7 ± 1.47d	18.0±1.66e
6	45.0 ± 5.54a	40.0 ±5.75b	33.0 ± 2.14c	38.3 ±3.16a	33.3 ± 2.14b	28.0±1.16c
LSD (5%)		2.8			2.4	
CV (%)		10.4			15.3	
	***Penicillium* incidence (%)**			***Penicillium* frequency (%)**		
ILD	0.00 ±0.00f	0.00 ±0.00f	0.0 ± 0.00f	0.00±0.00e	0.00 ±0.00e	0.0 ±0.00e
2	10.0±0.86c	5.0± 1.12d	2.0 ± 0.14e	7.0 ±0.58c	3.0±1.87d	1.0±1.01d
4	16.7 ±2.32b	11.3±1.19c	9.4 ± 1.10c	13.0±1.91b	8.0 ±1.51c	7.0±0.58c
6	22.4 ±1.47a	16.0 ±1.32b	12.2±1.17c	17.3 ±1.32a	12.0±1.17b	9.0 ± 1.46c
LSD (5%)		2.8			2.4	
CV (%)		0.92			2.7	

Mean values ± standard deviation of three replicates within each column sharing similar letters were not significantly different by LSD test at P≤0.05. CV: Coefficient of variation, LSD: least significant different, ILD: initial loading date.

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REFERENCES

American Association of Cereal Chemists (AACC) (2005). Approved methods of the AACC, 11th ed. Method 38-12A. St Paul, MN: American Association of Cereal Chemists.

Abass AB, Ndunguru G, Mamiro P, Alenkhe B, Mlingi N, Bekunda M (2014). Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. Journal Stored Product Research 57:49-57.

Ali RH, Mahdi M, Ali RB, Hojjatollah S (2007). Mycoflora of maize harvested from Iran and imported maize. Pakistan Journal of Biological Sciences 10(24):4432-4437.

Befikadu D, Waktole S, Solomon A, Geremew B, Sethu MR (2012). Influence of Agro-ecologies, Traditional Storage Containers and Major Insect Pests on Stored Maize (*Zea mays* L.) in Selected Woredas of Jimma Zone. Asian Journal of Plant Sciences 11(5):226-234.

Befikadu D, Waktole S, Solomon A, Geremew B, Sethumadhavarao G (2014). Mycoflora of Grain Maize (*Zea mays* L.) Stored in Traditional Storage Containers (*Gombisa* and Sacks) in Selected Woredas of Jimma Zone, Ethiopia. African Journal of Food, Agriculture, Nutrition and Development 14(2):6-10.

Binyam T, Girma A (2016). Detection of Fungi Infecting Maize (*Zea mays* L.) Seeds in Different Storages around Jimma, Southwestern Ethiopia. Journal of Plant Pathology and Microbiology 7(3):2-6.

Bosah BO, Omorusi VI (2014). Fungal species associated with stored Maize in Plateau State, Nigeria. Sci-Afric Journal of Scientific Issues, Research and Essays 2(9):410-411.

Chattha SH, Hasfalina CM, Mirani BN, Mahadi MR, Lee TS (2016). Food grain losses associated with indigenous storage methods and development of storage facilities for food security: International Food Research Journal 23:57-63.

Girma D, Tadele T, Abraham T (2006). Field infestation by *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) and its Management on Stored Maize at Bako, Western Ethiopia: MSc Thesis, Alemaya, Ethiopia.

Marta HE, Suryadi E, Ruswandi D (2017). Chemical composition and genetics of indonesian maize hybrids. American Journal of Food Technology 12(2):72-85.

Ishrat N, Shahnaz D (2009). Detection of seed borne mycoflora in maize (*Zea mays* L.). Pakistan Journal of Botany 41(1):443-451.

Kodwo A (2015). Traditional storage practices on the quality of maize a case study in the Shai osudoku district in the greater accra region: University of Ghana (College of Agriculture P.M.B 1018, Zuru, Nigeria.

Marasas WF, Burgess LWO, Anelich RY, Lamprecht SC, van Schalkwyk DJ (1988). Survey of Fusarium species associated with plant debris in South African soils. South African Journal of Botany 54: 63-71.

Marek A, Koloman K, Ján J, Pavol F, Milan K (2018). The effect of conditions and storage time on course of moisture and temperature of maize grains: BIO Web of Conferences 10, 02001 Contemporary

Research Trends in Agricultural Engineering.
Ng'ang'a J, Mutungi C, Imathiu S, Affognon H (2016). Low permeability triple-layer plastic bags prevent losses caused by insects on maize in rural on-farm stores. Food Security pp. 1-13.
Niamketchi L, Chatigre O, Konan Y, Biego H (2016). Nutritive compounds evolution of postharvest maize (*Zea mays* L.) stored in granaries with bio-pesticides from rural conditions in Côte d'Ivoire. International Journal of Innovative Research in Technology and Science 4(2):50-64.
Steel RGD, Torrie JH (1980). Principles and Procedures of Statistics. 2nd (Ed.) New York: McGraw-Hill.
Verga BT, Teren J (2005). Mycotoxin producing fungi and mycotoxins in foods in Hungary. Journal of Acta Alimentaria Akademiai pp. 267-275.

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Status of commercial maize milling industry and flour fortification in Kenya

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Maize is the most widely consumed staple food by the Kenyan population. Its wide consumption and centralized processing make it an appropriate fortification vehicle to supply essential micronutrients to the population. The legislation was enacted in 2012 that makes it mandatory for all commercial maize mills in Kenya to fortify the maize flour with specified micronutrients as a public health effort to reduce the prevalence of micronutrient deficiencies. However, there is limited information on the current status of maize milling and implementation of the flour fortification programme by these mills. A cross-sectional study was therefore carried out to characterize the commercial maize mills and determine the status of flour fortification in Kenya. Questionnaires were used to collect data. Information was obtained from 22 large-scale, 25 medium-scale and 31 small-scale mills. These mills had an installed capacity of 6084 metric tons/day of flour using roller and hammer mills. While all the large-scale mills implemented the recommended statutory flour fortification programs, only 45.8% of the medium and 24.1% of small-scale mills did so. There was evidence of weak quality management systems for fortified maize flour and most companies did not have trained mill operators. Regulatory monitoring was mainly done by the Kenya Bureau of Standards and the Ministry of Health. There is a need to enhance industry capacity in food fortification practices and fortification compliance.

Key words: Fortification, maize flour, maize mills, mill characteristics.

INTRODUCTION

Maize is one of the common staples in Kenya consumed by over 85% of the population. The per capita consumption ranges between 98-100 kg that translates to at least 2.7 M metric tons per year. Small-scale production accounts for about 70% of the overall production and the rest of the outputs are by the commercial producers. Maize can be processed into a variety of food and industrial products including starch, sweeteners, oil, beverages, glue, industrial alcohol, and fuel ethanol. The main forms in Kenya are maize flour and maize meal (Fiedler et al., 2014; Enzama, 2016).

Maize flour processed into thick porridge (ugali) is the most common form of maize consumed by the Kenyan population. Prior to milling, maize is a good source of

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vitamin B1, B6, phosphorus and a fair source of vitamin B_2, B_3, folate, biotin, and zinc. Most of these micronutrients, however, are lost during degerming and dehulling processes in milling (Peña-Rosas et al., 2014). Over-reliance on maize and low dietary diversity have contributed significantly to malnutrition due to micronutrient deficiencies in Kenya (Nyariki et al., 2002; Baro and Deubel, 2006). The main forms of micronutrient deficiencies in Kenya include vitamin A, iron, folate, vitamin B_{12}, iodine and zinc deficiencies (MoH, KeMRI and KNBS, 2013; KDHS, 2014). The latest micronutrient survey in the country revealed that the prevalence of Vitamin A deficiency among Pre-school children was 52.6%; Iron deficiency was at 36.1% among pregnant women and 21.8% among under 5 children; Zinc deficiency was at 83.3% in pregnant women and 82.3% in non-pregnant women; Folate deficiency was at 32.1% in pregnant women and 30.9% in non-pregnant women (MoH, KeMRI and KNBS, 2013).

The Government of Kenya enacted legislation requiring mandatory fortification of key commercially processed staples in 2012 as one of the approaches to help achieve one of the key objectives of improving the nutritional status and reducing micronutrient deficiencies among the vulnerable groups of the population (Pambo et al., 2017). Cereal flours are fortified with B-group of vitamins, iron, and zinc, while vegetable oils/fat and sugar are fortified with vitamin A (KNBS, 2010; EAC, 2011; Fiedler et al., 2014).

Selection of maize flour as an appropriate fortification vehicle was based on its widespread consumption among all population groups (Wokabi, 2013; Fiedler et al., 2014; Enzama, 2016; KNBS, 2017). Centralized processing of maize in commercial mills allows for ease of implementation of fortification programmes due to the advanced technology used in milling (Peña-Rosas et al., 2014). Maize flour fortification practice does not affect the quality and acceptability of flour to the consumers.

Fortification of staple foods is a cost-effective approach that has been used to supply micronutrients of public health concern to the target population. Programmes like salt iodization, milk fortification with vitamin D, rice fortification with vitamin A, iron and zinc, and folic acid fortification of flour have proved effective in reducing the prevalence of micronutrient deficiencies in populations (Allen et al., 2006; Zimmermann and Andersson, 2012; Aburto et al., 2014; Future and Relations, 2014; Hamner and Tinker, 2014; Atta et al., 2016).

Mandatory maize fortification was aimed to provide a sustained source of micronutrients relevant to the Kenyan population in addition to replacing some essential micronutrients lost during milling (Allen et al., 2006; Peña-Rosas et al., 2014). However, the success of the programme is yet to be determined as there is inadequate documented data on the maize milling practice and the extent of adoption of flour fortification programmes by the commercial mills in Kenya (Makhumula et al., 2014). This study was, therefore, designed to determine the characteristics of the maize milling industry and provide information on the status of flour fortification practice among commercial mills in Kenya (GOK).

MATERIALS AND METHODS

Sampling procedures

The number of all commercial maize mills registered by the Kenya Bureau of Standards was reported to be 150 (Masoud, 2013). At 90% confidence level (P=0.1), the minimum sample was determined to be 64 (Israel, 1992). The country, Kenya, was divided into 6 geographical clusters/ regions (Nairobi and Central, Eastern and North-Eastern region, Coast region, North Rift, South Rift, and Nyanza and Western regions). These regions shared some similar characteristics, including the level of urbanization and similarities in the ethnic communities inhabiting the regions. The former Nairobi and Central provinces were clustered to make Nairobi/Central region while Western and Nyanza provinces were clustered to make Western/Nyanza region (Figure 1). Eastern and North Eastern provinces were clustered together based on the fact that the two provinces are arid and semi-arid and are sparsely populated (KNBS, 2017).

Commercial maize mills that produce packaged flour were purposively selected from each of the clusters (regions). Within Coast region and Western/Nyanza region, mills were sampled by census since these regions were dominated by the small retail mills that are not mandated by the government of Kenya (Fiedler et al., 2014; Makhumula et al., 2014). These mills made up the secondary sampling units. The primary sampling units were the company managers, millers and quality control personnel who were involved in the interviews.

Data collection tools

The research applied a quantitative research tool using questionnaires, made up of 30 questions, as a guide for the interviews (Appendix 1). The questionnaires captured data on:

(i) Basic mill characteristics that comprised mills distribution, installed and actual milling capacities, employees and labor type, flour brands and packaging type and internal quality assurance practices by mills and regulatory bodies.
(ii) Flour fortification practices that comprised the extent of adoption on the mandatory fortification practices by the mills, premixes, fortification of equipment, mixers, fortification related to quality assurance practices and the general mill's perception of fortification on their profits.

The questionnaire was pretested to ensure clarity, logical flow and appropriateness of the questions used. This was done in 2 commercial maize mills located at Thika and Juja towns, respectively.

Ethical consideration

Permission to conduct the study was obtained from the Ministry of Health, Kenya. Data were collected from mills that voluntarily consented to be interviewed. In all the cases, an explanation of the purpose of the survey was given before the interview. The information obtained was held in confidence.

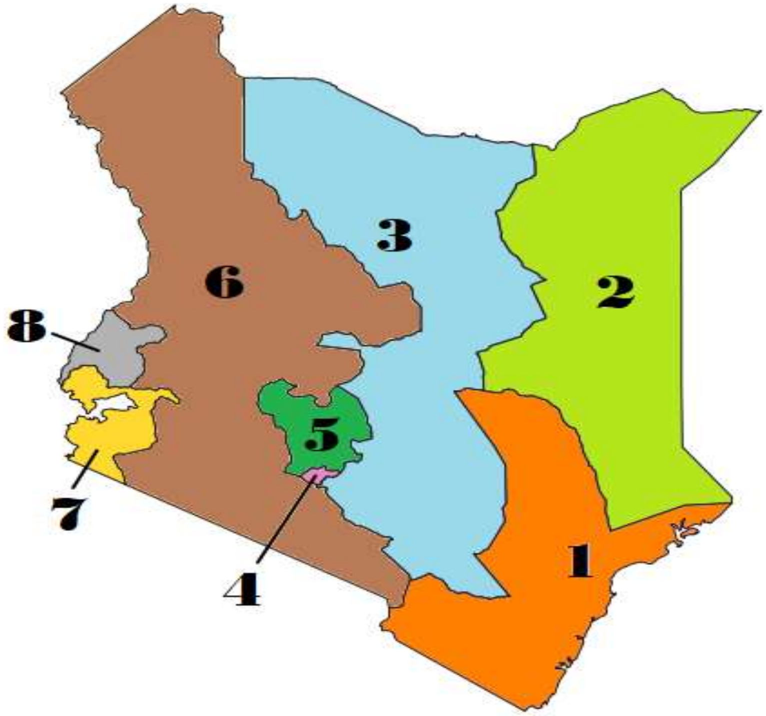

Figure 1. Map of Kenya with the 8 old provinces.

Data analysis

Data were analyzed using the Statistical Package for Social Sciences Version 23.0 (SPSS). Data were first entered into Excel worksheets before transfer to IBM SPSS statistics 23™. Commercial maize mills surveyed were categorized based on their respective daily milling capacities as described by Enzama et al. (2017) where mills producing over 50 metric tons (MT) per day of maize flour were considered large scale, those producing between 20 MT and 50 MT/day were medium scale while those producing below 20 MT per day were small scale. Descriptive statistics were used to describe the miller characteristics, fortification practices and quality assurance both external and internal. The data was presented in continuous prose as a qualitative report.

RESULTS AND DISCUSSION

Maize mill characteristics

Maize mills' distribution and characteristics of the respondents interviewed

A total of 78 mills were covered in the study from the six regions of Kenya. This was above the minimum sample size of 64 mills. The highest proportion of the mills (35.9%) was in Nairobi-Central region. The Rift valley region (North and South Rift regions) accounted for 25.7% of the respondents, Eastern and North Eastern accounted for 26.9% of the respondents while the coastal region, Nyanza and Western accounted for 7.6 and 3.8% of the total mills, respectively. During the survey, approximately 46% of the respondents were company directors and 23.6% were company managers. The other respondents were millers and quality control personnel.

Classification of the maize mills

A total of 22 mills (28.2%) were producing over 50 MT/day of maize flour thus were considered large scale, 25 mills (32.1 %) were producing between 20 MT and 50 MT/day thus considered medium scale, and 31 mills (39.7 %) were producing below 20 MT per day thus were grouped as small-scale (Table 1). The milling capacities for different commercial mills varied widely ranging from 0.96 MT per day to 500 MT per day (Table 1). More than half of the mills (57.69%), however, produced between 11 to 50 MT per day. Most of the mills were not operating at full capacity (Figure 2). The mills had a short supply of maize following maize shortage that had hit the country due to post-harvest losses and below average harvest. The mills were relying solely on rationed maize supply by the government. The total amount of flour produced by the mills was 4629 MT/day out of the possible installed capacity of 6084 MT/day.

Large-scale mills accounted for over three-quarters (76.2%) of the total maize flour (MT) produced daily. This was slightly higher than the earlier reports where large-scale mills accounted for about 66% of the flour in the Kenyan market (USAID, 2010). The dominance of large scale mills in the Kenyan milling industry provides an

Table 1. Characteristics of commercial maize milling industry structure in Kenya.

S/N	Characteristics		Small scale mills	Medium scale mills	Large scale mills
1	Number of mills surveyed		31	25	22
2	Milling technologies used	Roller mill	85.70%	95.80%	100%
		Hammer mill	14.30%	4.20%	
3	Installed milling capacity (MT/day)	Mean ± S.E	26.1± 5.05	47.45±7.1	172.8±32.01
		Range	1.92-144	19.92-192	48-600
		Total	726.89	1178.64	4136.4
4	Actual milling capacity (MT/day)	Mean ± S.E	9.26 ±1.23	31.97±1.809	148±26.802
		Range	0.08-19.2	24-49.92	55.2-500
		Total (%)	292.32 (%)	807.12 (%)	3530.16 (%)

*Small-scale mills have milling capacity below 20 MT/day; Medium scale mills have milling capacity between 20 and 50 MTY/day; Large-scale mills have milling capacity above 50 MT/day
S.E: Standard error.

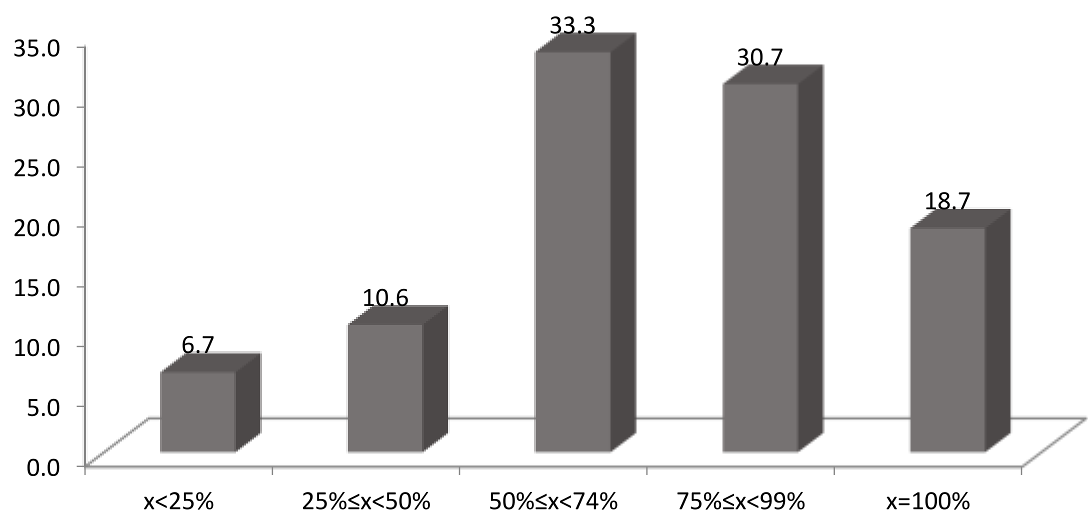

Figure 2. Percentage proportion of milling capacity compared to the mills installed capacities.
X: Proportion of milling capacity of mills.

opportunity to supply fortified flour to a larger population group. Large scale mills enjoy economies of scale in fortification thus low losses incurred in the implementation of fortification programs (Fiedler et al., 2014; Makhumula et al., 2014). The technology employed for milling varied with each category of mills but the processing steps were similar. Generally, the milling process involved the following steps: dehulling, degerming, milling and packaging of the flour. It was observed that the mills applied roller and hammer milling technologies. This resonates with the earlier findings of Fiedler et al. (2014) that roller and hammer milling technologies were used in maize milling. Roller milling accounted for over 93% of the milling technology used. All the large-scale mills (100%) used roller milling technology, while the technology was employed at a slightly lower rate of 96 and 85% in the medium and small-scale mills, respectively (Table 1). The preference of roller to hammer milling in Kenya is similar to the context of Zambia and Uganda maize milling (Fiedler et al., 2014). Hammer mills are simple and use small-scale technology that produces high extraction maize flour while roller mills are large and use advanced technology in milling. The feasibility of fortification in roller mills is higher compared to small scale mills that have a small out output levels making high incremental costs for the adoption of

Table 2. Proportion of skilled labour in commercial maize mills.

The proportion of skilled labour (%) in commercial maize milling	Number of mills
<10	31
11-20	24
21-40	10
41-60	6
61-80	3
81-90	2
91-100	2
Total	**78**

fortification in routine milling (Fiedler et al., 2014).

Skilled labour

The employees in the maize milling industries comprised both skilled and unskilled labour (Table 2). Skilled labour was limited to certain aspects of the milling process including miller operation, quality control, and administration while cleaning, packaging, and loading were carried out by non-skilled labour. Most of the mills (71%) had less than 20% skilled labour. Most of the skilled labour was found in large-scale industries. Presence of skilled labour in the milling industry is an important consideration for implementation of flour fortification. Training gaps in all aspects of fortification including fortification standards, premix handling and storage, doser operation, calibration and maintenance, and quality assurance practices can easily be addressed with a skilled workforce (WHO, 2016).

Flour packaging

Some mills had automated packaging of flour while others had manual packaging. Over 97% of the mills packaged their flour in Kraft papers of 1-2 kg, 46% packaged in sacks while approximately 43% of the mills packaged in both sacks and Kraft papers. Flour packaging is important in the interaction of nutrients with the environment. In cases of fortified flours, packages that are permeable to oxygen (Sacks) may lead to a reduction of the retention capacity of added vitamins. Mills should use packages that minimize exposure to some environmental conditions including heat, light, oxygen, humidity, and alkaline/acidic environment (Dunn et al., 2014; Kuong et al., 2016).

Maize flour brands in the market

A total of 101 brands of maize flour were identified. About a third of the brands (30.69%) were supplied by large-scale mills while medium and small-scale mills supplied 31 and 39 brands, respectively. Small-scale mills supplied flour within their geographical locality while medium-scale mills supplied mostly within their counties. Most large-scale mills supplied flour in certain regions of the country (63%) and a few supplied countrywide (Table 3). Consumers prefer specific flour brands. Maize flour brands and supply by commercial mills are important in estimating the coverage of commercially milled flour in the country (Aaron et al., 2017).

Internal quality assurance practices among mills

Less than one third (30%) of the maize mills had a laboratory for quality assessment and 28.6% had documented guidelines on quality control. Quality control practices are important in assuring the product quality and safety of the products for the consumers. Maize grain quality was considered by the mill before purchase for milling. Some of the important quality parameters highlighted by the mills were moisture content, colour, foreign materials, aflatoxin, and broken grains. All the mills (100%) confirmed checking maize moisture content. The recommended moisture content for maize before purchase is 12 -13% (Weinberg et al., 2008). Over four-fifths of the mills checked maize colour (84.6%) and the presence of foreign materials (85.5%) before buying (Figure 3).

The common quality tests conducted by the mills for inspecting maize flour included moisture analysis, aflatoxin analysis, and maize physical appearance (Table 4). The routine test carried out among most mills (88%) for flour was moisture determination. This is due to the negative impact of high moisture on the product. High moisture supports mold growth that renders the flour unpalatable (Weinberg et al., 2008). Checking the physical appearance of the flour was carried out by about half (48%) of the mills while aflatoxin testing was done by 36% of the respondents. Maize flour has been implicated in aflatoxin poisoning resulting from mold contamination of maize on the farm or in storage. Ensuring aflatoxin levels in flour below 20 ppb assures the safety of the

Table 3. Status of maize flour fortification in Kenya.

S/N	Characteristics		Small scale mills	Medium scale mills	Large scale mills
1	Proportion of mills fortifying (%)		24.1	45.8	100
2	Proportion of mills using logos (%)	KEBS logo only	58.6	45.8	0
		KEBS + Fortification logos	41.4	54.20	100
3	Type of packaging used by mills (%)	Sacks	37.9	50%	52.6
		Kraft paper/ Khaki	93.1	100	100
		Sacks + Kraft paper	31	50	52.6
4	Geographical coverage of maize flour products in the market (%)	District	3.4	12.5	0
		County	31	20.8	0
		Region	62.1	54.2	63.2
		Country	3.4	12.5	36.8
5	Distribution of doser brands among mills (%)	Buhler	0	16.7	77.8
		Chinese	75	66.7	5.6
		Yilmaz redurkto Turkey	0	8.3	5.6
		Roff	0	0	11.1
		Picture	12.5	0	0
		Fabricated	12.5	8.3	0

*Small-scale mills have milling capacity below 20 MT/day; Medium scale mills have milling capacity between 20 and 50 MTY/day; Large-scale mills have milling capacity above 50 MT/day.

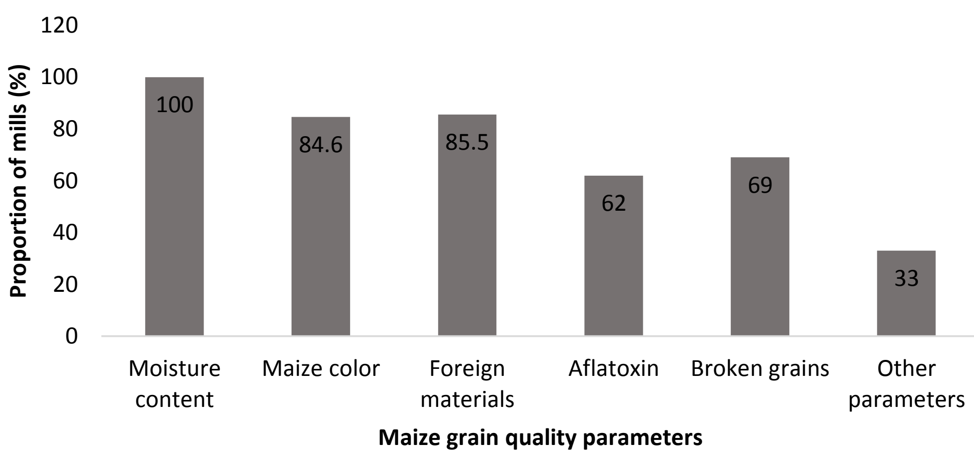

Figure 3. Maize grain quality parameters checked before milling by mills.
Others: Grain physical appearance, insect/pest residues, and fermentation rot.

product to consumers (Flanders et al., 2011). The frequency of internal monitoring of maize flour among the mills varied greatly among the mills. The practice varied from hourly checks to daily checks or even batch assessments. Over half of the companies (53%) carried out internal monitoring tests on every batch (Figure 4). The frequency of internal monitoring ensures the quality of the flour. The fineness of the flour grains, colour of the flour and moisture content of the flour are important quality parameters that should be monitored frequently.

Quality assurance practices among the mills by regulatory bodies

Over 95% of the mills had their maize flour samples tested in external laboratories. During external monitoring, maize grain moisture determination was carried out in

Table 4. Maize flour routine tests carried out by maize mills.

S/N	Maize flour routine tests in maize mills	No of mills	The proportion of mills carrying out routine tests (%)
1	Micronutrients test including iron spot tests and dosing amounts monitoring	5	10.0
2	Sensory tests that involve preparation of food from the products and tasting	8	16.0
3	Moisture analysis	44	88.0
4	Aflatoxin analysis	18	36.0
5	Physical appearance including flour colour, flour particle size/texture, weight on packaging, flour odor	24	48.0
6	Foreign materials including impurities and pest residues	6	12.0
7	Chemical and microbial test	8	16.0

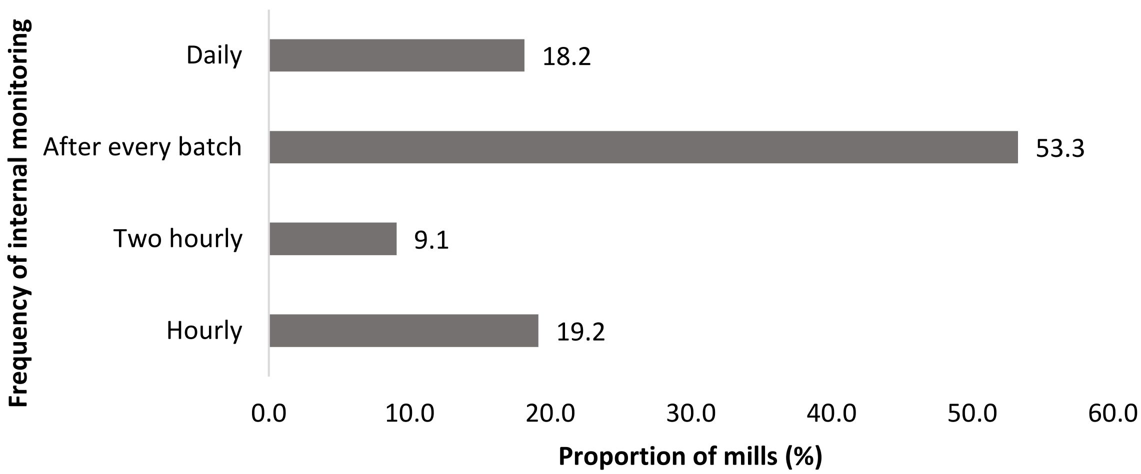

Figure 4. Frequency of internal monitoring among commercial maize mills.

all the mills while maize colour and foreign materials presence tests were carried out in approximately 85% of the mills surveyed. Aflatoxin levels in maize were carried out in 62% of the mills while broken grains were checked in 69% of the mills.

The frequency of external monitoring varied greatly from monthly to annually. Those that carried it out bi-annually and quarterly were 23.8 and 22.2%, respectively. Only 3.2% of the mills subscribed to weekly monitoring of flour. Two fifths (40%) of the mills perceived the cost of external monitoring to be affordable while 25% were not sure. About a third (32%) of the mills considered the cost of external monitoring to be high or very high. The implication may be that some companies do not appreciate the importance of quality control/assurance and perceived external monitoring as unnecessarily expensive.

Regulatory agencies involved in external monitoring of flour were the Kenya Bureau of Standards (KEBS), the Ministry of Health (MOH), the National Environment Management Authority (NEMA), and the Ministry of Trade. The proportion of mills inspected by these regulatory bodies is as shown in Figure 5. Most of the regulation related issues were handled by MOH and KEBS (> 95%). The frequency of monitoring by regulating agencies varied from weekly to annually. KEBS and MOH carried out monthly to quarterly evaluation while NEMA assessed annually (Figure 6). Nearly all (97%) of the mills reported that they had received feedback from the regulating agencies, though the timelines differed from immediate feedback to 3 to 6 months after inspection (Figure 7). Regulatory monitoring of commercial maize mills assures the safety of the products to Kenyans. This responsibility is accorded to the government and the industries. Capacity development of regulatory bodies to carry out external monitoring and regulation of the milling industry should be improved to reduce the duration of feedback to the mills.

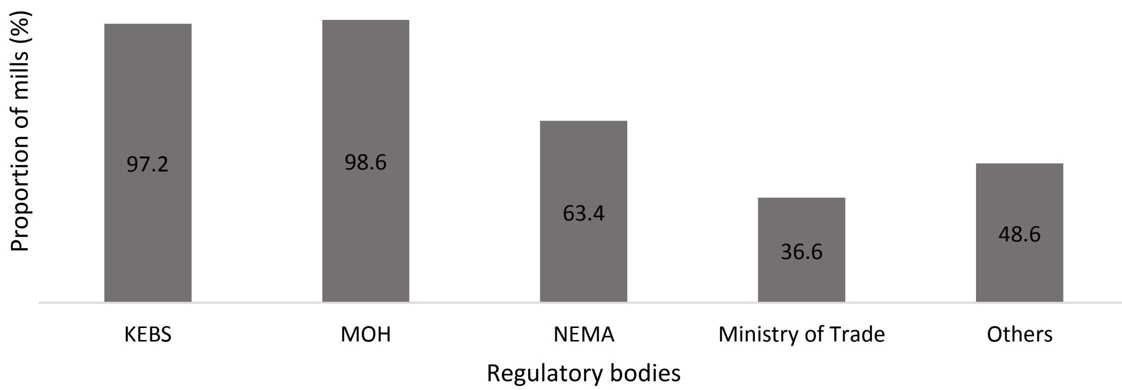

Figure 5. Regulatory bodies that had inspected the commercial maize mills.

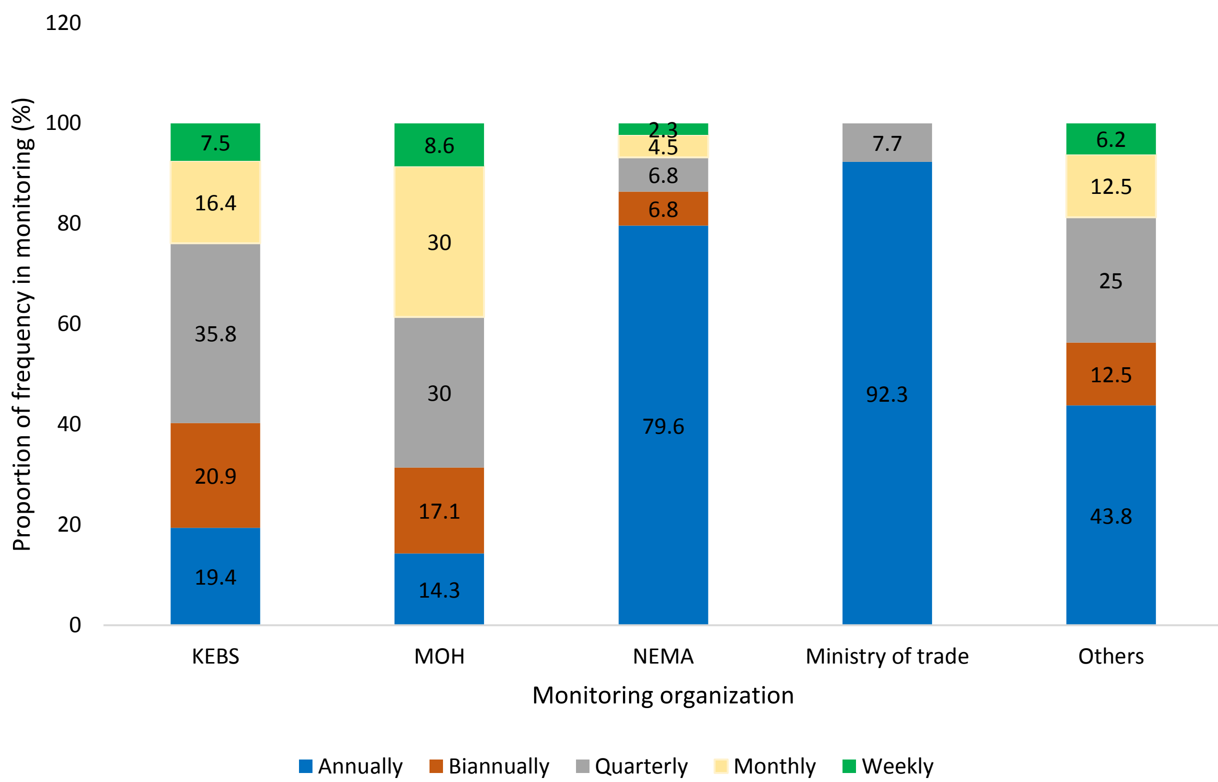

Figure 6. Frequency of inspection of commercial maize mills by regulatory bodies.

Current status of maize flour fortification in Kenya

The proportion of mills with flour fortification practice in place

Over half of the mills (51.39%) surveyed confirmed to have implemented the mandatory food fortification programs for maize flour as required in Kenya. All of the large-scale mills fortified the flour while less than half, 45.8% of the medium scale and 24.1% of the small-scale mills did so (Table 3). While there is a statutory requirement mandatory fortification, the practice is still low among the medium and small scale mills. Large scale mills enjoy economies of scale thus ease of adoption of the fortification programs in their daily milling activities (Fiedler et al., 2014). To verify whether food fortification was being carried out, the presence of the fortification logo and the standardization mark of quality from Kenya

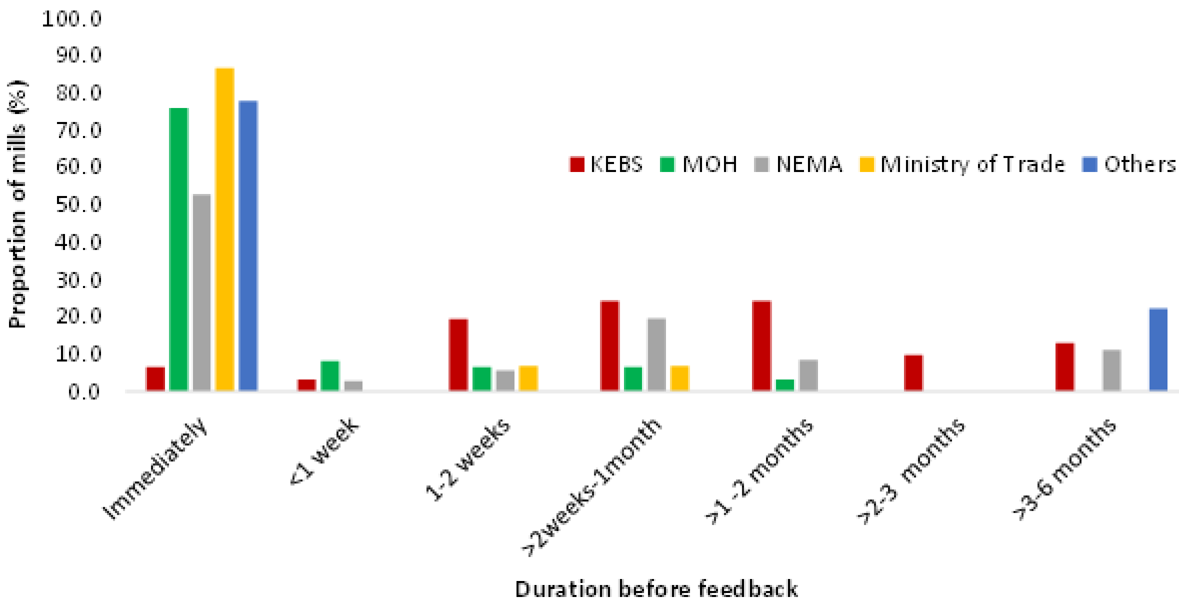

Figure 7. Duration before feedback by regulatory bodies.

Figure 8. Kenya fortification and KEBS logos (www.kebs.org).

Bureau of Standard, KEBS, were checked on all the flour packages. All mills (100%) confirmed the use of KEBS logo on their package. However, only 61.1% of the brands had both KEBS and the food fortification logos (Figure 8).

It was noted that approximately 10% of the mills that used the food fortification logo were not fortifying their products. This is misleading to consumers and regulators. A further check on why these companies were using the fortification logo without actually fortifying revealed that limited funds to buy premixes (concentrated micronutrient blends), food fortification technology (dosers) and poor knowledge and skills were the main challenges. These challenges force mills to lie so that they can remain competitive in the market. According to Makhumula et al. (2014), the imposition of mandatory flour fortification to all the mills risks collapse small scale mills that do not have the capacity to fortify (Makhumula et al., 2014).

Premix supply, usage, and storage

Mills that had implemented the mandatory flour fortification programs sourced their premixes from different suppliers. Bio Foods Products limited was the largest supplier of premix supplying to a third (32%) of the maize mills. Other important premix suppliers were High Nutrition Ltd (11.1%), Engrain EA. (9.7%), and Buhler Ltd (8.3%) (Table 5). All the premix suppliers were located in Nairobi, the commercial capital of Kenya, from where they supply the premixes to the mills countrywide.

Table 5. Premix suppliers in the Kenyan maize milling firms.

S/N	Premix supplier	No. of mills supplied to	The proportion of mills supplied to (%)
1	Bio Foods Products LTD	23	31.94
2	Chemicals and Solvents LTD	1	1.39
3	Engrain EA	7	9.72
4	Amesi Kenya LTD	3	4.17
5	Buhler LTD	6	8.33
6	High Nutrition LTD	8	11.11
7	Philips Pharmaceuticals	1	1.39
8	own importation	1	1.39
9	others	11	15.28

*Others: Engrain USA, Elcovit, Nutrivit, KEBS, New civic and Muxinga Nutrimix, Phillips pharmaceuticals, own importation, Chemicals and Solvents (EA).

Premix suppliers play an important role in the sustainability of flour fortification programs by ensuring a reliable premix market for the mills (Allen et al., 2006).

Premixes were stored under different conditions among the mills. About 69% of the mills reported storing the premix at room temperature, 25% in a cool dry place while 3% stored in the dark. According to the Food Fortification Initiatives flour millers' toolkit, premixes should be stored away from sunlight, excessive heat, and potential water damage. This is important in improving the retention capacity of the micronutrients in the premixes throughout their shelf life (Stoltzfus et al., 2008; Dunn et al., 2014; Kuong et al., 2016).

Vitamins in the premix have a limited shelf life and their biological activity and effectiveness are reduced over time (Dunn et al., 2014). Typically, premixes are packaged in polythene bags inside heavy cardboard boxes. Once opened, exposure to light, air, and high temperature have to be minimized to reduce degradation. Poor storage conditions also lead to a reduction in the retention capacity of the vitamin and subsequent non-compliance of flour to standards (Flour Fortification Initiative, 2008; Luthringer et al., 2015).

Fortification equipment (Dosers)

The proportion of mills that were equipped with dosers was 61% of the 78 mills surveyed. Buhler and unspecified Chinese doser brands were the most common and were used by 42.1 and 39.5% of the mills, respectively. Other doser brands used in the mills were Roff, Picture, and Yilmaz-redurkto (Turkey). Over 10% of the mills that had dosers installed had not started fortifying their maize flour. This resonates with the companies that were using the fortification logo but were not fortifying their flour. These mills expressed a lack of capacity and a reliable premix market to implement and sustain fortification.

The dosers installed were of different sizes depending on the milling capacity of the industry. Over three-quarters of large-scale mills (77.78%) had dosers of over 10 kg capacities. Over half (58.3%) of the medium scale mills had dosers of capacity above 10 kg while most of the small-scale mills (85.71 %) had small, dosers whose capacity was less than 5 kg. Doser capacity determines the amount of premix held at a certain point in time during milling. This, in turn, influences the ease of dispensing premixes to the flour during production.

Most of the dosers (93%) were reportedly compatible with the mills. For high doser efficiency, however, periodic calibration to ensure proper feeder operation within acceptable variation and dispense of accurate amounts of premixes in the flour is required. The frequency of calibration for most dosers varied from daily to never. About one-third of the mills (34.9%) reported never to have calibrated their dosers (Table 6). This raises concern on the quality of fortification (percentage compliance to standards) due to the unregulated dosing.

Some challenges that were reported to be associated with dosing included premix dosage variation arising from inconsistencies in flour flow rate and premix quality in terms of density variation. Other challenges included inadequate knowledge in doser calibration, poor doser installation and inadequate doser operation skills.

Mixer and /or mixing channel

Upon dosing, flour was mixed with the premix for homogeneity. The length of the mixing channel and the duration for mixing determines how homogenous the fortified flour was. Therefore, the presence of the mixing channel, its length and mixing time were indicators of the homogeneity of fortified flour. Most (82%) of the dosers were equipped with mixers of different brands. The predominant mixer brand among the mills was Buhler (40%) while unspecified Chinese brands and conveyor belt mixer were in 20 and 15% of the mills, respectively (Figure 9). Most of the mixers (96.8 %) were compatible

Table 6. Frequency of doser calibration by maize mills.

S/N	Frequency of Calibration	The proportion of commercial maize mill (%)
1	Never	34.1
2	After each Batch	7.3
3	Daily	14.6
4	Weekly	17.1
5	Monthly	4.9
6	Quarterly	4.9
7	Yearly	2.4
8	Other	14.6

*Other: Other doser calibrations included in case of machine breakdown, on work resumption, when the premix type is changed and when the milling capacity was changed.

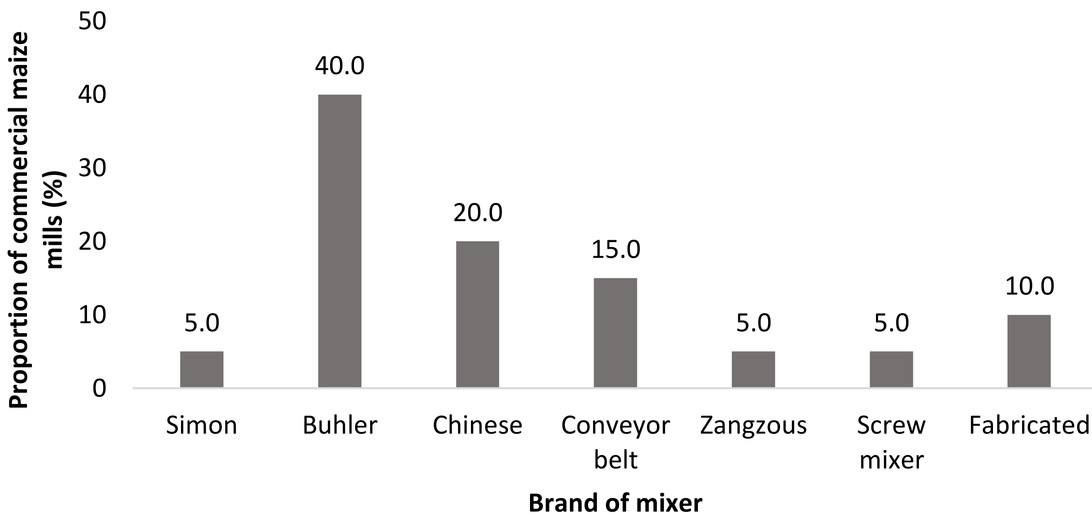

Figure 9. Mixer brands among commercial maize mills in Kenya.

with their respective mills.

Compliance with quality assurance for fortification by mills and regulatory bodies

There is a statutory requirement for all commercial maize mills to fortify their maize flour to the set legal standards in Kenya (Fiedler et al., 2014). However, there is no information on compliance with this law by commercial mills in the country (Makhumula et al., 2014). Continuous surveillance and monitoring are necessary for effective flour fortification program implementation. Internal monitoring at production level involved different quality control and quality assurance activities by the mills to ensure compliance (Allen et al., 2006). These included daily physical checks of the quantity of premix delivered, check on premix usage, periodic visual checks that the micro-feeder (doser) is working properly and laboratory tests to verify the efficiency of the fortification process. Iron spot test was the most common qualitative test used to confirm fortification. About a quarter of the mills (26.3%) had included aspects of fortification in their quality control guidelines. Micronutrient content analysis of fortified maize flour was carried out by 10% of the mills (Table 4). This means that internal monitoring of the quality of food fortification (compliance to standards) was poor.

External monitoring of the fortification process was conducted by the Kenya Bureau of Standards (KEBS) and the Food Safety Unit of the Ministry of Health (MOH) in Kenya. Monitoring for compliance should be carried out quarterly (KEBS, 2012). External regulatory monitoring was done by KEBS in over 95% of maize mills. Over half (60%) of the mills monitored the proximate composition and micronutrient levels in the flour. Micronutrient analysis by the regulatory bodies was carried out in 37% of the mills.

Perception of fortification on profits

The perception of the impact of fortification on mills' profits varied from being very high to very low. Most of the mills considered the cost to be low (41%) with minimal effect on their profits. However, about one-third of the mills (31.5%) stated that fortification significantly affects their profit margins while the rest were not sure of the effects of fortification on their profits.

Conclusion

The commercial maize mills surveyed supplied approximately 1.69 million MT of flour in a year. This corresponded to 76% of their installed capacity. The market was dominated by large-scale mills that produced over three-quarters of the flour consumed despite their small number. The majority of the labor force in the mills was unskilled. Roller milling was the predominant technology applied by the mills. All the large-scale mills implemented flour fortification. But the implementation rate among the medium and small-scale mills was low.

There is a need for concerted effort, from industry, and government (MOH, KEBS), to sustain the efforts of large-scale maize mills in food fortification and improve food fortification practice among medium scale and introduce the practice among small scale maize mills. Adequate surveillance systems need to be put in place to ensure flour compliance with the set legal standards for micronutrients. Tailored training programs on food fortification, quality assurance, and other innovative and cost-effective approaches should also be applied to scale up maize flour fortification by all commercial mills.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Aaron GJ, Friesen VM, Jungjohann S, Garrett GS, Neufeld LM, Myatt M (2017). Coverage of Large-Scale Food Fortification of Edible Oil, Wheat Flour, and Maize Flour Varies Greatly by Vehicle and Country but Is Consistently Lower among the Most Vulnerable : Results from Coverage Surveys in 8 Countries. The Journal of nutrition 147(5):984S-994S.

Aburto NJ, Abudou M, Candeias V, Wu T (2014). Effect of salt iodization to prevent iodine deficiency disorders: a systematic review with meta-analyses. WHO ELibrary of Evidence for Nutrition Actions 142 p.

Allen L, Benoist B, Dary O, Hurrell R (2006). Guidelines on Food Fortification with Micronutrients. Who, Fao Un, 341. https://www.who.int/nutrition/publications/guide_food_fortification_micronutrients.pdf

Atta CAM, Fiest KM, Frolkis AD, Jette N, Pringsheim T, St Germaine-Smith C, Metcalfe A (2016). Global birth prevalence of spina bifida by folic acid fortification status: A systematic review and meta-analysis. American Journal of Public Health, 106(1):e24-e34.

Baro M, Deubel TF (2006). Persistent Hunger: Perspectives on Vulnerability, Famine, and Food Security in Sub-Saharan Africa. Annual Review of Anthropology 35(1):521-538.

Dunn ML, Jain V, Klein BP (2014). Stability of key micronutrients added to fortified maize flours and cornmeal. Annals of the New York Academy of Sciences 1312(1):15-25.

East Africa Community(EAC) (2011). East African Standard for Fortified milled maize (corn) products-Specification. Available at: https://www.ffinetwork.org/about/calendar/2016/documents/Maize_standard_East_Africa.pdf

Enzama W (2016). Supply Chain Analysis Report, (September). https://doi.org/10.1007/978-3-662-10142-1_3

Enzama W, Afidra R, Johnson Q, Verster A (2017). Africa maize fortification strategy 2017–2026. Online: Smarter Futures.

Fiedler JL, Afidra R, Mugambi G, Tehinse J, Kabaghe G, Zulu R, Guyondet C (2014). Maize flour fortification in Africa : markets, feasibility, coverage, and costs. 1312:26-39.

Flanders WD, Bell C, Mwihia J, Ogana G, Likimani S, Straetemans M (2011). Comprehensive Assessment of Maize Aflatoxin Levels in Eastern Kenya, 2005–2007. (12):2005-2007.

Flour fortification initiative (2008). Recommended Practices for the Production and Procurement of Premix Used in Cereal Fortification Programs, (April), 1–15. http://www.ffinetwork.org/implement/documents/Premix_Best_Practice270408.pdf

Future T, Relations G (2014). Food fortification : A "techno-fix" or a sustainable solution to fight hidden hunger? **Available at : ?** https://www.tdh.de/fileadmin/.../Techno_Fix/Studie_Techno_Fix__Englisch.pdf

Hamner HC, Tinker SC (2014). Fortification of corn masa flour with folic acid in the United States: An overview of the evidence. Annals of the New York Academy of Sciences 1312(1):8-14.

Israel G (1992). Determining Sample Size. University of Florida Cooperative Extension Services, Institute of Food and Agriculture Sciences 85(3):108-113.

Kenya Demographic Health Survey (KDHS) (2014). Kenya Demographic Health Survey https://dhsprogram.com/pubs/pdf/fr308/fr308.pdf

Kenya Bureau of Standards (KEBS) (2012). Kenya Bureau of Standards: Monitoring and sampling of fortified foods - guidelines.

Kenya National Bureau of Statistics (KNBS) (2017). Kenya National Bureau of Statistics: Economic Survey. Available at: http://www.devolutionplanning.go.ke/images/hb/Economic Survey 2017.pdf

Kuong K, Laillou A, Chea C, Chamnan C, Berger J, Wieringa FT (2016). Stability of vitamin A, Iron and Zinc in fortified rice during storage and its impact on future national standards and programs—a Case study in Cambodia. Nutrients 8(1):3-11.

Luthringer C, Rowe L, Vossenaar M, Garrett G (2015). Regulatory Monitoring of Fortified Foods : Identifying Barriers and Good Practices. Global Health Survey and Practice 3(3):446-461.

Makhumula P, Dary O, Guamuch M, Tom C, Afidra R, Rambeloson Z (2014). Legislative frameworks for corn flour and maize meal fortification. Annals of the New York Academy of Sciences 1312(1):91-104.

Masoud AR (2013). The Role of Kenyan Maize Millers in Ensuring Food Security in East Africa. Available at: https://www.erepository.uonbi.ac.ke/handle/11295/59145

MoH, KeMRI, KNBS (2013). The Kenya National Micronutrient Survey 2011:1-122.

Nyariki DM, Wiggins SL, Imungi JK (2002). Levels and causes of household food and nutrition insecurity in dryland Kenya. Ecology of Food and Nutrition 41(2):155-176.

Pambo KO, Otieno DJ, Okello JJ (2017). Analysis of Consumer Preference for Vitamin A-fortified Sugar in Kenya. The European Journal of Development Research 29(4):745-768.

Peña-Rosas JP, Garcia-Casal MN, Pachón H, Mclean MS, Arabi M (2014). Technical considerations for maize flour and corn meal fortification in public health: Consultation rationale and summary. Annals of the New York Academy of Sciences 1312(1):1-7.

Stoltzfus RJ, Smith JL, Brooker S, Dror DK, Allen LH, Mburu ASW (2008). Vitamin Stability in Premixes and Feeds: A Practical Approach in Ruminant Diets. Nutrients 9(5):3875S-4061S.

USAID (2010). Staple Foods Value Chain Analysis. Available at: https:/www.ffinetwork.org/about/calendar/2016/documents/Maize_Scoping.pdf.

Weinberg ZG, Yan Y, Chen Y, Finkelman S, Ashbell G, Navarro S (2008). The effect of moisture level on high-moisture maize (*Zea mays* L.) under hermetic storage conditions — in vitro studies 44:136-144.

WHO guideline (2016). Fortification of maize flour and corn meal with vitamins and minerals. Geneva: World Health Organization;. License: CC BY-NC-SA 3.0 IGO.

Wokabi SM (2013). Sustainability of Maize production in Kenya. Kenya Agricultural Research Institute, Nairobi, Kenya 5(2):2.

Zimmermann MB, Andersson M (2012). Update on iodine status worldwide. Current Opinion in Endocrinology, Diabetes, and Obesity 19(5):382-387.

Appendix 1. Industry Questionnaire

BASELINE STUDY ON MAIZE FLOUR FORTIFICATION IN KENYA
Date…………………………………

Introduction
The Ministry of Health has identified food fortification (addition of vitamins and minerals to food so as to improve its nutritional quality) of common staples as one of the strategies in the prevention and control of micronutrient deficiencies. JKUAT in collaboration with the Ministry of Health endeavors to scale up maize flour fortification programs among commercial mills in the country.
In order to effectively support fortification, we are conducting a baseline survey to determine the current status of maize milling and flour fortification in the industries. Your participation will help us design how best to improve maize flour fortification activities in Kenya which will consequently improve the health, nutrition and overall quality of life of our citizens
The execution of this questionnaire will take about 30-40 minutes of your time. All the information gathered in the course of this study will be held in strict confidence and used only for the purpose of the study.
Kindly confirm your voluntary acceptance to take part in this study by ticking in the appropriate box below
Yes ☐ No ☐

Industry name:	**Respondent's Name:**
County:	**Designation:**
Town:	**Tel No:**
Year of establishment:	**Email address:**
Interviewer's Name:	

(1) How many employees does the company have? (*Tick appropriately*)

1 <5	2 6-10	3 11-30	4 31 -50	5 51- 100	6 101 -500	7 >500

(2) Could you segregate them by gender?
Number of males ☐ Number of females ☐

(3) What is the percentage of skilled labour in the factory? (*Tick appropriately*)

1 <10%	2 11-20%	3 21-40%	4 41-60%	5 61-80%	6 81-90%	7 91-100%

(4) What type of miller do you use?

Type of Miller	Installed Capacity (Ton/hr)	Actual Production Capacity (Ton /hr)
1. Hammer Miller		
2. Colloidal Miller		
3. Attrition Miller		
4. Others (specify)		

(5) What brands do you produce? Fill in the table below.

Product name	Fortified 1. Yes 2. No	Packaging 1.Plastics 2.Sacks 3.Kraft paper/khaki 4. Carton boxes 5. Metal 6. Foil	Do packages have logos? 1. Yes 2. No	Specify logo 1.KEBS 2.Fortification 3.Both 1 &2	Geographical coverage 1. District 2.County 3.Region 4.Country 5. International

Premixes

(6) Where do you get your premix from?

Source of premix	Unit
1. Bio foods products limited 2. Somochem Kenya limited 3. Chemical & solvents (EA) 4. Engrain East Africa 5. Remco Africa Ltd 6. Amesi Kenya Ltd 7. Buhler LTD 8. High nutrition limited 9. IMCD Kenya 10. Vital MOLECULES Ltd 11. Philips pharmaceuticals 12. Finken holdings ltd 14. Own importation 15. Others (specify)	1 kg = 1 5 kg = 2 10 kg = 3 25 kg =4 50 kg =5 100 kg =6 Others (specify) = 7

1. How do you store your premixes?

2. What challenges do you experience in the acquisition of premixes?

a)
b)
c)
d)
e)

Dozers

3. Do you have a dozer/feeder?
1. Yes
2. No

If yes?

Brand	Capacity

4. How often are the dozers calibrated?
1. After each batch
2. Daily
3. Weekly
4. Monthly
5. Quarterly
6. Bi-annually
7. Yearly
8. Others (specify)

5. What are the challenges experienced with dosing?

a)
b)
c)
d)
e)

Mixers

13. Is your dozer equipped with a mixer?
    1. Yes
    2. No

If yes?

Brand	Capacity

Quality Assurance/Quality Control

17. Do you have a laboratory or QA/QC room?
1. Yes
2. No

18. Do you have documented guidelines for QA/QC (Quality Assessment and Quality Control)
1. Yes
2. No

19. Do the QA/QC procedures incorporate elements of food fortification? (If the miller is already fortifying)
1. Yes
2. No

20. What flour routine tests are done in your lab?
a)
b)
c)
d)
e)

21. How often is this done in your lab? *(Internal)*
1. Hourly
2. Two hourly
3. After every batch
4. Daily
5. Weekly
6. Monthly
7. Quarterly
8. Semi-annually
9. Annually (once every year)

22. Are your samples tested elsewhere? (*External*)
1. Yes
2. No

If yes where………………….

23. What tests are done externally?
a)
b)
c)
d)

24. How often is this done?
1. Weekly
2. Monthly
3. Quarterly
4. Semi-annually
5. Annually (once every year)
6. Others (specify)

25. How long does it take to get the results? *(Tick where appropriate)*

1 < 1 week	2 1 week	3 1 month	4 2 -3 months	5 3- 6 months	6 7 –months -1 year	7 >1 year

26. What quality parameters are checked when maize grain is received
1. Moisture
2. Colour
3. Foreign materials
4. Aflatoxin
5. Others (specify)

27. Have you ever been inspected by regulating agencies?
1. Yes
2. No

28. If Yes, by which organization? *(Tick appropriately)*

1. KEBS	2. MOH Public health officers (National/County Government)	3. Ministry of Trade	4. Others, specify

29. How often are you inspected?
1. Weekly
2. Monthly
3. Quarterly
4. Biannually
5. Annually

30. How does fortification impact on your profitability?
1. Very significantly
2. Significantly
3. Not sure
4. Minimal

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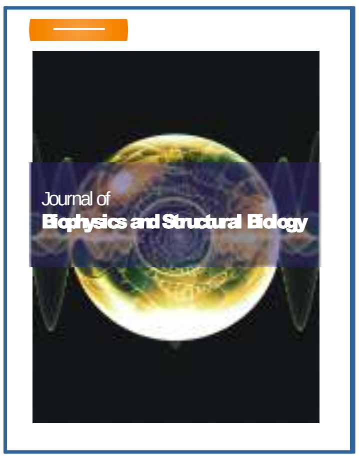

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