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ARTICLE

Use of Bitter Leaf (*Vernonia amygdalina*) Extract and Pasteurization Aim at Improving the Sensory Quality and Shelf-life of *Mpedli*, a Traditional Opaque Sorghum White Beer from Northern Cameroon

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ABSTRACT

The purpose of this study was to evaluate the sensory property and shelf life of the processed *mpedli* beer using aqueous leaves extract of *Vernonia amygdalina* (VA) and heat treatment. The white sorghum beer was made at the laboratory scale using home-made procedure (Control). Following filtration, the beer was blended with an aqueous leaf extract (1/10, v/v) of VA (BUB). Pasteurization (60 °C/30 min) was performed on a portion of the VA blended sample (BPB). The sensory parameters and shelf life of the three samples were evaluated at room temperature during a month storage. The sensory characteristics of blended and non-supplemented *mpedli* beer differed significantly ($p < 0.05$). During storage, the colour, bitterness, aroma, odour, viscosity, texture, and overall acceptability of the processed samples were improved. Bitterness ($r = 0.898$; $p < 0.01$) and odour ($r = 0.930$; $p < 0.01$) were both highly correlated with the acceptance of the processed beer. The non-supplemented samples had the highest sensory scores 48 hours after preparation, while the relevant sensory ratings in processed BUB and BPB samples were recorded from the 12th to the 21st and 27th day of storage, respectively. The findings suggest that combining pasteurization with addition of aqueous leaf extract of VA may help small-scale brewers for improving the sensory quality and extending the shelf life of *mpedli*. According to the findings, the use of bitter leaf could be proposed as an alternative hop in the local brewing industry and may increase incomes of producers of local sorghum beer.

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1. Introduction

Food processing is becoming a recurring activity in developing countries. Brewing is among the most recurrent food transformation technology. Despite the high importance of directly consuming cereals, it is estimated that the latter is greatly processed for the production of alcoholic [1,2] and non-alcoholic [3] drinks than fruits. Most of the brewed drinks surrounding the market are processed by highly specialised industries but the African population have their own approach, which is still rudimentary and less documented. Beer production dates from prehistoric era and it is the most consumed beverage worldwide [4]. In west and central Africa, beer production is highly undertaken by women but most final products are only destined for men consumption [5]. In the northern part of Cameroon, the white sorghum is used in the production of an indigenous beer called *mpedli*, also known as white kapsiki beer. *Mpedli* beer, like many other cereal-based beverages, is regarded as good source of minerals and probiotic required for the metabolism of living cells [6]. The production of this local northern beer is a source of income and employment for many young ladies in northern Cameroon, which is considered as the least developed and poorest region of the country [7,8]. However, due to the poor hygienic quality of this traditional beer, unpreserved *mpedli* has a very short shelf-life that cannot exceed 48 hours at room temperature [9]. To overcome the short-term shelf life of this indigenous beer, proper preservation techniques like refrigeration, irradiation, heat treatment or the use of plant extract as natural food supplement are required. However, due to financial constraints and increased production costs, some techniques involving thermal treatment or irradiation may be difficult to apply for *mpedli* producers [10]. As a result, the import of plant extracts appears to be a viable option for addressing shelf life and quality issues of the local sorghum-based beers [11].

Besides being alcoholic, beer is highly valued for its bitterness. Hops are responsible for the bitter taste [12]. Brewers influenced the sensory quality, stability, and health safety of beers in the ancient brewing system by adding medicinal and edible plants that contained active principles responsible for bitterness or flavouring of the beer. In the 21st century, a resilient approach is being put in place to encourage the consumption of natural or less processed products, including herbal beers, depending on the region [13]. Indeed, due to their antimicrobial activities against certain pathogens, antioxidative properties, and essential oils, plants have been used as beer additives for flavouring and, more importantly, as food preservatives since ancient times [14].

Vernonia amygdalina is a perineal edible vegetable common to tropical Africa [15]. It is commonly known as *Ndolé* or bitter leaf in Cameroonian local markets. The leaves of this plant are considered as nutraceutical because they are used as both food and medicine [16]. The medicinal properties of this plant are related to the presence of bioactive compounds [17] but its bitterness is a key component, which serves as a hop in local beer production [18]. As such, the addition of aqueous extract of *Vernonia amygdalina* (VA) may result in *mpedli* beer to have a longer shelf life because of its bacterial and antifungal effects [19]. However, because the indigenous beers are served in an actively fermenting state with no pasteurization stage, VA extract coupled to the pasteurization could improve both the shelf-life and nutritional value of the *mpedli* beer because the plant contains various relevant nutrients (vitamins, minerals, carbohydrates, free amino acids, and fat) [20]. This combined preservation technique may also be an effective alternative to the synthetic beer preservatives, which can be harmful to consumers' health [21]. Given consumer interest in less processed or natural food products, a newly developed *mpedli* beer containing *Vernonia amygdalina* as a natural beer additive may also appeal to health-conscious consumers [22]. Therefore, the purpose of this study was to assess the efficacy of adding VA aqueous leaf extract with or without pasteurization on sensory quality and shelf-life of *mpedli* beer. This study was undertaken because there has been insufficient attention paid to the use of indigenous bitter vegetables as local hops in the Cameroonian brewing industry.

2. Materials and Methods

2.1 Plant Materials

White sorghum grains, *Sorghum bicolor* (madjeri) and the leaves of *Vernonia amygdalina* were the main plant materials used in this study (Figure 1). The white sorghum was purchased from IRAD Maroua while the mature fresh leaves of *Vernonia amygdalina* were manually harvested from Bouha village, Mayo-Tsanaga Division, Far North Region, Cameroon. Both plant materials were authenticated by botanical experts in the Department of Biological Sciences, University of Maroua, Cameroon. The collected leaves were sorted and shed dry until a constant weight was obtained. The dried leaves were ground, sieved, and the powder obtained was introduced into air free sealed plastic bottles for further use.

2.2 Preparation of Aqueous Extract of *Vernonia amygdalina* Leaf

The powdered material was extracted with distilled water (1:50 w/v). The mixture was stirred at 500 runs/min for 6 hours and the preparation was allowed to stand for 18 hours before being filtered through Whattman n° 2. The filtrate was refrigerated at 4 °C until further use.

2.3 White Sorghum-based "*Mpedli*" Beer Production and Treatment Process

The method previously described by Bayoï et al. [9] and recently re-used by Bayoï and Etoa [23] was used to produce *mpedli* beer. The sixth of the sorted sorghum grain was malted, while the remaining five sixth were milled into non-malted flour. The flour was soaked in water for about 10 h after which the whole content was cooked to a dough called "*fufu*". After cooling at room temperature, the "*fufu*" was kneaded and the malted flour was sequentially added to obtain the wort which was covered and allowed to ferment for 48 hours at room temperature. The resulting alcoholic fermented white sorghum beverage was filtered through muslin material and partitioned into three aliquots. Two of them served as test samples were adjuncted with the bitter leaves aqueous extract (1/10, v/v). One of the blended aliquots was pasteurized at 60 °C for 30 minutes [24]. The remaining aliquot was used as control and left without VA extract blending. Both assay and control samples were labelled and stored for a month at room temperature. The three-treatment groups of samples as shown in Figure 1 were labelled as follows:

- Control non-supplemented *mpedli* beer (CMB);
- Blended unpasteurized *mpedli* beer (BUB);
- Blended and pasteurized *mpedli* beer (BPB).

2.4 Sensory Analysis and Shelf-life Estimation

To evaluate the sensory attributes of *mpedli* beer samples during storage, a descriptive test with a 9-point-hedonic scale system, ranging from dislike extremely = 1 to extremely like = 9, was used [25]. After the preliminary training section, a panel of sixteen members (male and female, ages 19 to 32 years) was assembled, and ten of them were retained. The members were recruited among the university community (students and staff) and the experienced consumers of the fermented alcoholic beverage. Thirty millilitre (30 mL) of the concoction was randomly served to the panelists in transparent coded cups to assess the sensory attributes. Every morning between 7 a.m. and 8 a.m., the analysis was carried out in the Food and Microbiology laboratory, unit of IRAD Maroua, Cameroon. The sensory attributes such as colour/appearance, odour, taste (bitterness, acidity, and alcoholic), aroma, texture, viscosity, and overall acceptability were appreciated and scored by the panelists. After being graded, the tested sample was sipped and the tongue was immediately rinsed with mineral water before the next sample was evaluated. The sensory attributes were followed by the same panel over a four-week period, and the shelf life was estimated by testing the samples after 0, 2, 4, 6, 8, 12, 15, 18, 21, 24, and 27 days of storage at room temperature.

2.5 Statistical Analysis

The experiments were repeated three times, and the results were presented as mean ± standard deviation. The mean values were analysed using one-way ANOVA, and the HSD Turkey test was used to discriminate pairs of mean values that were significantly different at probability level of $p < 0.05$. Moreover, radar plots were created to reveal close similarities between the samples, and principal component analysis (PCA) was used to assess correlation

(a) **(b)** **(c)**

Figure 1. Dried bitter leaf (a); white sorghum grains (b); blended and non-Supplemented beer samples (c)

between the sensory attributes and the association between the beer samples during the storage. To perform univariate and multivariate statistical analysis, STATGRAPHICS and XLSTAT software were used, respectively.

3. Results

3.1 Sensory Properties of Beer Samples during Storage

3.1.1 Colour, Odour and Aroma

The colour, aroma and odour scores of *mpedli* beer samples during storage are compiled in Table 1. There were not significant changes ($p>0.05$) in terms of colour of treated beer samples throughout the storage at room temperature. However, odour and aroma attributes significantly varied ($p<0.05$) for both unprocessed and processed samples. Independently to the storage time, there were significant differences between treated and untreated control beer samples in terms of colour ($p = 0.0000$), odour ($p = 0.0223$) and aroma ($p = 0.0019$). The scores were ranged between 4.60±2.10 and 7.30±1.76; 2.90±1.79 and 6.90±1.66; and 3.20±2.20 and 6.60±0.84, for the sensory attributes colour, odour and aroma respectively. The colour of BUB (unpasteurized blended with VA aqueous leaf extract) and BPB (blended and pasteurized) samples was highly graded on the 12th (7.20±0.91) and 21st (7.10±1.44) day of storage respectively, while the CMB control sample was most appreciated on the zeroth day (7.30±1.76), when freshly prepared. Odour (4.70±1.70 and 6.90±1.66) and aroma (4.10±1.72 and 5.90±1.37) of the BPB samples increased with storage time from the 0th to 12th day of storage. BPB samples were the most graded in terms of odour (5.58±0.75) whereas BUB ones were the most appreciated in regards to aroma (5.55±0.68) compared to CMB control samples (4.57±1.10 and 4.59±0.80, respectively).

3.1.2 Taste Descriptors

Table 2 presents taste sub attributes grouped as taste descriptors into bitterness, acidic and alcoholic of *mpedli* beer. Changes of taste attributes of BPB samples were not significant ($p>0.05$) while those of BUB and CMB samples varied significantly ($p<0.05$) during storage time. According to the processing method, bitterness and alcohol taste were significantly different ($p = 0.0008$ and $p = 0.0116$, respectively), while acidic taste was not significant ($p = 0.0702$) between the beer samples. Bitter taste of BUB and BPB was most appreciated on the 8th and 27th day of storage (6.60±1.34 and 6.30±1.63, respectively). Alcoholic taste of BPB samples received the best grades after day 8 and day 27 of storage (6.7±0.82 and 6.80±1.31, respectively). BUB samples were well scored in terms of alcoholic taste on the 8th day of storage (6.90±0.73). However, the CMB samples registered their greatest scores for bitterness (5.80±5.86 and 6.60±1.17, respectively) and alcoholic taste (6.60±1.34 and 6.40±1.64, respectively) on both the 0th and 2nd day of storage. The acidity of BUB and BPB *mpedli* beer was most appreciated on the sixth (6.40±0.84) and eighteenth (6.10±2.02) day of storage, while CMB samples recorded the highest scores on the 0th and 2nd day of storage (6.10±1.66 and 6.10±1.72, respectively). During storage, BUB samples were globally rated

Table 1. Mean scores for colour, odour and aroma attributes of *mpedli* beer samples during storage at room temperature

Storage time (days)	Colour			Odour			Aroma		
	CMB	BUB	BPB	CMB	BUB	BPB	CMB	BUB	BPB
0	7.30±1.76^{a}	6.70±1.63^{a}	4.60±2.10^{a}	5.30±1.56^{ab}	5.10±1.20^{ab}	4.70±1.70^{a}	5.70±1.63^{ab}	5.60±1.83^{ab}	4.10±1.72^{a}
2	6.40±1.42^{a}	6.80±1.22^{a}	4.60±1.64^{a}	6.50±0.70^{a}	6.30±1.25^{ab}	5.00±1.63^{ab}	6.00±1.24^{a}	6.60±0.84^{a}	4.00±1.88^{a}
4	5.80±2.14^{a}	7.10±0.73^{a}	4.90±1.59^{a}	4.90±2.02^{ab}	6.50±1.08^{b}	5.00±2.05^{ab}	4.80±1.81^{ab}	6.00±0.94^{ab}	5.30±1.63^{a}
6	5.90±1.85^{a}	7.00±0.94^{a}	5.80±2.20^{a}	5.10±2.13^{ab}	6.00±1.63^{ab}	6.10±0.87^{ab}	6.00±2.16^{a}	6.00±1.41^{ab}	5.50±1.43^{a}
8	5.80±1.54^{a}	7.20±0.78^{a}	6.20±0.78^{a}	4.90±1.96^{ab}	6.40±0.96^{ab}	6.10±0.87^{ab}	4.30±1.82^{ab}	6.00±0.94^{ab}	5.60±1.26^{a}
12	5.20±2.01^{a}	7.20±0.91^{a}	5.90±1.79^{a}	2.90±1.79^{b}	6.40±0.69^{ab}	6.90±1.66^{ab}	3.20±2.20^{b}	6.20±1.13^{ab}	5.90±1.37^{a}
15	5.00±1.26^{a}	6.30±1.41^{a}	6.10±1.96^{a}	3.50±2.32^{b}	4.10±1.91^{a}	5.80±1.98^{a}	4.10±2.02^{ab}	5.80±1.03^{ab}	4.60±1.17^{a}
18	6.20±1.34^{a}	6.30±1.41^{a}	5.70±1.82^{a}	5.80±1.31^{ab}	4.60±1.77^{ab}	4.70±1.76^{ab}	3.80±1.98^{ab}	4.40±1.47^{b}	5.30±1.15^{a}
21	6.00±1.49^{a}	6.80±1.13^{a}	7.10±1.44^{a}	3.70±2.54^{ab}	5.00±1.88^{ab}	5.60±1.95^{ab}	4.80±1.75^{ab}	4.90±1.52^{ab}	5.40±1.34^{a}
24	5.40±1.34^{a}	6.30±1.33^{a}	6.60±1.77^{a}	3.60±2.45^{ab}	4.80±1.93^{ab}	5.30±1.94^{ab}	4.70±1.76^{ab}	5.70±1.41^{ab}	5.50±1.50^{a}
27	5.90±2.02^{a}	7.00±0.94^{a}	6.60±1.64^{a}	4.10±2.37^{ab}	5.80±2.14^{ab}	6.20±0.63^{b}	4.80±1.13^{ab}	5.50±1.50^{ab}	5.90±1.52^{a}
Mean score	5.90±0.62	6.79±0.35	5.83±0.83	4.57±1.10	5.55±0.85	5.58±0.75	4.59±0.80	5.55±0.68	5.19±0.66
p-value	0.0000*			0.0223*			0.0019*		

CMB: Control non-supplemented *mpedli* beer; BUB: Blended unpasteurized *mpedli* beer; BPB: Blended and pasteurized *mpedli* beer. For each sensory attribute, mean values in the column not followed by the same superscript lowercase letter (s) were different at $p < 0.05$ by storage time. (*) P-value lower than 0.05 indicating significant difference by processing method.

Table 2. Taste sub attributes of *mpedli* beer samples during storage

Storage time (days)	Bitterness			Alcoholic			Acidic		
	CMB	BUB	BPB	CMB	BUB	BPB	CMB	BUB	BPB
0	$5.80{\pm}5.8^{6b}$c	$5.80{\pm}1.87^{abc}$	$5.10{\pm}2.07^{a}$	$6.60{\pm}1.34^{a}$	$5.70{\pm}1.41^{abc}$	$5.50{\pm}1.26^{a}$	$6.10{\pm}1.66^{b}$	$5.50{\pm}2.01^{abc}$	$5.10{\pm}2.02^{a}$
2	$6.60{\pm}1.17^{c}$	$6.60{\pm}1.57^{c}$	$4.60{\pm}1.83^{a}$	$6.40{\pm}1.64^{ab}$	$6.90{\pm}1.59^{c}$	$5.50{\pm}2.17^{a}$	$6.10{\pm}1.72^{b}$	$6.30{\pm}1.05^{bc}$	$4.80{\pm}1.87^{a}$
4	$5.50{\pm}1.90^{abc}$	$6.60{\pm}1.34^{c}$	$5.30{\pm}2.00^{a}$	$5.00{\pm}2.30^{ab}$	$6.40{\pm}1.07^{bc}$	$5.70{\pm}2.16^{a}$	$4.40{\pm}1.71^{ab}$	$6.10{\pm}1.28^{bc}$	$5.40{\pm}2.06^{a}$
6	$4.40{\pm}1.95^{abc}$	$6.50{\pm}0.70^{bc}$	$6.00{\pm}1.63^{a}$	$5.30{\pm}2.3^{ab}$	$5.80{\pm}1.13^{abc}$	$6.20{\pm}1.54^{a}$	$4.60{\pm}2.54^{ab}$	$6.40{\pm}0.84^{c}$	$5.80{\pm}1.47^{a}$
8	$4.80{\pm}2.25^{abc}$	$6.60{\pm}1.34^{c}$	$6.00{\pm}0.94^{a}$	$4.80{\pm}2.20^{ab}$	$6.90{\pm}0.73^{bc}$	$6.70{\pm}0.82^{a}$	$4.20{\pm}2.61^{ab}$	$5.80{\pm}1.68^{abc}$	$5.40{\pm}1.89^{a}$
12	$2.80{\pm}1.03^{a}$	$6.10{\pm}1.44^{abc}$	$5.70{\pm}1.56^{a}$	$3.60{\pm}1.95^{b}$	$6.50{\pm}0.84^{c}$	$7.00{\pm}1.05^{a}$	$2.90{\pm}2.28^{a}$	$5.20{\pm}1.39^{abc}$	$5.10{\pm}1.10^{a}$
15	$3.40{\pm}2.01^{ab}$	$4.30{\pm}1.94^{a}$	$5.70{\pm}1.15^{a}$	$3.60{\pm}2.11^{b}$	$4.50{\pm}2.22^{ab}$	$6.10{\pm}1.10^{a}$	$2.50{\pm}1.64^{a}$	$3.60{\pm}1.57^{ab}$	$4.10{\pm}1.10^{a}$
18	$3.30{\pm}2.26^{ab}$	$4.40{\pm}1.17^{ab}$	$6.20{\pm}1.87^{a}$	$4.40{\pm}1.26^{ab}$	$4.10{\pm}1.28^{a}$	$6.30{\pm}1.05^{a}$	$3.10{\pm}1.28^{ab}$	$3.30{\pm}1.41^{a}$	$6.10{\pm}2.02^{a}$
21	$3.90{\pm}2.23^{abc}$	$5.90{\pm}1.52^{abc}$	$5.90{\pm}1.79^{a}$	$4.80{\pm}2.25^{ab}$	$4.20{\pm}1.98^{ab}$	$5.40{\pm}1.71^{a}$	$3.40{\pm}2.22^{ab}$	$3.80{\pm}2.85^{abc}$	$4.20{\pm}2.09^{a}$
24	$3.80{\pm}2.30^{abc}$	$5.90{\pm}1.72^{abc}$	$6.50{\pm}1.50^{a}$	$4.80{\pm}1.68^{ab}$	$5.70{\pm}1.82^{abc}$	$5.50{\pm}1.17^{a}$	$2.80{\pm}2.20^{a}$	$3.20{\pm}2.48^{a}$	$4.70{\pm}2.26^{a}$
27	$4.50{\pm}1.84^{abc}$	$6.30{\pm}1.25^{abc}$	$6.30{\pm}1.63^{a}$	$4.50{\pm}2.27^{ab}$	$6.10{\pm}1.28^{abc}$	$6.80{\pm}1.31^{a}$	$3.60{\pm}2.41^{ab}$	3.80±2.44	$4.70{\pm}2.16^{a}$
Mean score	4.44±1.16	5.91±0.83	5.75±0.56	4.89±0.96	5.71±1.02	6.06±0.59	3.97±1.25	4.82±1.28	5.04±0.62
P-value	0.0008*			0.0116*			0.0702		

CMB: Control non-supplemented *mpedli* beer; BUB: Blended unpasteurized *mpedli* beer; BPB: Blended and pasteurized *mpedli* beer. For each sensory attribute, mean values in the column not followed by the same superscript lowercase letter (s) were different at $p < 0.05$ by storage time. (*) P-value lower than 0.05 indicating significant difference by processing method.

the highest in terms of bitterness (5.91±0.83), while BPB samples were better judged than CMB samples in terms of alcoholic (6.06±0.59 versus 4.89±0.96) and acidic taste (5.04±0.62 versus 3.97±1.25).

3.1.3 Viscosity, Texture and Overall Acceptability

The sensory ratings of the texture, viscosity and overall acceptability of *mpedli* beer during storage are presented in Table 3. Except for the overall acceptability of BUB samples which displayed significant variations ($p<0.05$), all the other attributes for both treated and untreated beer samples were not significant ($p>0.05$) throughout storage period. The viscosity and texture scores of the processed beer samples increased from the 0^{th} to the 12^{th} day of storage for BUB samples (6.30±1.82 to 7.00±0.93 and 6.50±1.43 to 7.20±1.03, respectively) and 27^{th} day for BPB samples (5.40±2.45 to 6.70±1.76 and 4.10±2.46 to 6.80±2.27, respectively). In terms of viscosity (7.00±0.94 and 6.80±2.27) and texture (7.20±1.03 and 6.70±1.76), BUB and BPB samples were most graded on the 12^{th} and 27^{th} day of storage respectively, while CMB samples were most preferred on the 8^{th} and 24^{th} day of storage (6.40±1.34 and 6.90±1.37, respectively).

These results showed a significant difference in terms of viscosity ($p = 0.0340$) and texture ($p = 0.0025$), but BUB samples were most preferred for both attributes through the storage. These samples recorded 69% (mean score 6.23) compared to 65% (mean score 5.85) and 60% (mean score 5.42) viscosity rating for the control CMB and processed BPB samples respectively. In the same trends, 72% (mean score 6.49±0.54) of texture rating was attributed to BUB samples while 68% (mean score 6.15±0.45) and 62% (mean score 5.56±0.70) of the same attribute were shown for CMB and BPB samples, respectively.

The overall acceptability of BPB samples did not significantly change while relevant variations ($p<0.05$) were found for CMB and BUB samples during the storage. The unpreserved CMB samples were most appreciated when fresh, on the 0^{th} day of storage (6.60±1.26) while the blended and unpasteurized BUB samples were most appreciated from the 2^{nd} to 12^{th} storage day (7.10±0.09 to 7.10±0.56, respectively), with the highest acceptance recorded on the 4^{th} and 6^{th} storage day (7.20) and the pasteurized and blended the BPB samples were most appealed from the 15^{th} to the 27^{th} storage day (6.40±1.17 to 7.00±1.33, respectively). Globally, the processed *mpedli* beer was significantly ($p = 0.0047$) more accepted than non-supplemented *mpedli* drink. The BUB and BPB samples recorded 72.3% (mean score 6.51) and 69% (mean

Table 3. Viscosity, texture and overall acceptability of *mpedli* beer samples during storage

Storage time (days)	Viscosity			Texture			Acceptability		
	CMB	BUB	BPB	CMB	BUB	BPB	CMB	BUB	BPB
0	5.50±2.27^{a}	6.30±1.82^{a}	4.10±2.46^{a}	6.10±2.18^{a}	6.50±1.43^{a}	5.40±2.45^{a}	6.60±1.26^{a}	6.40±0.69^{ab}	5.50±1.90^{a}
2	5.90±1.37^{a}	5.60±1.77^{a}	4.70±2.49^{a}	6.40±1.77^{a}	6.40±1.50^{a}	4.40±2.36^{a}	6.80±1.13^{a}	7.10±0.99^{a}	5.20±1.93^{a}
4	5.80±1.68^{a}	6.90±0.87^{a}	4.40±2.06^{a}	5.70±1.82^{a}	6.90±1.52^{a}	4.80±1.81^{a}	5.60±1.95^{ab}	7.20±0.91^{a}	5.40±1.57^{a}
6	4.90±1.10^{a}	6.70±0.94^{a}	5.40±2.31^{a}	5.80±1.39^{a}	6.80±1.39^{a}	5.30±2.31^{a}	5.70±1.70^{ab}	7.20±0.78^{a}	6.40±1.07^{a}
8	6.40±1.34^{a}	6.30±1.76^{a}	4.70±1.56^{a}	6.40±1.77^{a}	6.20±1.61^{a}	5.10±1.72^{a}	5.90±1.19^{b}	6.70±0.48^{ab}	6.40±0.51^{a}
12	6.30±2.05^{a}	7.00±0.94^{a}	5.50±1.58^{a}	5.50±2.36^{a}	7.20±1.03^{a}	6.10±1.44^{a}	4.50±1.71^{b}	7.10±0.56^{a}	6.70±0.82^{a}
15	5.40±1.64^{a}	5.10±1.52^{a}	6.00±1.33^{a}	5.60±2.01^{a}	5.20±1.22^{a}	5.50±1.26^{a}	4.40±1.34^{ab}	5.30±1.25^{b}	6.40±1.17^{a}
18	6.30±1.49^{a}	5.90±1.59^{a}	5.10±1.37^{a}	6.20±1.47^{a}	6.70±1.33^{a}	5.40±1.71^{a}	5.10±1.19^{ab}	5.70±1.15^{ab}	6.20±1.13^{a}
21	6.20±1.98^{a}	5.70±0.94^{a}	6.50±1.26^{a}	6.50±2.06^{a}	6.00±1.69^{a}	6.10±1.37^{a}	5.70±0.94^{ab}	6.10±1.19^{ab}	6.50±1.17^{a}
24	6.20±1.75^{a}	6.80±1.87^{a}	6.40±1.68^{a}	6.90±1.37^{a}	6.80±2.09^{a}	6.40±2.17^{a}	5.20±1.03^{ab}	6.30±1.49^{ab}	6.90±1.19^{a}
27	5.50±1.77^{a}	6.20±1.31^{a}	6.80±2.2^{7}a	6.60±1.77^{a}	6.70±1.76^{a}	6.70±1.76^{a}	5.20±1.13^{ab}	6.50±1.17^{ab}	7.00±1.33^{a}
Mean score	5.85±0.48	6.23±0.61	5.42±0.91	6.15±0.45	6.49±0.54	5.56±0.70	5.52±0.75	6.51±0.63	6.24±0.61
p-value	0.0340*			0.0025*			0.0047*		

CMB: Control non-supplemented *mpedli* beer; BUB: Blended unpasteurized *mpedli* beer; BPB: Blended and pasteurized *mpedli* beer. For each sensory attribute, mean values in the column not followed by the same superscript lowercase letter (s) were different at $p < 0.05$ by storage time. (*) P-value lower than 0.05 indicating significant difference by processing method.

score 6.24) overall acceptability rating respectively, while the CMB samples only had 61% (mean score 5.52) acceptance during the storage period at room temperature.

3.2 Radar Plots

Figure 2 represents the global view of the *mpedli* beer at the end of storage. It emerges that, the blended samples portrayed a similar radial representation against the control non-supplemented samples. It also has been noted that storage at room temperature upgrades general appreciation of the treated beer samples (BUB and BPB) compared to unpreserved ones (CMB). Therefore, the BUB samples were found most graded for its colour/appearance, bitterness, aroma, viscosity, texture and overall acceptability while the BPB ones were most liked for its acidic and alcoholic taste.

3.3 Correlation between the Sensory Attributes of the Treated Sorghum Beer Samples during Storage

The association between the organoleptic characteristics of BUB and BPB *mpedli* beer samples during storage is presented in both Tables 4 and 5, respectively. With the unpasteurized and blended BUB samples (Table 4), a positive and significant interrelation was found between colour and bitterness ($r = 0.797$; $p < 0.01$); odour and colour ($p = 0.906$; $p < 0.01$); odour and bitterness ($r = 0.868$; $p < 0.01$); odour and alcoholic taste ($r = 0.862$; $p < 0.01$). Aroma was highly correlated to odour ($r = 0.795$; $p < 0.01$), bitterness ($r = 0.870$; $p < 0.01$), and alcoholic taste ($r = 0.920$; $p < 0.01$). All the properties evoked above, positively influenced the overall acceptability of BUB samples; however, bitterness and odour attributes were found more loaded to the overall acceptability of the indigenous beer ($r = 0.898$; $p < 0.01$ and $r = 0.930$; $p < 0.01$, respectively). Colour and bitter taste were more correlated ($r = 0.819$; $p < 0.01$) in BPB samples than in BUB ones. Viscosity significantly affected bitterness ($r = 0.697$; $p < 0.05$) and colour ($r = 0.869$; $p < 0.01$) in the pasteurized and blended BPB samples. Aroma of BPB samples was mainly linked to the bitterness ($r = 0.779$; $p < 0.01$). A positive and relevant correlation was found between texture and viscosity ($r = 0.801$; $p < 0.01$) in BPB samples during storage. The acceptance of BPB samples was positively linked to viscosity ($r = 0.819$; $p < 0.01$), texture ($r = 0.862$; $p < 0.01$), bitterness ($r = 0.887$; $p < 0.01$) and colour ($r = 0.894$; $p < 0.01$).

3.4 Multivariate Analysis

To visualise the relationships of *mpedli* beer with their sensory attributes during the storage, principal component analysis (PCA) was carried out using 33 samples and 9 attributes that showed statistical significance (p-value < 0.0001) according to the sphericity test of Bartlett. The Kaiser-Meyer-Olkin (KMO) value of 0.832 indicated that the sampling was sufficient for PCA analysis. As shown by the PCA biplot, the main sample differences and similarities, as well as sensory attributes, were reduced to two main dimensions, F1 and F2, which accounted for 59.15% and 23.64%, respectively, and both explained 82.79% of the total variation (Figure 3). The F1 dimension mainly

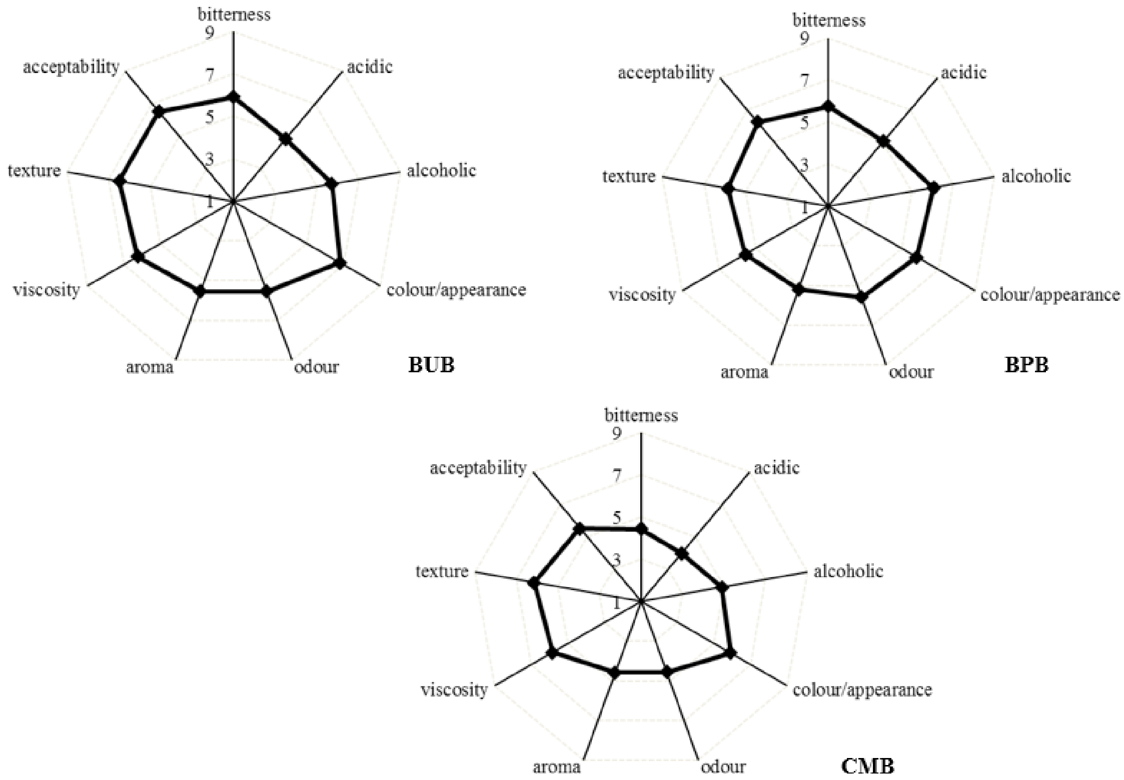

Figure 2. Radar plots for treated and control *mpedli* beer. CMB: Control non-supplemented *mpedli* beer, BUB: Blended unpasteurized *mpedli* beer and BPB: Blended and pasteurized *mpedli* beer

Table 4. Pearson coefficients between the sensory attributes of BUB samples during storage period

Colour	Bitterness	Alcohol	Viscosity	Odour	Aroma	Texture	Acceptability
1	0.797**	0.696*	0.497	0.90^{6*}*	0.611*	0.406	0.794**
	1	0.813**	0.559	0.868**	0.870**	0.485	0.898**
		1	0.506	0.862**	0.920**	0.444	0.821**
			1	0.556	0.439	0.859**	0.679*
				1	0.795**	0.557	0.930**
					1	0.357	0.860**
						1	0.676*
							1

(*): r values are statistically significant at $p < 0.05$; (**): r values are statistically significant at $p < 0.01$.

Table 5. Correlation between the sensory attributes of blended and pasteurized BPB *mpedli* beer samples

Colour	Bitterness	Alcohol	Viscosity	Odour	Aroma	Texture	Acceptability
1	0.819**	0.265	0.869**	0.604*	0.684*	0.763**	0.894**
	1	0.398	0.687*	0.479	0.77^{9*}*	0.725*	0.887**
		1	0.058	0.655	0.626*	0.286	0.526
			1	0.504	0.483	0.801**	0.819**
				1	0.610	0.537	0.696*
					1	0.604*	0.767**
						1	0.862**
							1

(*): r values are statistically significant at $p < 0.05$; (**): r values are statistically significant at $p < 0.01$.

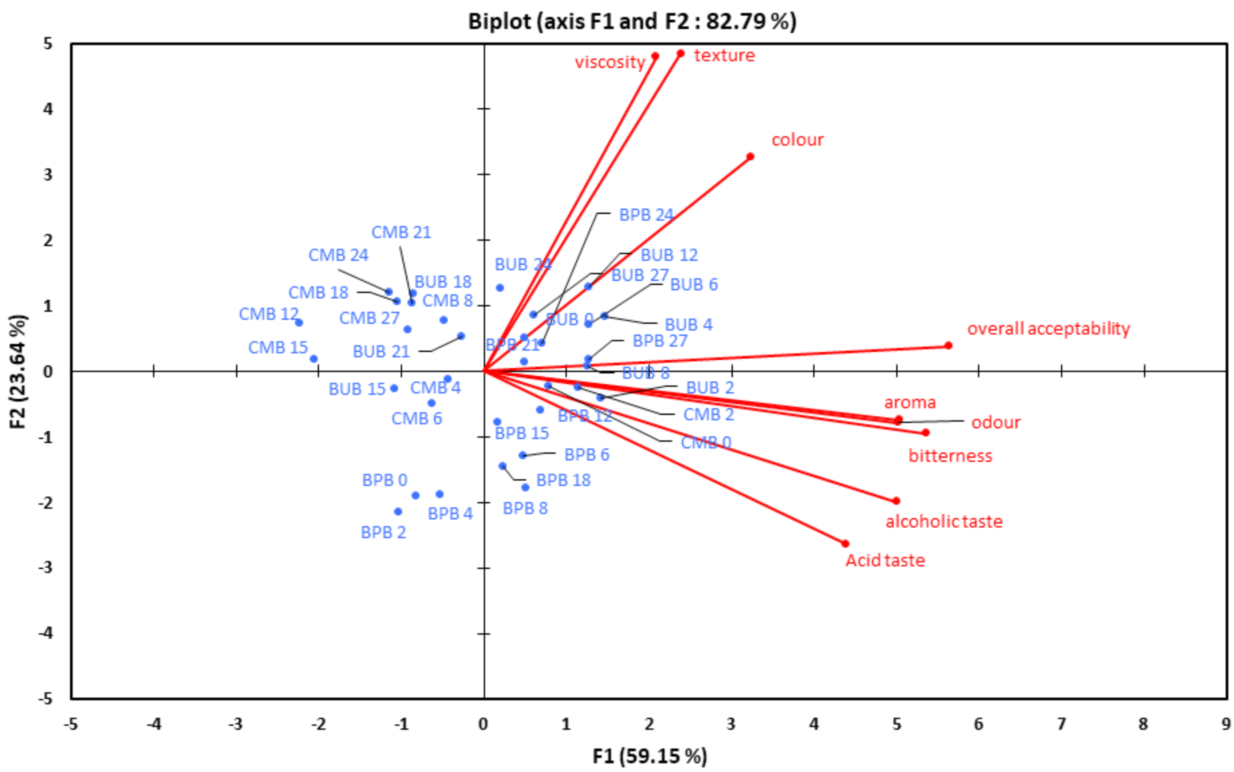

Figure 3. PCA loadings for sensory attributes and the scores of *mpedli* beer after varimax rotation ($p < 0.0001$; KMO = 0.832). Beer samples are coded as Figure 1. Digits 0 to 27 represent number of storage days

accounted for the sensory attributes odour, aroma, bitterness, acidic taste, alcoholic taste, and overall acceptability which were loaded on the positive side of this factor. The unpreserved and control CMB 0, CMB 2, unpasteurized blended BUB 2, BUB 8, and pasteurized blended BPB 12, BPB 27 samples recorded high positive sensory scores for these attributes. While colour, viscosity and texture contributed positively to the F2 dimension and VA blended samples BUB 12, 24 and 27 registered high positive score for the three sensory attributes mentioned above.

4. Discussion

It was observed that the colour, odour, taste (bitterness and alcoholic), aroma, texture, and overall acceptability of beer samples varied significantly during the storage. This implies that pasteurization treatment and addition of aqueous extract of *Vernonia amygdalina* leaf had an effect on the organoleptic characteristics of the *mpedli* beer. As with some indigenous beverages, it has been shown that blending may increase both the shelf life and sensory acceptance of the product [26]. Though the blended samples witnessed relevant grade in the aforementioned attributes, the blended and unpasteurized *mpedli* beer samples registered the greatest scored in terms of colour/appearance, viscosity, bitter taste, texture and overall acceptability. According to Nielsen [27] and Salanţă et al. [28], colour is one of the important characteristics that reinforce quality and acceptability of food products. The difference in colour between treated and unpreserved beer samples resulted from the addition of *Vernonia amygdalina* leaf extract. Leaves of VA are well-known for their high concentration in phytochemicals and natural phytopigments like green chlorophyll. This last component was responsible for the greenly opaque appearance of the processed *mpedli* samples [29]. The increase in colour of treated beer samples with storage time matched with the observation done by Cao et al. [30], who showed that the colour of beer increased linearly during storage at room temperature. The relevant sensory scores registered by control *mpedli* samples only during the first 48 hours after the production should be the result of microbial alteration, which caused deterioration of the *mpedli* beer after this storage period. In line with Bayoï et al. [9], unpreserved local beverages have shelf life less than 48 hours at room temperature. According to Cao et al. [30] and Malfliet et al. [31], the quality of beers is greatly affected by temperature and storage time. The BPB blended and pasteurized *mpedli* beer recorded the highest scores in the acidic and alcoholic taste, while the lowest grades were recorded for viscosity and texture. The heating use during the pasteurization process has greatly influenced the nature of processed beer. The heating accelerates evaporation as such BPB sample became more concentrated making it more viscous (porridge), high texture with an opaque colour. Two sensory characteristics very rejected by the consumers of sorghum-based beer like *mpedli* [32]. Moreover, the high scores for alcoholic and acidic taste attributes of pasteurized and blended *mpedli* beer were also associated to the heat treatment. During heating, there is hydrolysis of residual starch and disaccharides into glucose molecules which are easily converted in either alcohol or organic acids by fermenting microorganisms which escaped to the combined effect of heating treatment and antimicrobial action of the plant extract [33]. However, the panelist respondents reported that both alcoholic and acidic taste of pasteurized and blended BPB samples were just about right during storage period. According to *mpedli* consumers, this beverage is preferred when the alcohol content is moderately high. Therefore, most of indigenous beers are accepted at high level alcoholic [34]. Despite technological development, the production of manufactured beers with low levels of alcohol is more and more pertinent [12]. The bitter taste of *mpedli* samples positively affected the acceptability of the beers. So, blended samples were more accepted than non-blended ones. Bitterness is a characterisitic property of manufactured beers [28]. According to Pluháčková et al. [35], the bitter taste was the most appreciated and graded with beer samples fortified with some Czech medicinal herbs and plants. Plant secondary metabolites are rich in polyphenols, flavonoids, xanthones, phenolic acids, and resins with characteristics tastes [36]. Among the commercially used hops, polyphenols, flavouring agents and hops resins constitute the major bitter agents in the brewing process [37]. Unfortunately, bitterness is not among the sensory attributes found in traditional African beers [18]. Therefore, the use of bitter plant species as *Vernonia amygdalina* should be considered as a useful path to upgrade the processing of sorghum-based beer and improve the quality of the local indigenous beers [14]. The extracts from *Vernonia amygdalina* are known to contain secondary phytoconstituents like Vernoniosides which are a group of saponins likely responsible for bitter taste of the leaves. The bitter taste had been also associated with the presence of alkaloids, tannins, and glycosides [17]. These compounds made VA leaves act as a bittering agent and a hop substitute used for controlling microbial contamination in beer brewing without reducing the quality of malt [19]. Even with this supplementation action, the bitter taste of the processed beer varied greatly. Unpasteurized samples were more bitter than pasteurized ones. This variation resulted from the heating action (pasteurization) which led to the volatilisation of some metabolites responsible for the bitter taste of the blended *mpedli*. Odour was found as one of the major attributes contributing to the overall acceptability of the *mpedli* beer. The treated samples were more preferred than untreated control samples in terms of odour. This was consistent with increase in storage time. The reason may be attributed to off-odour produced from the 2nd day of storage altering quality and acceptance of untreated *mpedli* samples. While, both pasteurization and VA aqueous leaf extract, which are considered as two antimicrobial treatments, slow the formation of off-odour and reinforce the "leafy flavour" of the vegetable extract making processed *mpedli* more pleasant contrary to untreated *mpedli*, which was attractive freshly (0th day of storage). The unpasteurized blended BUB sample was highly preferred between 4th and 6th day of storage and the pasteurized blended BPB one recorded relevant acceptance from the 15th to 27th day of storage. This suggests that BPB sample registered the highest shelf life and confirmed the efficacy of combined preservation techniques compared to unifactorial one. This is in the same line with findings reported by Konfo et al. [14] with African traditional sorghum beers and Ayirezang et al. [39] with pito beer from Ghana and Nigeria.

5. Conclusions

The adjunction of the aqueous leaf extract of *Vernonia amygdalina* and pasteurization have greatly and positively influence most of the sensory characteristics and the shelf life of the *mpedli* beer. Irrespective of the treatment made, the colour, viscosity, texture, bitterness, acidic taste, aroma, odour and alcoholic taste affected the overall acceptability but the bitter taste and the odour were the key determining factor. With respect to these attributes, the BUB blended beer samples were the most appreciated but the BPB blended and unpasteurized *mpedli* beer had a milder appreciation. Apart from the trends in the sensory parameters, it was noticed that processed *mpedli* beer had extended shelf life over the untreated sample. Therefore, the pasteurized and blended *mpedli* beer registered the most valuable shelf-life extension. As with the sensory parameters, the aqueous leaf extract of VA and fabulous heating action during pasteurization contributed positively for it. Substantially, the aqueous leaf extract of VA contains important elements necessary to enhance the sensory characteristics and shelf life of *mpedli* beer and more so, its bitterness makes it a potential source of natural hops which may be exploited in the Cameroonian brewing industry.

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This research received no external funding.

Conflict of Interest

All authors declare that no competing interest exist. The beverage used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use this product as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the brewing company rather it was funded by private efforts of the authors.

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ARTICLE

Asymmetric Impacts of Rising Food Prices on Household Welfare in South West Ethiopia

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ABSTRACT

Food price inflation is pervasive effects to household welfare and macroeconomy. The study estimated Quadratic Almost Ideal Demand system of six food groups to simulate money costs of food prices inflation on households' welfare and predict relative potency of income and price policies to counteract the effects in a particular context of South West Ethiopia. It drew on Household Income and Consumption Expenditure Survey data of 519 households collected by the Central Statistical Authority of Ethiopia. While response to income change of households is commodity specific, the rural dwellers respond more than urban counterparts to price changes. The welfare losses due to higher food prices fall heavily more on urban households than rural counterparts. On average, it requires resource allocation as large as percentage increases in prices which could be achieved through a mix of price and income policies to keep households' welfare at pre-price change level.

1. Introduction

Food prices will remain a topical issue of Least Developing Countries (LDCs) so long as food dominates budget of households [1-6]. Higher prices signal deficiency in supply to counterbalance demand side factors. Higher future population entails the challenge for feeding in the light of urbanization. Economic growth leads to diversification in nutritional diets and higher demand for high value food staffs [3,7]. The dynamic shifts in consumer preferences towards high value foods coupled with shocks such as drought will exacerbate deficiency in staple foods. The rise in inequality concomitant to income growth means that the rich afford both high value foods and staples while the poor cannot.

A higher food price implies a lower real income and a lesser consumption bundle limiting substitution of cheaper staples for preferable ones. Also, the poor have to compromise other life essentials [8] to be able to acquire minimum calory intake. The less diversified diet leads to deficiency

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in nutritional intake pervasive to household welfare [3]. For instance, the financial crises and food price surge of 2008 derived 175 million people worldwide into hunger and undernourishment [3]. The monthly report by Central Statistical Authority (CSA) shows that food prices have been increasing over the recent years by close to 40% a year and the burden of the price upsurge falls heavily on vulnerable poor households who spend nearly 80% of expenditure on foodstuff ①[6].The pervasive effects spill over to the macro-economy as social and political instability [2].

Food prices have attracted the attention of academics and practitioners for their asymmetric effects across different spectrums of livelihoods. i) Higher food prices are a blessing for net producers while it hurts net buyers [1,2,4,5]. Over the long run, higher prices have the potential to benefit rural households if it is incentive enough by turning them into net sellers [9]. ii) The negative effects are disproportionately borne owing to household characteristics such as headships, education, sex, age, residence location. The poor households are the most adversely affected group [1,5,6,10] due to deprivations of resources such as land, employment, and asset, etc. iii) welfare effect of price changes varies based on the weight of commodities in the budget of the household [1,4].

The current study shares the same motives with previous studies on Ethiopia and elsewhere to quantify the welfare cost of higher food prices but, in a particular context of Southwest Ethiopia. Capitalizing on the responses of consumers to changes in the economic environment, the research adds to the current body of knowledge in three ways :

First, it applied the current state-of-the-art framework known as Quadratic Almost Ideal Demand System (QUAIDS) by using Non-Linear Seemingly Unrelated Regression (NLSUR) to estimate food demand systems. The model helps to test the nonlinear curvature in food demand systems and the estimator imposes theoretic restrictions simultaneously controlling for censoring and endogeneity. Second, theoretic consistent elasticities provide insights into the potency of income and price policies to keep households well off in the event of price changes. Third, based on the second-order approximation, the study simulated Compensating Variations (CV) to establish discriminatory effects of higher food prices across different clusters of households.

Following the introduction, section two presents a review of recent literature. The third section presents the methodology applied to estimate elasticities and compute welfare effects. Section four discusses the results. Section five concludes along with policy implications.

① Visit https://tradingeconomics.com/ethiopia/inflation-cpi & the agency's web

2. Review of Literature

Demand elasticities are powerful tools for capturing adjustment in food consumption patterns that follow shocks to the budget constraints of households and quantifying the resulting welfare impact [11]. Once estimated, the welfare measure is used to establish nutritional deficiency and food security of households. Elasticity estimates also provide information that guides interventions to mitigate pervasive effects of price increases. Higher-income elasticity than price counterpart provides evidence for the more likely scope of income policy to achieve welfare outcomes [1,2,4,6,9,11,12].

Reliable estimates are likely to come from a system of demand functions that measure the household behavioral responses while simultaneously capturing heterogeneity in household characteristics. Unbiased and consistent measurements make results transferable [2]. However, there is an acute dearth of literature providing consistent elasticity estimates even at the continental level [7]. By a systematic review of empirical studies on food demand in Africa, observed high heterogeneity in income elasticities across countries, which could be partly an estimation issue. They highlighted the need for more country-specific studies supported with state-of-the-art methodologies to better inform agricultural and food policies. There are variant functional forms of demand models with desirable qualities dictated by demand theory.

One of contemporary the state of art frameworks is the Quadratic Almost Ideal Demand System (QUAIDS) pioneered by Banks et al. [13]. It is an improvement over the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer [14] after the latter failed to take account of non-linearity between food consumption and income. Moreover, QUADS has an exceptional quality of functional flexibility for obtaining luxuries (or necessities) goods for different income levels [2,3,11]. The framework is the best fit for a cross-sectional study based on low-income countries and is used for current study.

Many authors had drawn impressive results for different countries based on the QUADS. Prifti et al. [10] measure welfare impact on households in Lesotho by simulating prices of maize by 20%, 40%, and 60% and determine that it costs incomes amounting to 8.8%, 15.5%, and 20.3% respectively to keep consumption at the pre-shock level. They conclude that households need 40% more income to stay well off for every one percent increment in the price of maize during 2015/16.

Mbegalo et al. [2] quantifies that 22% food price inflation during the 2008-2012 years in Tanzania costs 11% of incomes of both the poor and middle classes and 8% that of rich households.

In India, 10 percent higher food prices derived nearly 5% rural and 2% urban households into poverty, amounting to 6% and 4% income loss respectively [3]. Besides, the author showed that both welfare and poverty effects get double when stimulated for a 20 percent price increment. Adekunle et al. [1] corroborate this finding that rural households are more vulnerable as there are more productive job opportunities in urban than rural areas. Moreover, Quentin et al. [4] showed that dominant food items in the budget of households determine poverty and welfare effects. By simulating the prices by 10 percent and 40 percent, rural households were worse hit by cereals and roots crops while animal products and vegetables severely affected urban counterparts.

Adekunle et al. [1] examine the welfare effects of food prices inflation on Nigerian households employing direct and indirect approaches. Second-order effects show that overall price rose by 2.38% between 2010 and 2016 and reduced Nigeria's net buyers' mean annual expenditure by 2 percentages while it increased net sellers' real income by 1.58%. According to first-order estimates, for a 1% increase in the price of cereals, an increase of 1.84% in the household income is required to allow individuals to enjoy real welfare.

Attanasio et al. [5] estimate that the average rural household in Mexico lost about 20% of food expenditure to higher food prices during 2011 alone, which reduces to 16% and 14% respectively when households are compensated with 50 Peso per week and 5% price subsidy. In rural Ethiopia, the poor are the worst adversely affected group by food inflation and the impact dies out as one jump to higher income group [6].

Akbari et al. [8] measure the welfare effects on Iranian urban households of 47 percent food price inflation between 2009/10-2011/12 as 49.9 percent food expenditure to keep households consumption at pre-price shock level.

3. Materials and Methods

Quadratic Almost Ideal Demand System

One way to express expenditure function of QUAIDS is ②:

$$\ln e(p,u) = \ln a(p) + \frac{b(p)U}{1-U\lambda(p)} \quad (1)$$

where $lna(p)$ is a transcendental price index given by:

$$lna(p)=\alpha_0 + \sum_{i=1}^{n} \alpha_i lnP_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} lnP_i lnP_j \quad (2)$$

b(p) is Cob- *Douglass price aggregator defined as :*

$$b(p) = \prod_{i=1}^{n} P_i^{\beta_i} = \exp(\textstyle\sum_i \beta_i lnP_i) \quad (3)$$

$\lambda(p)$ = is a differentiable, homogenous function

$\lambda(p) = \sum_i^n \lambda_i lnP_i$

where

$$\sum_i^n \lambda_i = 0 \quad (4)$$

U is utility & p is a set of prices and the subscript i = 1,....n denotes the number of food groups in the demand system.

Applying Shephard's lemma to (1) and substituting for U in the indirect utility function obtain expression for the QUAIDS:

$$w_i = a_i + \sum_{i=1}^{n} \gamma_{ij} lnP_j + \beta_i \ln\left(\frac{m}{a(P)}\right) + \frac{\lambda_i}{b(p)} \ln\left(\frac{m}{a(p)}\right)^2 + \varepsilon_i \quad (5)$$

where w_i is the expenditure share for the i^{th} food, a_i, Y_{ij}, β_i and λ_i are the parameters to be estimated; a_i is the constant coefficient in the i^{th} share equation, Y_{ij} is the slope coefficient associated with the j^{th} good in the i th share equation, P_j is the price of the j^{th} good, and m is the total expenditure on the system of foods; and ε_i is error term.

Demographic variables enter the system of budget share equations via a_i as intercept terms ③:

$$w_i = a_i + \sum_{j=1}^{k} \delta_{ij} D_j + \sum_{i=1}^{n} \gamma_{ij} lnP_j + \beta_i \ln\left(\frac{m}{a(P)}\right) + \frac{\lambda_i}{b(p)} \ln\left(\frac{m}{a(p)}\right)^2 + \varepsilon_i \quad (6)$$

where δ_i and δ_{ij} are parameters to be estimated and D_j is socio-demographic variables. Theoretical restrictions are given as follows:

Adding up of budget shares requires ($\sum_{i=1}^{n} w_i = 1$):

$$\sum_{i=1}^{n} \alpha_i = 1; \sum_{j=1}^{k} \delta_{ij} = 0 \sum_{i=1}^{n} \gamma_{ij} = \sum_{i=1}^{n} \beta_i = \sum_{i=1}^{n} \lambda_i \quad (7)$$

Homogeneity of zero degree in price:

$$\sum_{i=1}^{n} \gamma_{ij} = 0 \quad (8)$$

And

Slutsky symmetry: $Y_{ij} = Y_{ji}$ (9)

Two econometric issues have to get dealt with before estimation: one is censored demand equations attributed to zero consumption, which leads to corner solution. Zero consumption arises due to factors such as non-preference, non-affordability, purchase infrequency, non-availability, and self-consumption during the recall period of the sur-

② where $\log U = \frac{\log X}{b(p)+\lambda(p)\log X}$ is indirect utility function of *quadratic logarithmic budget share systems when* $\log X = \frac{b(p)U}{1-U\lambda(p)}$

③ Where $ai = ai + \sum_{j=1}^{k} \delta_{ij} D_j$ and $\sum_{j=1}^{k} \delta_{ij} = 0$

vey [11,15,16]. If not accounted for, regressing the censored QUADS model yields biased coefficients.

Shonkwiler et al. [17] propose a two-step econometric technique for handling censoring problem as described below: the first step obtains consistent estimates for d_i; the probability that a household consumes the food item by using probit model. Denote ϕ(.) and ϕ (.) respectively for the cumulative and density functions of standard normal distribution to derive expectation for observed budget share as:

$$W_i^* = \Phi(\mathcal{Z}_i' d_i) W_i + \varphi\phi(\mathcal{Z}_i' d_i) \quad (10)$$

where **z**s are observed characteristics. The second step replaces d_i with estimates to recover the parameters of demand system.

The second is endogeneity, which warrants attention here because expenditure may be correlated with unobserved variables in budget share equations or jointly determined with the budget shares [13,18] and results in biased and inconsistent parameter estimates [19,20]. To deal with endogeneity issue, censored demand system is augmented by residuals from reduced form expenditure model as below:

$$W_i^* = \Phi(\mathcal{Z}_i' \alpha_i)\left\{\alpha_i + \sum_{j=1}^{k} \delta_{ij} D_j + \sum_{i=1}^{n} \gamma_{ij} \ln P_j + \beta_i \ln\left(\frac{m}{a(P)}\right) + \frac{\lambda_i}{b(p)} \ln\left(\frac{m}{a(p)}\right)^2 + \sum \tau \acute{v}_i\right\} + \delta_i \varphi\phi(\mathcal{Z}_i' \alpha_i) \quad (11)$$

Demand Elasticities

By differentiating (14) with respect to lnm and ln P_j , for using afterwards to determine respectively expenditure and price elasticities, we get the following:

$$\epsilon_i = \frac{\partial w_i^*}{\partial lnm} = \Phi(\mathcal{Z}_i' \alpha_i)\left(\beta_i + \frac{2\lambda_i}{b(p)}\left\{ln\left[\frac{m}{a(P)}\right]\right\}\right) \quad (12)$$

$$\epsilon_{ij} = \frac{\partial w_i^*}{\partial lnp_j} = \Phi(\mathcal{Z}_i' \alpha_i)\left\{\gamma_{ij} - \epsilon_i\left(\alpha_j + \sum_{i=1}^{n} \gamma_{jk} lnP_k\right) - \frac{\lambda_i}{b(p)}\left\{ln\left[\frac{m}{a(P)}\right]\right\}^2\right\} \quad (13)$$

where P_k, *a price index is* calculated as the arithmetic mean of prices for all k food groups. Then, conditional expenditure elasticities are written as,

$$E_i = \frac{\epsilon_i}{w_i^*} + 1$$

and the conditional Marshallian price elasticities are derived as,

$$E_{ij}^u = \frac{\epsilon_{ij}}{w_i^*} - \vartheta_{ij},$$

where ϑ_{ij} is Kronecker delta defined as $\vartheta_{ij} = \begin{cases} 1 \; for \; i = j \\ 0 \; otherwise \end{cases}$.

Using the Slutsky equation allows us to derive, the conditional Hicksian (compensated) price elasticities as $E_{ij}^c = \frac{\epsilon_{ij}}{w_i^*} + E_i w_i^*$.

Hicksian price elasticities measure the response of a particular quantity of a commodity as price changes for a constant level of utility while the Marshallian price elasticities do the same for a constant level of income.

Welfare measures

Compensating variation was computed in a bid to quantify welfare effects of price hikes. The compensating variation is money transfer needed to compensate the consumers for the price changes so as to restore them to pre-shock positions.

Let Pc_{t-1}, M_{t-1} and U_{t-1} respectively denote vector of prices and money income and utility level before price changes: Pc_t and M_t represent respectively vector of prices and money incomes after price changes, and e_{t-1}, and e_t respectively denote expenditure functions before and after price changes. The compensation variation at time t is expressed in terms of expenditure function as,

$$CV = e(Pc_t, U_{t-1}) - e(Pc_{t-1}, , U_{t-1}) \quad (14)$$

Positive value indicates reduction in consumer welfare and vice versa for negavie.. The second order Taylor expansion ④ of the minimum expenditure function is given as:

$$\Delta \ln e_{it} = \sum_i w_{it} \Delta \ln p_{it} + \frac{1}{2} \sum_i \sum_i \varepsilon_{ij}^c w_{it} \Delta \ln p_{it} \Delta \ln p_{jt} \quad (15)$$

where P_{it} is vector of consumer are prices at time t; W_i is the budget share; ε_{it}^c is the conditional compensated price elasticity of commodity i with respect to the price change of good j; and Δsymbol stands for the variation between before and after shock period.

Data Sources and Descriptive statistics

The study used Household Income and Expenditure Survey (HIES) data collected by the Central Statistical Authority (CSA) of Ethiopia during 2016/2017. The data consist of information on various quantities of household consumables including non-food items; consumption expenditures and household demographics. The CSA's data covered a representative sample of 30,229 households nationally. After cleaning the original data of potential outlier observations, it draws on consistent data of

④ The first term of the right had expression denote the first order Taylor expansion

519 households for the South West region of which 296 of them are rural. ⑤ Back in 2016/16, the region consists of three zones Bench Maji zone consists of 265 households; Kaffa 132 (only rural) and Sheka Zones consist of 132 and 122 households respectively.

The CSA data on consumables were grouped into two distinct components: food and non-food items. The non-food groups include consumables such as housing, clothing, education, health, transport, and recreation. There are 18 food sub-groups according to CSA classifications making it difficult to analyze the demand for each commodity group. The decision to construct commodity groupings is left to the discretion of researchers and consequently is made on an ad-hoc basis as there is no theoretical basis [1]. However, for ease of practical and computational reasons, previous studies [6,9,11] were consulted and food commodities were classified into six groups: cereals, pulses and oils, root crops, fruits, and vegetables, animal products and other groups [11]. Nevertheless, aggregating food items into groups make it difficult to compute the prices of aggregated bundles. As a result, unit values calculated by dividing the purchase value by quantity were used despite the limitations that they might contain measurement errors, hide quality differences, reflect non-linear price quantity relations due to prices homogeneity [3,5,6]. For each food commodity group, the prices indices are computed as weighted means of commodities in that group, the weights being the mean budget shares of each item.

As shown in Table 1 cereals followed by other foods groups dominate the consumption patterns in the region. To urban dwellers, animal products and pulses and oils are preferred to fruits & vegetables to root crops while rural residents consume more quantities of pulses and oils, root crops, and fruits & vegetables than animal products.

⑤ Bench-Maji zone was dissolved into Bench-Sheko & Maji zones recently.

4. Results and Discussions

After making corrections for zero consumption in systems of demand equations and endogeneity in expenditure and household demographics, the QUADS was estimated using [21] nlsur. The estimator imposes theoretical restrictions such as symmetry, adding up, and homogeneity of QUADS mentioned in the last section. The different structural parameters for expenditure, expenditure square, and prices, demographic and instrumental variables are reported along with their p-values in Table A1 (Appendix). The statistical significance of most of the coefficients indicates that the commodity expenditure shares are responsive to prices and income and the household demographic variables included in the model.

An increase in own prices reduce quantities consumed of all food groups while that of cross price reduces and increases the quantity of others respectively for substitute and complimentary foods.

The significant coefficients for squared expenditure provide evidence in support of QUADS specification whereas the positive and negative sign of the expenditure and its square respectively indicate the property of Engle's curve; the consumption rises first and then fall as income increases consistently with that found by Mbegalo et al. [2] for rural Tanzania. Statistical significances of linear, square, and cubic terms of the residuals show the relevance of the instruments for controlling endogeneity.

Table 1. Food budget shares and proportion of zero expenditures(in brackets) by category

Items	Rural				Urban		
	Bench-Maji*	Kaffa	Sheka	Total	Bench-Maji	Sheka	Total
Cereals	0.34 (0.01)	0.17 (0.04)	0.17 (0.12)	0.22 (0.04)	0.35 (0.06)	0.11 (0.07)	0.28 (0.03)
Pulses & oils	0.11 (0.12)	0. 19 (0.27)	0.16 (0.09)	1.16 (0.08)	0.14 (0.14)	0.13 (0.04)	0.14 (0.12)
Root crops	0.10 (0.32)	0.16 (0.12)	0.17 (0.27)	0.14 (0.21)	0.03 (0.22)	0.16 (0.25)	0.07 (0.28)
Fruits & vegetables	0.18 (0.03)	0.11 (0.02)	0.15 (0.05)	0.14 (0.03)	0.13 (0.08)	0.11 (0.03)	0.13 (0.07)
Animal products	0.11 (0.46)	0.11 (0.75)	0.15 (0.27)	0.11 (0.47)	0.14 (0.34)	0.23 (0.26)	0.16 (0.32)
Other foods	0.16 (0.10)	0.26 (0.08)	0.19 (0.02)	0.20 (0.01)	0.20 (0.006)	0.23 (0.00)	0.20 (0.50)

Source: author's computation from CSA data

Larger family size is associated with higher consumptions of animal products and other food groups whereas it negatively influences demand for cereals, pulses & oils andd root crops. The positive association between household size and consumption of animal products is consistent with that obtained by Tefera et al. [6].

Headship difference in sex significantly affects the consumption of four food groups. For a rural community, head age increment is associated with a reduction in consumption of animal food and other foods and a rise in that of cereals. Across the three groups, there is a visible difference in consumption patterns due to residence between Bench Maji, Kaffa, and Sheka zones for most of the food groups.

Demand Elasticities

The marginal elasticities only represent quantity responses to changes in prices, incomes, and other determinants and consequently do not help to establish welfare effects of price changes. Representative expenditure and price elasticities have to be estimated at means of sample data for they are more certain than marginal changes. These are discussed in this section.

From Table 2 it can be seen that all food items across the three groups are normal goods as indicated by positive and significant coefficients. Animal products and other food are luxury items consistent with many previous studies [1,2,6,9]. The fact that consumption increases with income are an indication that households had yet not achieved desired quantities of the two food groups. The demand for pulses & oils has the lowest elasticities followed by fruits & vegetables and cereals. In other words, these goods are necessities, and fruits & vegetables are unitary elastic for urban residents. That is, the proportion of income expended on these food groups decreases as income increases whereas that of fruits and vegetables increases at the same rate as an expenditure. Thus, it is expected that an increase in income will shift consumption patterns away from cereals, fruits & vegetables, root crops, pulses & and oils toward animal products and other food.

Tables 3 and 4 respectively present Marshallian and Hicksian own and cross-price elasticities. The former represents changes in the quantity demanded as a result of changes in prices while capturing both substitution and income effect, whereas, Hicksian elasticity of demand denotes only the substitution effect as a result of price change keeping the level of utility constant. Hence, it is as expected that compensated elasticities are lower than the uncompensated counterparts.

Table 2. Expenditure elasticities

Items	Overall	Rural	Urban
Cereals	0.41 (0.08)***	0.41 (0.09)***	0.51 (0.08)***
Pulses & oils	0.17 (0.09)*	0.32 (0.11)***	–0.007 (0.12)
Root crops	–0.05 (0.16)	–0.02 (0.15)	–0.05 (0.26)
Fruits & vegetables	0.40 (0.12)***	0.57 (0.13)***	1.00 (0.11)***
Animal products	4.67 (0.4)***	3.37 (0.42)***	3.03 (0.27)***
Other foods	1.41 (0.15)***	2.14 (0.16)***	1.31 (0.15)***

The on diagonals cells are own-price elasticities. It can be observed from the two tables that wherever they are significant own-price elasticities are negative. The demand for all goods in the rural, cereals, pulses & oils and fruits & vegetables in urban are inversely related with own prices. An increment in own prices of those goods reduces demands consistent with theory. At the regional level, all goods except animal and other food have negative coefficients as well. Furthermore, the rural households' demand for animal products and other foods are price elastic implicating the quantity demands of the two goods fall at higher rates than price increment. As theoretically expected, the uncompensated elasticities are more elastic than compensated ones.

The off diagonals cells are cross-price elasticities, which measure the degree of substitutability and complementarily among commodities for negative and positive coefficients respectively. Of 90 estimated each uncompensated (Marshallian) and compensated (Hicksian) cross-price elasticities, 45 and 57 respectively are significantly different from zero at conventional significance levels. All coefficients except two are less than one in absolute value implying a weak response of one commodity group to changes in the price of the other. There is strong substitutability between animal products and other food as shown by higher cross-price elasticities; for one percentage increment in the price of other food, demand for animal products falls by 2.89 percent. On the other hand, the demand for other food falls by 3.96 percent in response to a percentage rise in the price of animal products of which the income effect is 1.05 percent. It is found that cereals are consumed along with pulses & oils, animal products, and other food while they are substitutes for root crops and fruits and vegetables. Thus, consumption of cereals falls as prices of the former groups rise and increase with prices of the later. This is consistent with patterns of consumption expected in Ethiopia.

Table 3. Marshallian (uncompensated) own and cross price elasticities.

Overall						
Equation	Cereals	Pulses and oils	Root crops	Fruits & vegetables	Animal products	Other foods
Cereals	**–0.81** **(0.03)*****	–0.03 (0.02)	–0.09 (0.02)***	–0.07 (0.02)***	0.32 (0.05)***	0.26 (0.05)***
Pulses & oils	0.014 (0.03)	**–0.52** **(0.04)*****	–0.02 (0.03)	0.12 (0.03)***	–0.07 (0.05)	0.12 (0.06)
Root crops	–0.14 (0.05)***	0.007 (0.05)	**–0.30** **(0.06)*****	–0.09 (0.04)***	0.29 (0.08)***	0.29 (0.10)***
Fruits & vegetables	–0.13 (0.03)***	0.09 (0.03)***	–0.11 (0.03)***	**–0.82** **(0.03)*****	0.37 (0.06)***	0.19 (0.06)***
Animal products	–0.27 (0.08)***	–0.59 (0.09)***	–0.19 (0.07)***	–0.11 (0.06)*	0.45 (1.61)	–3.96 (1.59)**
Other foods	0.04 (0.03)	–0.08 (0.04)**	–0.02 (0.03)	–0.02 (0.03)	–1.47 (0.73)**	–0.14 (0.84)
Rural						
	Cereals	Pulses and oils	Root crops	Fruits & vegetables	Animal products	Other foods
Cereals	**–0.72** **(0.04)*****	–0.007 (0.03)	–0.08 (0.03)***	–0.02 (0.02)	0.07 (0 .04)***	0.34 (0.05)*
Pulses & oils	0.03 (0.04)	**–0.65** **(0 .05)*****	–0.02 (0 .03)	0.08 (0.03)**	0.04 (0.05)	0.20 (0.06)
Root crops	–0.04 (0.05)	0.03 (0.05)	**–0.50** **(0.06)*****	–0.07 (0.04)*	0.18 (0.07)***	0.40 (0.09)***
Fruits & vegetables	–0.06 (0.04)	0.04 (0.04)	–0.13 (0.04)***	**–0.88** **(0.04)*****	–0.1 (0.05)***	0.32 (0.07)***
Animal products	–0.51 (0.09)***	–0.41 (0 .11)***	–0.12 (0 .09)	–0.16 (0.07)***	**–4.47** **(2.32)***	2.29 (2.36)
other foods	–0.07 (0 .04)*	–0.16 (0.04)***	–0.05 (0.04)	–0.03 (0.03)	0.91 (0.82)	**–2.75** **(0.83)*****
Urban						
	Cereals	Pulses and oils	Root crops	Fruits & vegetables	Animal products	Other foods
Cereals	**–0.69** **(0.07)*****	0.02 (0.03)	–0.11 (0.02)***	-0.15 (0.03)***	0.25 (0.07)***	0.17 (0.07)
Pulses & oils	0.2 (0.07)	**–0.4** **(0.08)*****	–0.004 (0.04)	0.15 (0.05)***	–0.08 (1.11)**	0.11 (0.11)
Root crops	–0.4 (0.13)***	–0.03 (0.10)	–0.001 (0.12)	–0.02 (0.09)	0.34 (0.27)	0.09 (0.28)
Fruits & vegetables	–0.5 (0.06)***	–0.02 (0.05)	–0.07 (0.04)*	**–0.77** **(0.05)*****	0.31 (0.11)***	–0.01 (0.11)
Animal products	–0.19 (0.15)	–0.53 (0.12)***	–0.01 (0.11)	0.05 (0.10)	–2.46 (3.15)	0.11 (3.03)
Other foods	–0.01 (0.08)	–0.12 (0.07)	–0.05 (0.07)	–0.05 (0.06)	–0.31 (2.16)	–1.39 (2.14)

***, **, * denote significance at 1, 5 and 10 percent, respectively. Standard errors in brackets.

Table 4. Hicksian (compensated) own and cross price elasticities.

Overall						
Equation	Cereals	Pulses and oils	Root crops	Fruits & vegetables	Animal products	Other foods
Cereals	**–0.70 (0.04)*****	0.04 (0.02)***	–0.05 (0.02)***	–0.008 (0.02)***	0.37 (0.04)***	0.35 (0.04)***
Pulses & oils	0.06 (0.03)***	**–0.50 (0.04)*****	–0.002 (0.03)	0.14 (0.02)***	0.09 (0.05)	0.21 (0.05)***
Root crops	–0.16 (0.05)***	0.001 (0.04)	**–0.30 (0.06)*****	–0.10 (0.04)	0.29 (0.08)***	0.28 (0.08)***
Fruits & vegetables	–0.02 (0.03)***	0.15 (0.03)***	–0.07 (0.03)**	**–0.75 (0.03)*****	0.41 (0.05)***	0.28 (0.05)***
Animal products	0.99 (0.11)***	0.12 (0.07)***	0.27 (0.07)**	0.57 (0.07)***	0.93 (1.61)	–2.89 (1.59)*
Other foods	0.41 (0.05)***	0.13 (0.03)***	0.12 (0.04)***	0.18 (0.03)***	–0.13 (0.72)	0.46 (0.72)
Rural						
	Cereals	Pulses and oils	Root crops	Fruits & vegetables	Animal products	Other foods
Cereals	**–0.62 (0.04)*****	0.07 (0.03)***	–0.03 (0.02)	0.04 (0.02)***	0.10 (0.04)	0.43 (0.04)***
Pulses & oils	0.10 (0.04)***	**–0.60 (0.05)*****	0.02 (0.03)	0.12 (0.02)***	0.07 (0.05)	0.27 (0.05)***
Root crops	–0.05 (0.04)	0.03 (0.04)	**–0.49 (0.06)*****	–0.07 (0.04)	0.18 (0.06)	0.40 (0.07)***
Fruits & vegetables	0.08 (0.03)***	0.13 (0.03)***	–0.06 (0.03)	**–0.79 (0.04)*****	0.18 (0.05)	0.45 (0.05)*
Animal products	0.31 (0.12)	0.13 (0.10)	0.31 (0.10)***	0.36 (0.09)***	**–4.20 (2.32)***	3.07 (2.34)
Other foods	0.45 (0.04)***	0.19 (0.04)**	0.23 (0.04)***	0.31 (0.03)*	1.08 (0.82)	**–2.26 (0.84)*****
Urban						
	Cereals	Pulses and oils	Root crops	Fruits & vegetables	Animal products	Other foods
Cereals	**–0.53 (0.07)*****	0.09 (0.03)***	–0.08 (0.02)**	–0.08 (0.02)**	0.31 (0.07)***	0.28 (0.06)***
Pulses & oils	0.18 (0.07)***	**–0.35 (0.07)*****	–0.004 (0.04)	0.15 (0.04)***	–0.08 (0.10)*	0.11 (0.11)**
Root crops	–0.44 (0.13)**	0.03 (0.10)	–0.002 (0.12)	–0.02 (0.09)	0.34 (0.26)	0.09 (0.26)
Fruits & vegetables	–0.18 (0.06)**	0 .16 (0 .05)***	–0.008 (0.04)	–0.63 (0.06)	0.45 (0.10)***	0.21 (0.10)
Animal products	0.74 (0 .15)***	–0.10 (0 .10)	0.16 (0.10)	0.45 (0.10)***	–2.05 (3.13)	0.80 (3.06)
Other foods	0.39 (0.08)***	0.06 (0.07)	0.02 (0.07)	0.13 (0.06)	0.49 (1.84)	–1.09 (1.81)

***, **, * denote significance at 1, 5 and 10 percent, respectively & Standard errors in brackets.

Comparison of expenditure and price elasticities reveals interesting policy prescriptions about the relative effectiveness of income and price policies vis-avis rural and urban areas. It is observed that the large expenditure elasticities for urban areas implicate relative effectiveness of income policies to offset pervasive impacts of higher food prices over those of prices and whereas the larger price elasticities of the rural households emphasize the opposite.

Effects of price changes on Consumer welfare

The compensated elasticities are used to compute the welfare effects of simulated 20 and 40 percent increments in food prices. The CV measures the total transfer required to compensate all households for the price changes they experienced as a percentage of their initial total expenditure. The first order (static) approximation measures consumption responses to price changes while ignoring household behavioral responses. In contrast, the second-order (dynamic) approximation removes the substitution effects as if households are able to change their consumption patterns when prices change. Therefore, given the substantial observed price changes, substitution effects can be non-trivial, and first-order approximations may lead to significant biases and are inappropriate [13]. Table 6 shows how much first-order Taylor expresses is inflating over second-order approximation.

On average, a 20 percent increment in food prices reduces the purchasing power of southwest households by about 25 percent. When food prices were raised by 40 percentages, the loss reaches as large as 45 percent. According to the first-order approximation estimates, the welfare losses are 75 and 95 percentages for respective price simulations. Based on the second-order approximation, however, it suffices to compensate the households with a little higher income than the percentage rise in prices.

Consistent with [2,5,6] it was observed that food price hikes hart urban households than the rural counterparts. The welfare losses for worst-hit urban households, upper quintile are 78 and 1.22 percent receptively for 20 and 40 percent price increment. The least hit rural households losses from the same are 21 and 42 percentages respectively.

5. Conclusions

The following insights were drawn from the results of the study: (i) Household demand for foods are affected not by price and income alone but reflect differences in tests and preferences across households due to size, sex, age, education, and location. The non-linear curvature in-demand system provides information about the characteristics of food demand in southwest Ethiopia. (ii) The elasticities at the mean of the sample are also consistent with consumer theory: all food staffs are normal goods; animal products and other food being luxury items in the expenditure composition of households. All significant the own-price elasticities were all negative and the demand for most of foods is sensitive to cross prices. Higher-income elasticities of urban households imply relative potency of income policies over price policies to mitigate negative

Table 5. simulated welfare effects of price increases

First order effects of proportion of expenditure						
	20% increase			40% increase		
	Overall	Rural	Urban	Overall	Rural	Urban
25th percentile	0.43 (0.03)***	0.38 (0.03)***	0.48 (0.04)***	0.60 (0.03)***	0.56 (0.04)***	0.64 (0.04)***
50 th percentile	0.66 (0.03)***	0.64 (0.04)***	0.67 (0.04)***	0.83 (0.03)***	0.84 (0.04)***	0.83 (0.04)***
75th percentile	0.86 (0.04)***	0.83 (0.06)***	0.88 (0.04)***	1.04 (0.04)***	1.01 (0.06)***	1.05 (0.06)***
Mean	0.74	0.69	0.78	0.92	0.89	0.95
Second order effects of proportion of expenditure						
	20% increase			40% increase		
	Overall	Rural	Urban	Overall	Rural	Urban
25th percentile	0.27 (0.03)***	0.21 (0.04)***	0.32 (0.04)***	0.42 (0.04)***	0.50 (0.04)***	0.75 (0.05)***
50 th percentile	0.46 (0.04)***	0.49 (0.03)***	0.53 (0.05)***	0.65 (0.04)***	0.70 (0.04)***	0.98 (0.04)***
75th percentile	0.76 (0.05)***	0.73 (0.08)***	0.78 (0.07)***	1.00 (0.06)***	0.98 (0.04)***	1.22 (0.06)***
Mean	0.25	0.22	0.28	0.45	0.42	0.52

*** denote significance at 1 & figures in brackets are Standard errors.

consequences on welfare while the larger elasticities indicate the reverse. (iii) The results for simulated effects of higher prices showed that higher food prices erode the purchasing power of the household and are pervasive to welfare the burden falling largely on urban households. In order to mitigate the negative consequences on the dietary of households, average households need percentage income compensation as large as the percentage increment in food prices. But, the lower-income households in both groups need at least three-fold percentages as large as the average.

Nevertheless, these findings should have been drawn from a framework that incorporates the production side for rural households and from data sets that capture rencent developments.

Conflict of Interest

The author declares that there is no conflict of interest related to the research.

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Appendix

Table A1. Quadratic Almost Ideal Demand Systems estimates

		Overall	Rural	Urban
Linear term	β_1	–0.03 (0.03)	–0.08 (0.03)**	–0.05 (0.02)***
	β_2	–0.03 (0.03)	–0.09 (0.03)***	0.07 (0.01)***
	β_3	0.15 (0.03)***	0.003 (0.03)	0.06 (0.02)***
	β_4	–0.09 (0.03)***	0.04 (0.02)**	0.06 (0.01)***
	β_5	0.007 (0.05)	0.15 (0.04)***	–0.006 (0.04)
	β_6	–0.007 (0.05)	–0.06 (0.04)	0.02 (0.03)
Quadratic term	λ_1	0.03 (0.006)***	0.02 (0.004)***	0.02 (0.004)***
	λ_2	0.01 (0.004)***	0.002 (0.004)***	0.03 (0.003)***
	λ_3	0.04 (0.004)***	0.02 (0.003)***	0.02 (0.004)***
	λ_4	0.0009 (0.005)	0.006 (0.004)	–0.006 (0.003)**
	λ_5	–0.05 (0.01)***	–0.009 (0.005)*	0.02 (0.006)***
	λ_6	–0.02 (0.01)**	–0.03 (0.0005)***	–0.04 (0.007)***
Prices	γ_{11}	**–0.04 (0.009) *** **	**–0.07 (0.01) *** **	**–0.08 (0.02)*** **
	γ_{21}	–0.003 (0.007)	0.007 (0.01)	0.009 (0.01)
	γ_{31}	–0.017 (0.007) **	–0.006 (0.009)	–0.034 (0.007)***
	γ_{41}	–0.02 (0.007) ***	–0.009 (0.007)	–0.06 (0.008)***
	γ_{51}	–0.01 (0.01)	–0.04 (0.01) ***	–0.001 (0.01)
	γ_{61}	0.012 (0.008)	–0.01 (0.02)	0.004 (0.01)
	γ_{22}	**–0.08 (0.009) *** **	**–0.07 (0.01) *** **	**–0.09 (0.01) *** **
	γ_{32}	–0.005 (0.008)	0.01 (0.01)	0.008 (0.004)
	γ_{42}	0.02 (0.007)***	0.011 (0.008)	–0.0004 (0.004)
	γ_{52}	–0.07 (0.02)***	–0.06 (0.01) ***	–0.08 (0.02) ***
	γ_{62}	–0.02 (0.009)*	–0.04 (0.02) **	–0.032 (0.016) **
	γ_{33}	**–0.09 (0.009)*** **	**–0.08 (0.01) *** **	**–0.07 (0.007)*** **
	γ_{43}	–0.03 (0.007)***	–0.014 (0.01) **	–0.01 (0.006)**

	γ_{53}	–0.03 (0.013) **	–0.03 (0.016)*	–0.01 (0.01)
	γ_{63}	–0.01 (0.011)	–0.04 (0.01)***	–0.016 (0.014)
	γ_{44}	–0.04 (0.009)***	–0.02 (0.005)***	–0.03 (0.007)**
	γ_{54}	–0.01 (0.014)	–0.009 (0.11)	0.042 (0.014)****
	γ_{64}	–0.003 (0.009)	0.005 (0.11)	0.0003 (0.014)
	γ_{55}	**–0.4 (0.17)** **	–0.18 (0.19)	–0.05 (0.41)
	γ_{65}	–0.27 (0.16)*	0.32 (0.19)*	0.107 (0.41)
	γ_{66}	**–0.29 (0.16)** **	–0.23 (0.19)	–0.06 (0.41)
Family size	δ_{11}	–0.001 (0.001)	–0.0006 (0.0013)	–0.004 (0.002)**
	δ_{21}	–0.001 (0.0008)	–0.0021 (0.001)**	–0.003 (0.001)***
	δ_{31}	–0.003 (0.0008)***	–0.004 (0.001)***	–0.0006 (0.0008)
	δ_{41}	–0.0008 (0.0008)	0.0003 (0.0008)	–0.0009 (0.0008)
	δ_{51}	0.0030 (0.0016)*	0.002 (0.0013)*	0.004 (0.002)**
	δ_{61}	0.0026 (0.0011)**	0.004 (0.002)**	0.005 (0.002)***
Sex	δ_{12}	–0.007 (0.006)	–0.017 (0.006)***	–0.011 (0.007)
	δ_{22}	0.009 (0.004)**	–0.002 (0.005)	0.003 (0.004)
	δ_{32}	0.012 (0.004)***	0.003 (0.005)	0.001 (0.003)
	δ_{42}	0.007 (0.004)**	–0.008 (0.004)**	0.0126 (0.004)***
	δ_{52}	–0.013 (0.008)	0.005 (0.006)	–0.005 (0.008)
	δ_{62}	–0.009 (0.006)*	0.02 (0.008)**	–0.001 (0.008)
Age	δ_{13}	0.0002 (0.0002)	0.0004 (0.0002)**	0.0001 (0.0002)
	δ_{23}	–0.0001 (0.000)	0.00013 (0.00014)	–0.00012 (0.0002)
	δ_{33}	0.000018 (0.00014)	0.00018 (0.00015)	0.00018 (0.0011)
	δ_{43}	–0.00004 (0.0001)	0.00014 (0.00012)	0.00003 (0.0011)
	δ_{53}	0.0003 (0.0003)	–0.0004 (0.0002)**	–0.00004 (0.0003)
	δ_{63}	–0.00031 (0.00018)	–0.0004 (0.0002)	–0.00012 (0.0003)
Literacy	δ_{14}	0.0032 (0.008)	–0.008 (0.009)	–0.006 (0.011)
	δ_{24}	0.008 (0.006)	0.005 (0.007)	0.0014 (0.007)
	δ_{34}	0.004 (0.006)	0.001 (0.008)	0.006 (0.005)
	δ_{44}	0.0008 (0.005)	0.010 (0.006)	–0.005 (0.006)
	δ_{54}	–0.0125 (0.01)	–0.001 (0.008)	0.004 (0.012)
	δ_{64}	–0.0034 (0.006)	–0.007 (0.010)	–0.0014 (0.011)
Years of schooling	δ_{15}	0.0011 (0.0008)	0.002 (0.0016)	0.0017 (0.001)*

	δ_{25}	–0.0009 (0.0008)	–0.0006 (0.001)	–0.00002 (0.0006)
	δ_{35}	0.0006 (0.0006)	–0.0001 (0.0013)	0.0005 (0.0004)
	δ_{45}	0.0007 (0.0005)	–0.003 (0.001)***	0.0009 (0.0004)**
	δ_{55}	–0.0003 (0.001)	–0.0009 (0.001)	–0.003 (0.0018)*
	δ_{65}	–0.0017 (0.001)	0.0024 (0.002)	–0.00007 (0.002)
Kaffa dummy	δ_{16}	0.058 (0.007) ***	0.07 (0.007)***	---
	δ_{26}	–0.023 (0.006) ***	–0.01 (0.004)***	---
	δ_{36}	–0.047 (0.006) ***	–0.02 (0.005)***	---
	δ_{46}	0.012 (0.004) ***	0.027 (0.005)***	---
	δ_{56}	0.009 (0.015)	0.003 (0.012)	---
	δ_{66}	–0.009 (0.013)	–0.07 (0.015) ***	---
Sheka dummy	δ_{17}	0.06 (0.007) ***	0.06 (0.008)***	0.06 (0.008)***
	δ_{27}	–0.025 (0.006) ***	–0.005 (0.005)	–0.014 (0.006)***
	δ_{37}	–0.06 (0.006) ***	–0.025 (0.006)***	–0.05 (0.005)***
	δ_{47}	–0.008 (0.005)	0.012 (0.004)***	0.08 (0.004)**
	δ_{57}	0.05 (0.01)***	–0.032 (0.008)***	0.011 (0.013)
	δ_{67}	–0.011 (0.009)	–0.015 (0.01)	–0.02 (0.012)*
V	δ_{18}	–0.06 (0.015)***	0.09 (0.017)***	–0.07 (0.023)***
	δ_{28}	–0.049 (0.01)***	0.06 (0.017)***	–0.075 (0.016)***
	δ_{38}	–0.045 (0.01)***	0.068 (0.016)***	–0.008 (0.011)
	δ_{48}	–0.014 (0.01)	0.068 (0.013)***	(0.010) (0.011)
	δ_{58}	0.13 (0.02)***	–0.14 (0.023)***	0.010 (0.11)
	δ_{68}	0.034 (0.018)**	–0.15 (0.028)***	0.13 (0.03)***
v-square	δ_{19}	–0.007 (0.12)	0.02 (0.016)	0.01 (0.03)
	δ_{29}	–0.0139 (0.009)	0.02 (0.011)*	–0.0018 (0.02)
	δ_{39}	–0.008 (0.009)	0.017 (0.011)	–0.12 (0.016)***
	δ_{49}	0.06 (0.009)***	–0.013 (0.008)	0.03 (0.017)**
	δ_{59}	–0.04 (0.016)***	–0.01 (0.016)	0.042 (0.012)***
	δ_{69}	0.005 (0.012)	–0.034 (0.017)*	0.038 (0.028)
v-cub	δ_{110}	0.07 (0.016)***	–0.003 (0.014)	0.019 (0.026)
	δ_{210}	0.024 (0.011)**	–0.017 (0.01)	0.027 (0.032)
	δ_{310}	0.025 (0.011)**	–0.018 (0.011)	–0.104 (0.019)***
	δ_{410}	–0.038 (0.01)** *	–0.063 (0.009)***	–0.0018 (0.014)

	δ_{510}	–0.057 (0.019)** *	0.05 (0.01)	0.036 (0.016)**
	δ_{610}	–0.02 (0.016)	0.05 (0.016)***	–0.0005 (0.03)
Constant	α_1	0.026 (0.066)	–0.017 (0.07)	–0.036 (0.038)
	α_2	–0.117 (0.05)**	–0.19 (0.06)***	0.0006 (0.028)
	α_3	0.20 (0.054)***	–0.04 (0.08)	0.119 (0.02)***
	α_4	–0.127 (0.048)***	–0.012 (0.06)	0.075 (0.02)***
	α_5	0.78 (0.105)***	0.48 (0.12)***	0.52 (0.07)***
	α_6	0.24 (0.094)**	0.78 (0.12)***	0.311 (0.07)***

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ARTICLE

Assessment of Pesticide Use against Tephritidae Fruit Fly and Other Pest among Small-scale Solanaceous Vegetable Farmers in Bugorhe-Kabare the Democratic Republic of Congo

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ABSTRACT

Ninety-six farmers interviewed in Kabare, east of the DR Congo during 2021. Farmers majority were males (79.17%), ranging 30 to 60 years, used different pesticides in vegetable farms and the main solanaceous crops cultivated is tomato. The use of insecticide and fungicide were high, with many different formulations of the different class types recorded in use, (20%) endocrine disruptors, (40%) cholinesterase inhibitors, (35%) carcinogen and potential carcinogens suspected to be. A lot of out of those pesticides are unregistered for general use. Farmers applied pesticide once a week and they didn't have specific instructions. The skin effects, headaches and dizziness are dominant. They do not have a good system of pesticide packaging management. For reducing pesticide application, we propose options of agro ecology. We suggest that the Congolese government must create a quarantine, control and surveillance service for phytosanitary products, fruits and vegetables within the DRC country and at these borders. Also, it needs urgent action from the federal and regional governments to formulate policy, design legislation, and enforcing for its implementation concerning the supply, transportation, storage, appropriateness, and application of harmful pesticides.

1. Introduction

Different types of insect pests afflict production in western Albertan Rift area [1,2]. Tephritid fruit flies such as *Dacus bivittatus* (Bigot), *D. punctatifrons* Karsch, *Bactrocera dorsalis* (Hendel), *B. latifrons* (Hendel), *Ceratitis cosyra* (Walker), *C. rosa* Karsch, *C. fasciventris* Bezzi, *C. capitate* (Wiedemann), *Zeugodacus cucurbitae* (Coquillett) and other pests such as *Anarsia lineatella* Zeller (Lepidoptera, Gelechiidae), *Comstockaspis perniciosus*

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(Comstock) (Hemiptera: Diaspididae) constitute a major constraint to increased production of fruits and vegetables in orchards and gardens [3-7] and those small-scale farmers has a lack of fundamental horticultural knowledge [8]. For example, the native species of tephritid fruit flies cause high damage and serious problems to growers. However, the invasion of *B.* dorsalis has exacerbated the situation, with damage frequency reaching 100% in the absence of effective control [9,10]. This species is highly invasive than local fruit fly species in smallholder crops [9]. Even today, Abang et al. [11,12] show significantly losses through direct damage to fruits, vegetables and loss of market opportunities. According to Mengistie [13,14], Fikadu [15] pesticide refers to a wide range of compounds including insecticides, herbicides, fungicides, rodenticides, molluscicides and plant growth regulators. Promoting the sustainability, several authors [11,16-20] demonstrated that agro-pesticide technologies (insecticides, fungicides and herbicides) were one of the driving forces for the development of agriculture. Moreover, requirement of pesticides is higher in Bugorhe area at Kabare, South Kivu province. Bugorhe area is one of the major suppliers of vegetables in the Bukavu town. However, the sharp increase in the urban population of Bukavu town poses several challenges, including food security (supplying these cities with food), job creation and income generation [21,24]. In order to meet these challenges, poor families in cities resort to market gardening [24,25]. These market garden centers generally exploit fruit vegetables (tomato, chili, pepper, eggplant, okra, and watermelon), tubers/bulb (carrot, onion) and some exotic leafy vegetables (scallions, leek). Indeed, Ekesi [10] reported that. Again, market garden smallholders have a lot of difficult to get chemical pesticides, traps, lures and food baits, lack of IPM method and IPM experts, use and consequences chemical, lack of packaging management. Those market garden smallholders saw and knew fruit flies and other pest at solanaceous crop. In addition, the market garden smallholders do not know the good way to use chemical pesticides and traps such as lures as well as food bait are not sold in the east of the DRC in general and in South Kivu in particular. Relatively no pesticides on market garden such as solanaceous crop in study area. However, paper assesses farmers' smallholders chemical use in control of Solanaceous (tomato, eggplant, pepper, chili) pests Bugorhe-Kabare area at the western of Albertan Rift area.

2. Materials and Methods

The study was carried out in Bugorhe area, which is located at the Kabare territory (Latitude: 2° 30′ and 2° 50′S, Longitude: 28° 45′ and 28° 55′E, Southwestern of the Kivu Lake) at the South Kivu province, eastern part of DR Congo. It is peripheral to the Kahuzi-Bièga National Park is located in the community Kabare chiefdom in South Kivu Province and inhabited by the Bashi ethnic group [25]. The survey covered the period from January 01 to March 28; 2021. Simple random sampling was used. This least biased technique and also gives every element an equal chance for selection during the study [26] and some criteria were followed by the quota method [27,28]: being market gardeners (tomato, pepper, eggplant and pepper) and/or sellers of phytosanitary products and in one of the localities of the Bugorhe group, 12 market gardeners of these solanaceous and sellers of phytosanitary products of male and female sexes combined and chosen by locality, the freedom of choice left to the investigator. The sample size is 96 market gardeners. Research instrument includes reconnaissance survey interview questionnaire test, interview and field survey, smallholder vegetables and focus group discussions. Semi-structured type of questionnaire considering the purposed of study the farmer's practices, their knowledge and perceptions regarding the uses of pesticides. These include the socio professional characteristic of small-scale solanaceous vegetable farmers, crop production, main market gardeners' crops used, types of pesticides, pesticide application, pesticide mixtures used, trend in pesticide use, reasons given, system pesticide packaging management. Data were obtained from primary and secondary sources. Items were designed based on published literature on the subject as well as the authors' experiences in the field. Data were collected through survey face-to-face interviews with farmer's farm workers during activities. The questionnaire was designed and translated into Kiswahili (the national language) is understood by the majority of farmers and pre-tested small samples of farmers in the same areas before using it in this study. The data being encoded in Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA, USA) and R (R Core Team, 2018) were analyzed. Two-way ANOVA was used at the significant level of 1%. The Tukey multiple comparison was being used too at the confidence level of 95%. Before the variance analyze application, normality verification of data distribution hypothesis was being done by the Bartlett's K-squared test and the descriptive result was expressed by percentage.

3. Results and Discussion

3.1 Socio Professional Characteristic

The majority of farmers were male (79.17%) with an average age of 30, ranging from 30 to 60, reported the use of different pesticides in more vegetable farms in Bughore-Kabare zone. According to their level of education, 46.87% of these men attended primary school and 36.46% secondary school and 16% university, while 63.54% of them did not have agricultural training and 36.46% are trained in agriculture. Mawussi [29] and Mondedji [30] show a small percentage woman (8%~28%) are involved in market gardening in Togo too. The low involvement of women in the production of fruit vegetables (tomato, chili, eggplant and pepper) could be explained in the fact of that, women are generally not empowered to apply the phytosanitary treatment required by these crops [21]. Acquiring product, preparing and using, and for uninitiated who constitute a large proportion of peasant women. Our result joined the results of Mawussi [29] and Wade [30], the market gardeners farm carried on through no employment and/or no decent salary with a level of primary and secondary school.

3.2 Solanaceous Output in Study Area during the Period of 2017 to 2021

The mean of tomato (5780 kg ± 471.17) differed to the mean of eggplant (4700 kg ± 158.11). The Table 1 presented the ANOVA summary of solanaceous output in study area during the period of 2017 to 2021.

The Table 1 shows a significant difference between the outputs of market garden crop. In case of years, there is no difference, *i.e.*, during the five years solanaceous products were the same with a high tomato output. This result is similarly to that of the South Kivu Agricultural Inspector [32].

3.3 Main Market Gardeners' Crops Used

The main cultivated solanaceous crops grown in the Bughore area is tomato (*Lycopersicon esculantum*) at 47.92% followed by eggplant (*Solanum melongena*) at 36.46%, pepper (*Capsicum frutescens*) at 10% and pepper (*Capsicum annum*) at 5.21%. His reasons for choosing vegetable crops one of them for their short-cycle, easy-to-practice crops, another group for their short-term profitable investment and the last group for their crops with very high market value per unit area. This may be explained the important income generation and job creation [31,33] and in order to meet these challenges, poor families in cities resort to urban and peri-urban agriculture, in particular market gardening [31,33]. Ngowi [34] reported similar result.

3.4 Types of Pesticides

Farmers in the Bughore-Kabare region most often use insecticides (44.79%) and fungicides (43.75%) but also 4.17% herbicides and 7.29% rodenticides due to the production of tomatoes, eggplants, peppers and peppers and other vegetables. The type of pesticides used in different crops depended on the pest population and their potential damage to the crop as well as farmers' perception pest management practices. Pesticides were supplied in containers ranging from 0.5 liters to 5 liters or in ranging from 0.5 kilograms to 25 kilograms. In most cases, liter and kilogram were common, as well as of quantities by vendors. Beránková [35], Sougnabe [36] reported similar result in African countries and worrying risk values for the exposure of market gardeners to pirimicarb and Chlorpyrifos-methyl. Given large number pesticides used and the frequency of application (very high risk of bioaccumulation of pesticides). chemical pesticides cannot unless the methods of use are perfectly mastered [37,38].

The Table 2 presents pesticides found in study area such as Cobox, Cypercal, Dimethoate, Dithane M45, Dursban, Dust, Dynamec, Funguran, Ivory 80WP, Mamba, Polytrin, RedCat, Ridomil, Rogor, Roundup, Selecron, Shumba dust, Sumithion, Thiodan and Thionex). In the Bughore-Kabare area, insecticides and fungicides registered of being endocrine disruptors (20%), 40% cholinesterase inhibitors and 35% were carcinogenic potentially carcinogenic. Many end-of-use pesticides were not registered for general use. However, the acelamectin (abamectin, abactin, acetamiprid) and dichlorvos, dimethoate and dithiocarbamates (Glucocorticoids), sulfate, metalaxyl-M, zinc, manganese, and mancozeb were also used. Gupta [39] have found that and other authors [40-44]. More of farmers applied pesticide once a week. The fact that pesticides are more expensive [45,46]. Assogba-Komlan [47] reported that too.

Table 1. ANOVA summary of solanaceous products

Source of variance	Df	Somme of square	Square of mean	F value	Pr (>F)
Years	1	144500	144500	1.199	0.30973
Market gardener's crop	1	2916000	2916000	24.199	0.00172 **
Residuals	7	843500	120500		
Tukey multiple comparison					
	Difference	lower	upper	p adj	
Tomato- eggplant	1080	560.8586	1599 .141	0.0017151	

Codes of signification: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 2. Types of pesticides used in Bugorhe-Kabare area (2021), classified using the WHO Hazard Class and health effects (2005) [34,38]

Trade Name	Common Name	WHO Class[a]	Health Effects[b]	Target pests	Registration status[c]
Cobox	Copper oxychloride	III		Fungus	R
Cypercal	Cypermethrin	II	SE, PC	Larger-grain-borer	R
Dimethoate	Dimethoate	II		Insects	R
Dithane M45	Mancozeb	U	SE, C	Blight, downy-mildew, fruit fly, leaf-rust, wilting	R
Dursban	Chlorpyrifos	II	CI	Armyworm, cutworms, stem-borer	R
Dust	Methyl+permethrin	NK	PC	Stem-borer	R
Dynamec	Abamectin	II		insects	R
Funguran	Copper hydoxide	III		Leaf-rust	R
Ivory 80WP	Mancozeb	U	SE, C	Blight	R
Mamba	Glyphosate	U		Weeds	R
Polytrin	Cypermethrin	II		Insects, thrips,	R
RedCat	Zinc phosphide	Ib		Rats	U
Ridomil	Mancozeb+metalaxyl	NK	SE, C	Blight, spidermite	R
Rogor	Dimethoate	II		Stalkborer	U
Roundup	Glyphosate	U		Weeds	R
Selecron	Profenofos	II	CI	Aphids, fruit-borer, stemborer, spidermite, thrips, whitefly insects,	R
Shumba dust	Fenitrothion+deltamethrin	II	CI	Larger-grain-borer	R
Sumithion	Fenitrothion	II	CI	Stem-borer	U
Thiodan	Endosulfan	II	SE	Beetle, larger-grain-borer, leafminer, red-ants, stem-borer	R

Legend: [a]1a = Extremely hazardous; 1b = Highly hazardous; II = Moderately hazardous; III = Slightly hazardous; U = Unlikely to present acute hazard in normal use; NC = Not classified; NK = Not known. [b]CI = Cholinesterase Inhibitor, C = Carcinogen, PC = Possible Carcinogen, SE = Suspected Endocrine Disruptor (ILO, 2005) [38]. [c]R = Registered for General Use (Full, Provisional or Restricted); U = Not registered for General Use (not in the register, experimental use).

3.5 Pesticide Application and Mixtures Used

Farmer applies once a week depending on the type of vegetable crop. Twenty-eight point zero four percent of farmers reported two pesticide applications and five times (10.42%) and six times (7.29%) per week, *i.e.* routine pesticide applications. The majority of farmers applied pesticides once a week. The fact that pesticides are more expensive and use cultural control methods and occasionally botanical pesticides. More farmers surveyed applied mixtures of pesticides (Table 3).

Reported pesticide mixtures included fungicide + insecticide (Dithane M45 and Ascozeb 80 WP) reapplied to pepper and tomatoes, Maneb and Rocket EC to tomatoes, eggplants and pepper. In addition, other pesticide mixtures are two fungicides + insecticide (Dithane M45, Ascozeb 80 WP and Ivory 80 WP) applied on chili and tomatoes, two insecticides (Thiodan and Rocket EC) used on tomatoes and eggplant, insecticide + fungicide (Thiodan and Dithane M45) applied to pepper, chili, eggplant and tomatoes. These two mix. Either had no tanks mixes. Ghorbel [48] in Benin, Lwin [49] in Tunisia and Smit [50] in Birmania (Myanmar) reported the similar results. They observed that there was an interaction between fungicides, insecticides and water mineral content that influenced the efficacy of individual pesticide against fungal pathogens and insect mortality and some tank mixtures induced phytotoxicity on tomato. There is limited information on the reaction and effects of the mixtures observed in this study. According Antonella [51], WHO/UNEP [43] Epstein [52], the total exposure to the chemical is the sum of exposure during pesticide storing, mixing, applying and disposing of the chemicals.

Table 3. Pesticide mixtures used by small-scale vegetable farmers

Pesticides combination	Types of pesticides	Target crops
Dithane M45, Ascozeb 80 WP	Fungicide + insecticide	Pepper, tomatoes
Maneb, Rocket EC	Fungicide + insecticide	Eggplants, pepper, tomatoes
Dithane M45, Ascozeb 80 WP, Ivory 80WP	Two Fungicides + insecticide	Chili, tomatoes
Thiodan, Rocket EC	Two insecticides	Eggplants , tomatoes
Thiodan, Dithane M45	Insecticide + fungicide	Chili,eggplants,tomatoes, pepper

3.6 Trend and Reasons Given

62.5% of farmers who responded to the trend in over 3 years 20.83% thought and 16.67% in decreasing. In Bughore-Kabare region is on the rise as they farm in relatively similar environments and international organizations have started assisting them with agricultural inputs such as vegetable seeds. With the increase in the use of pesticides, there is also a decrease in bees observed by farmers in the environment of the study area. Our results joined results of Abate [53], Belzunces and Colin [54], Borneck and Bricout [55], Tasei [56].

According Melaku [57], Desalegn [58], Melisie [59], Krystyna [60], Guesh [61] insecticides and herbicides had been reported as significant causes of the death of the colonies and absconding. Indeed, Chauzat [62], MOWR [63] show that improper use of insecticide leads to the honeybee's death and Melisie [59] reported the decline of honeybee products and crop yield are among the significant constraints of the beekeeping sector.

The reasons for increasing trends in pesticide use are increasing insect damage, agricultural area, insect pests, plants and number of pests. The constant ones are that the area, less pests, even everywhere and pesticides used. Ngowi [34], Gizachew [64], Mengistu and Beyene [65], Mengistie [13,14] reported their research's the trend of chemical utilization, including usage by smallholders, has been increasing. The reasons for the tendency to the downside are heavy rains, unavailability of pesticides, price increase, less harvest, drought, good farm preparation and reduced agricultural area. With the increase in the use of pesticides, there is also a decrease in bees observed by farmers in the environment of the study area. This result is the same to the result of Ngowi [34].

3.7 Perception of Pesticide Poisoning Symptoms

Hundred farmers use chemical in study area. However, the most common symptoms reported and included skin effects (37.5%), neurological system disorders (headache, dizziness) were (20.83%). Additionally, farmers reported suffering from sneezing (6.25%), excessive sweating (5.21%), coughing and poor vision (3.12%), nausea (2.08%) and stomach pain (1.04%). Therefore, skin effects, headaches and dizziness are dominant in the Bughore-Kabare region. The three routes of exposure to pesticides: dermal, respiratory and oral [66]. Almost 750,000 people contract a chronic disease such as cancer each year because of exposure to pesticides, nerve damage, infertility and deformities, etc. In addition, although developing countries only employ 20% of all chemicals used in agriculture globally, they still account for more than 99% of deaths worldwide because of human poisoning pesticides [36]. The studies are carried out in Indonesia [67] and in Ivory Coast [68] reported.

3.8 System of Pesticide Packaging Management

Sixty-two point five percent of the farmers answered that the management system for pesticide containers is to leave them and keep them on the stakes and/or sticks in the field, while 20.83% buried them and 16.67% burned them. The management of packaging and packaging waste has a very pronounced ecological, social and economic significance. Pesticide packaging management system used by farmers is stake and/or stick in field in Bughore-Kabare area as they have no training in pesticide use, water pollution water, air, soil and living beings hence the problem of poisoning in the environment. Our result is similarly to result of Ahouangninou [69]. The abandonment of packaging in the field poses a great danger to children and the uninitiated who may use it as second-use packaging and containers. Incineration of packaging (including pesticide waste and contaminated materials) is also not a good practice because during combustion, some pesticides produce highly toxic fumes which inhalation and / or contact are harmful to the human body and animals [69]. Likewise, 6% farmers burie packaging, residues and waste of pesticides. It presents the risk of contamination of groundwater. Pesticide packaging is generally abandoned in the field or incinerated as initially observed in other African countries [36,69]. According to Muliele [23], Nkolo area in west of DR Congo and its surroundings, the market garden fields being mainly installed along waterways for watering facilities, part of the packaging abandoned in the field ends up in the course of water carried by strong winds or runoff. The same is true for pesticides accumulated in the soil, which, after heavy rains, carried in the runoff to the rivers and volatile particles during the treatment, some of which are deposited directly in the rivers. At the end of the treatment, the market gardeners wash and wash their clothes in the streams. Contamination of waterways with pesticides is therefore not excluded in the study area, even though most market gardeners claim to maintain sprayers in the field so as not to pollute the waterways. Our result is in the same way to result of Muliele [23], WHO [70], Jeyanthi and Kombairaju [71] reported that.

4. Conclusions

Investigations were made with market gardeners on the evaluation of the use of chemical pesticides in the fight against solanaceae pests (tomato, eggplant, pepper, pepper) in the Bugorhe-Kabare region in the west of the region of the Alberta Rift. Smallholder farmers use them poorly due to lack of training, hence the poisoning. Also to contribute to the reform policy in the Bughore-Kabare region in the east of the DR. Congo, we need strict control over all the sale of chemical pesticides. The Congolese government must create a quarantine, control and surveillance service for phytosanitary products, fruits and vegetables within the DRC country and at these borders. Additionally, it needs urgent action from the federal and regional governments to formulate policy, design legislation, and enforcing for its implementation concerning the supply, transportation, storage, appropriateness, and application of harmful pesticides.

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Author Contributions

Jean Augustin Rubabura Kituta had the idea and designed the research. Jean Augustin Rubabura Kituta, Jean Berckmans Muhigwa Bahananga, Alex Lina Aleke and François Ndatabaye Lagrissiprepared the manuscript. Jean Augustin Rubabura Kituta and François Ndatabaye Lagrissi led the survey and data processing. Jean Augustin Rubabura Kituta, Jean Berckmans Muhigwa Bahananga and Alex Lina Aleke contributed to interpretation of the results and revision of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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ARTICLE

The Influence of Storage Conditions on the Microbial Quality of *Daucus carots* (Carrots) and *Capsicum annuum* (Green Pepper)

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ABSTRACT

The influence of different storage conditions on the microbial quality carrot *(Daucus carots)* and green pepper *(Capsicum annuum)* was determined using standard microbiological method from day zero to day ten. Total bacteria count for carrot stored at room temperature ranged from Log_{10}Cfu/g 3.22 to 7.45 and for carrot stored at refrigeration temperature ranged from Log_{10} Cfu/g 2.13 - 3.14. Total bacteria count for green pepper stored at room temperature ranged from Log_{10}Cfu/g 4.22 to 7.45 and for green pepper stored at room temperature ranged from 1.12 to 4.14 for refrigeration temperature. Bacteria isolated includes *E.colI* (4%)*, Bacillus sp.* (8%), *Pseudomonas* (16%), *Proteus vulgaris* (4%), *Staphylococcus sp.* (28%), *Klebsiella* (8%), *Salmonella* (12%)*, Micrococcus sp.* (12%) and *Acinetobacter* (8%). Fungal count for carrot at room temperature ranged from Log_{10} 2.22 to 2.54 Cfu/g and 2.01 to 2.34 Cfu/g for refrigeration temperature. Fungal count for green pepper at room temperature ranged from Log_{10} Cfu/g 3.02 to and 7.45, Log_{10}1.81 Cfu/g to 3.34 for refrigeration temperature. Fungal isolated includes *Penicillium* (33.3%), *Aspergillus* (53.3%), *and Candida* (13.4%). Proximate composition indicates that moisture, ash, carbohydrates, lipid and fibre are lower at room temperature compared to refrigeration temperature. Temperature and storage duration have been said to affect the content of fruits and vegetables, therefore constant temperature and appropriate storage condition should be maintained.

1. Introduction

In recent years, outbreaks linked with fresh produce have emerged as an important public health concern and reported illnesses following consumption of raw produce or related products have been linked to bacteria, parasites and viruses [1]. Fresh produce can be contaminated with pathogens not only in the field, but also by several postharvest conditions such as wash and rinse water, unhygienic human handling, transport vehicles, cross contamination, improper storage, processing and packaging [2]. The low sanitation standards especially during postharvest handling and an increased consumption of raw produce and related products have generated heightened concerns

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for food safety in developing countries [3-5]. Fresh produce means fruits and vegetables that have not been processed in any manner. Vegetables are necessary in our daily diet. They bestow not simply the key nutritional fibre component of our rations but a choice of micronutrients, together with minerals, vitamins and antioxidant compounds [6].

Green-Pepper (*Capsicum annuum*) is an essential agricultural crop, not only because of its economic usefulness, but because of its high content of ascorbic acid. Green-Pepper is a warm season annual crop which can be grouped to the family Solanaceae. It is regarded as “sweet” since they do not possess the pungent chemical (capsaicin) present in hot peppers. It is one of the common and highly used vegetable crops cultivated in tropical and subtropical parts of the world [7]. There are many important vegetable crops in thy world and green pepper happen to be one of them, it is perishable in nature and this result to its quick deterioration after harvest under poor post harvest management [9]. It is known for its water loss, sunscald and heat destruction. Fresh green chilies losses moisture very easily after harvest and starts to wrinkle accompanied with change in colour within a few days without proper storage condition [8,10]. Strong physiological activities, shriveling, wilting and fungal diseases are the most common post harvest problems associated with green pepper.

Carrot is a well known vegetables with functional food compositions such as minerals and vitamin. Carotenoids and other antioxidants in carrot are useful in the interference of oxidation processes, as well as in equalizing free radical activities. Therefore, carrots and their fresh produce may shield humans against different kinds of cancer and cardiovascular diseases [11].

Time and temperature are one of the most important factor that enhances the quality and increase the shelf life of most vegetables and fruits. Refrigeration is also vital in controlling spoilage. It is of vital importance to prevent temperature fluctuations because this can cause chilling injury, irregular softening, and spoilage. However storage conditions for both vegetables in this study are kept at refrigeration and room temperature since one of the factors increasely influencing individual health and longevity and safe high-quality food. The poor shelf-life of vegetables had led to it’s increased number of spoilage, huge losses and market lost during harvest as observed by large heaps of unsold rotten vegetable in the refuse dumps of rural and urban markets. The study aim at determining the effect of storage on the microflora and physicochemical quality of green pepper and carrot.

2. Materials and Methods

2.1 Sample Collection

Carrot and green pepper samples were purchased from the market. The samples were firm, undamaged and fresh. The samples were brought in clean bags to the laboratory.

2.2 Methods of Storage

Two storage methods were adopted. These included standard refrigeration at 4 °C and on a clean concrete floor (under room temperature). The refrigeration was done using Haier Thermocool. Storage of pepper on concrete floors is mainly practiced in rural areas but also in cities. The samples were maintained under the different storage conditions for 10 days. They were taken out briefly to make observations and to collect samples for microbial assessment (composition and load analysis) at an interval of 2 days. An initial microbial assessment was conducted prior to storage (day 0), then on day 2, 4, 6, 8 and finally the 10th day. All materials (media, glass ware) used in this study were sterilized in an autoclave at 121 °C at 15 psi for 15 minutes.

2.3 Microbiological Analysis of Samples

2.3.1 Total Bacteria Count

10 g of carrot and green pepper both at refrigerated and room temperature was weighed into 90 mL of peptone water under aseptic condition. It was then placed in a stomacher for 2 minutes and homogenize and diluted serially, then 0.1 mL aliquot of the dilutions 10^{-2} and 10^{-3} using a sterile syringe and inoculate on a Plate Count Agar (PCA) surface was done as described by Afam-ezeaku *et al*. [12].

2.3.2 Total Fungi Count

10 g of carrot and green pepper both at refrigerated and room temperature was weighed into 90 mL of peptone water under aseptic condition. It was then placed in a stomacher for 2 minutes homogenize and dilute serially, an aliquot (0.1 mL) was transferred into the test tubes and diluted serially. From the dilutions of 10^{-1}, 0.1 mL aliquot was transferred aseptically into freshly prepared potato dextrose agar media plate and also 10^{-2} and were spread for both carrot and green pepper was done as described by Afam-ezeaku *et al*. [12].

2.3.3 Purification of Bacteria Isolates

With a sterile wireloop, a loopful of each distinct colony was picked up and transferred to the edge of a freshly prepared Nutrient Agar plate to make a smear and streaked. Streaked plates were incubated at 37 °C for 24 hours. After that, colonies that grew on the streaked plates where transferred on agar slants and incubated at 37 °C for 24 hours to obtain stock culture. Isolates were identified based on their morphological and cultural characteristics on growth media. Identification materials, reagents and protocols according to [53] were used to identify discrete colonies from the bacteriological media of sub-cultured isolates. The isolates were characterized and identified based on their colony characteristics and subjected to a serie of biochemical test for confirmation.

2.3.4 Purification of Fungi Isolates

With a sterile needle, distinct colony was cut out and transferred to the edge of a freshly prepared Potato Dextrose Agar plate and placed in a reversed form and incubated at 37 °C for 2-5 days. After which, distinct colonies that developed from the plates were transferred on agar slants and incubated at 37 °C to obtain stock culture. The cultural characteristics of each fungi isolates were identified according to their colour, shape and the cell morphology was done based on mycelia, hyphae, septate, spore formation using lactophenol blue. A piece of the mycelium from the Petri plates was mounted on a clean grease free slide using a sterile wire loop and covered with a cover slip, after which a drop of lactophenol cotton blue was added and examined with the microscope.

3. Results and Discussion

Figure 1 presents the total bacteria count for carrot at room temperature ranged from Log$_{10}$Cfu/g 3.22 to 7.45 and for refrigeration temperature it ranged from Log$_{10}$Cfu/g 2.13 - 3.14. Figure 3 shows the Total Bacteria count for green pepper at room temperature ranged from Log$_{10}$Cfu/g 4.22 to 7.45 and 1.12 to 4.14 for refrigeration temperature. Figure 2 presents the Fungal count for carrot at room temperature ranged from Log$_{10}$ 2.22 Cfu/g to 2.54 Cfu/g and 2.01 Cfu/g to 2.34 Cfu/g for refrigeration temperature. Figure 4 shows the Fungal count for green pepper at room temperature ranged from Log$_{10}$3.02 Cfu/g to and 7.45, Log^{10}1.81 Cfu/g to 3.34 Cfu/g for refrigeration. Figures 5 - 8 show the comparison of different storage temperature on the total bacteria and fungal counts of carrot and green pepper.

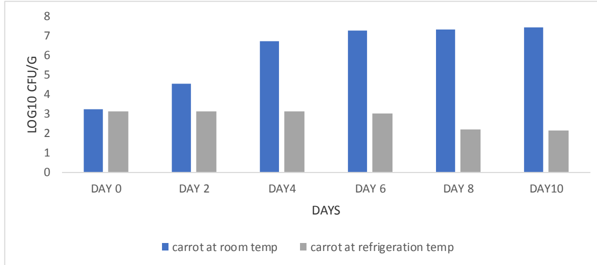

Figure 1. Total bacteria count of carrot at different storage conditions

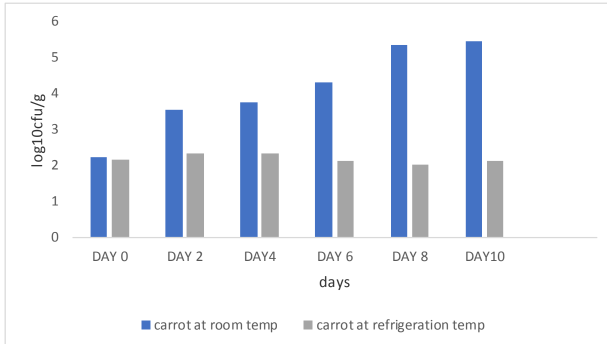

Figure 2. Total fungi count for carrot at different storage conditions

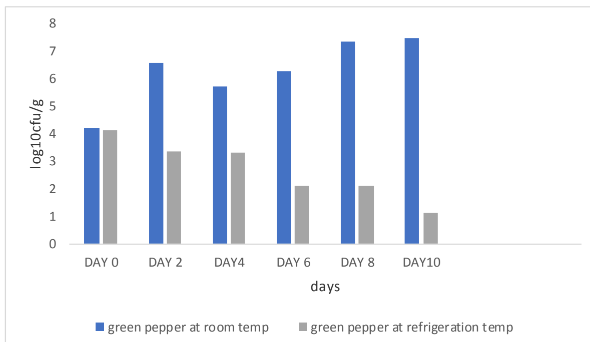

Figure 3. Total bacteria count for green pepper at different storage conditions

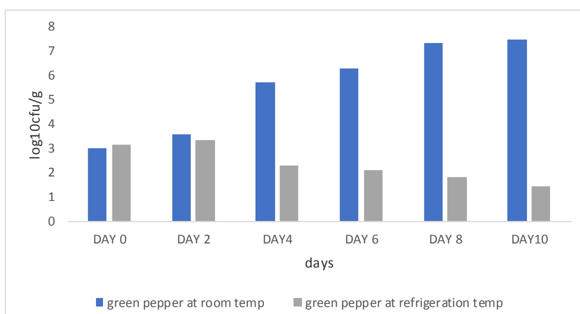

Figure 4. Total fungi count for green pepper at different storage conditions

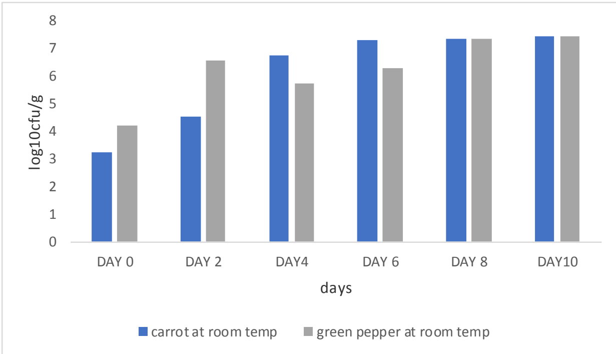

Figure 5. Total bacteria count for carrot and green pepper stored at room temperature

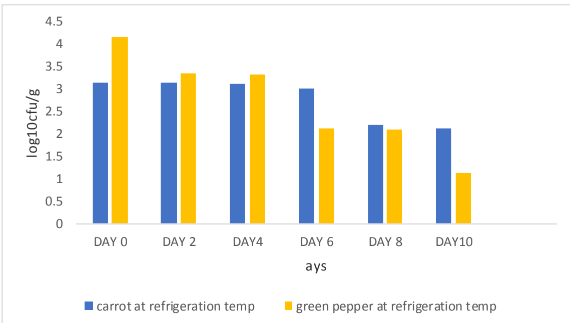

Figure 6. Total bacteria count for carrot and green pepper at refrigeration temperature

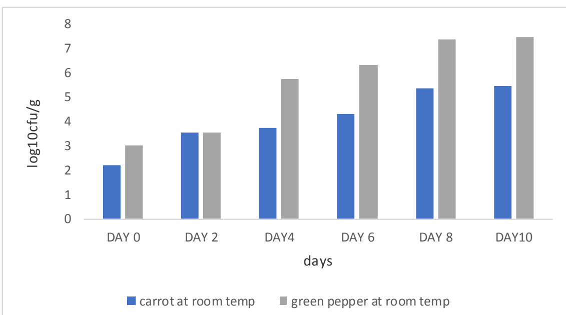

Figure 7. Total fungi count for carrot and green pepper at room temperature

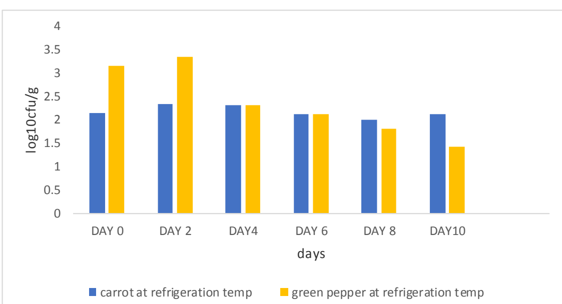

Figure 8. Total fungi count for carrot and green pepper at refrigeration temperature

3.1 The Effect of Storage Condition on the Microbial Quality of Carrot and Green Pepper

The degree of contamination in vegetables and fruits has been known to depend on the clean water, harvesting, transportation, storage temperature and processing of the produce [13]. The total bacteria count for carrot at room temperature ranged from Log_{10}Cfu/g 3.22 to 7.45 and for refrigeration temperature ranged from Log_{10}Cfu/g 2.13 - 3.14. While the total bacteria count for green pepper at room temperature ranged from Log_{10}Cfu/g 4.22 to 7.45 and 1.12 to 4.14 for refrigeration temperature. Mritunjay and Kuma [14] reported that most of these microorganisms managed to grow in the storage temperature. Therefore, high counts are an indication of exposure to contaminants because of the existence of favorable conditions [15]. The Hazard Analysis and Critical Control Points-Total Quality Management (HACCP-TQM) Technical Guidelines states the microbial limits for raw foods, where the food samples grouped based on colony forming units as expressed in Log_{10} per gram; less than 4,4–6.69, 6.69–7.69 and greater than 7.69 log CFU g^{-1} (aerobic plate count) is termed as good, average, poor, and spoiled food, respectively [16]. According to the guideline the mean counts of green pepper and carrot stored at room temperature are log_{10} 7.5 and 7.3 respectively and are regarded as poor according to the stated guideline. Green pepper and carrot stored at refrigeration temperature is log_{10} 3.5 and 3.3 respectively is regarded as good according to the stated guideline. Aerobic organisms reflect level of contamination and microbiological indicator for food quality [15,17]. Foods are considered as harmful when they possess high number of aerobic mesophilic microorganisms, even if the organisms are not known to be pathogenic [18]. The fungal count for carrot at room temperature ranged from Log_{10} 2.22 Cfu/g to 2.54 Cfu/g and 2.01 Cfu/g to 2.34 Cfu/g for refrigeration temperature. Fungal count for green pepper at room temperature ranged from Log_{10}3.02 Cfu/g to and 7.45, Log^{10}1.81 Cfu/g to 3.34 Cfu/g for refrigeration.Fungi isolated includes *Penicillium* (33.3%), *Aspergillus* (53.3) and *Candida*(13.4%). Hameed *et al.* [19] reported that the storage temperatures of 0 °C and 10 °C had reduced respiration rate at removal day which may be linked to fruits being kept under low temperature, the respiration rate reduces and as temperature increases, the rate of respiration is faster because every 10 °C increase the rate of respiration is roughly doubled [9]. After a week of shelf–life the fruit kept at 10 °C showed the lowest rate of respiration while the 0 °C storage showed the maximum rate, significantly different from all other storage temperatures. This result is similar with the studying of [20] who discovered that respiration rates of peppers stored at 10 °C lowered over the storage period of 20 days. And also freshly harvested chili or other hot peppers should be stored at 10 °C with 80-90% RH [21-23].

It can be stated that the variation in the temperature range played a great role in fastening the decay of the stored samples [24,25]. An increase in the temperature affected the respiration of the green pepper and carrot. which yielded to weight loss and softening of the outer layer of the green pepper and carrot. Nevertheless, the sample stored in the refrigerator retained its firmness and weight for a longer period before showing any signs of spoilage.

Bacteria isolated includes E*.coli* (4%)*, Bacillus sp.* (8%), *Pseudomonas* (16%), *Proteus vulgaris* (4%), *Staphylococcus sp.* (28%), *Klebsiella* (8%), *Salmonella* (12%)*, Micrococcus sp.* (12%) and *Acinetobacter* (8%). Organisms isolated is similar to these authors [12,27]. An increased bacteria counts obtained for the fruits and vegetables in this study are in accordance to these authors [12,26-28,31]. The high level of microbial contamination observed in the fruits and vegetables in this study may be a reflection of storage conditions and how long these produce were kept before they were obtained for sampling. bacteria on the produce may multiply over time depending on the storage conditions especially those that are phsychro-trophic [32,33].

The occurrence of *E.coli* in both carrot and green pepper is indicative of faecal contamination. Some strain of *E.coli* are known to cause of diarrhea, gastroenteritis and other urinary tract infection. *Staphylococcus aureus, Pseudomonas, and Bacillus* spp. are food contaminants from humans and the surroundings, its occurrence in food however, need to be put in check because they have been reported as known cause of the major food borne diseases [34].

In the present study, *Micrococcus* spp. was among the most occurring organism this is as a result of its presence in wastewater and soil [35]. This is in accordance to the study of Guchi and Ashenafi [36] who reported *Micrococcus* spp. is one of the most occuring microflora isolated from lettuce and green pepper in Addis Ababa, Ethiopia. *Micrococcus* spp. which are common environmental bacteria that can be present in fresh vegetables through cross-contamination, for example, from wastewater used by the grower during irragation. *Micrococcus* is thought to be a saprotrophic organism, thought it can be an opportunistic pathogen, especially with compromised immune individuals, such as HIV patients [38]. The prevalence of *Staphylococcus aureus* (28%) in this study was lower than that report in the study of Halablab *et al*. [38] who stated higher prevalence of *Staphylococcus aureus* (51.5%) from Lebanon. The presence of *Staphylococcus aureus* (28%) in study was similar to those obtained by Ikpeme *et al.,* 2011 (25%-33%). In this study, the prevalence of *Samonella* spp. in carrot and green pepper was higher than that reported [36,39] who indicated 10% in lettuce and green pepper and 11% in broccoli and cauliflower respectively.

The fungi isolates from both carrot and green pepper include *Candida* spp. (13.4%), Aspergillus spp. (53.3%) and *Penicillin notatum* (33.3%). These partly similar to the findings of Li - cohen and Bruhn [41] who discovered that species of fungi linked with the spoilage of some edibles fruit include species of *Aspergillus, Fusarium, Pencillium, Rhizopus. Pencillium and Mucor* spp*. Aspergillus* spp. are environmental contaminants, which can cause deterioration of fruits and vegetables [42]. Mycotoxins are produced by some these fungi and are implicated in cases of mycoses [43]. *Aspergillus* spp. which was isolated fungi in this study is known to produce aflatoxins which is associated with liver cancer [44].

Significant change was obtained from the room temperature compare to the reduction in cold storage. This indicates that cold storage could decrease the rate of respiration and loss of energy substrate and this significant decline could be contributed to usage of sugar respiration process [50]. Temperature is a foremost reason affecting microbial growth. Refrigeration is deal for storage of nearly all perishable fresh produce. Mould growth and chilling injuries ought to be taken into account as well as the length of storage [51].

The greater diversity of bacteria was obtained when compare to fungi which could be attributed to the relative high moisture content of fruits which subjects them to more bacteria that fungal attacks [52] in both vegetables a great number of pathogens are known to exert effects on the microbial load acquired during the period of study. As much as these pathogen levels are not detrimental to human health, it is however an indication that proper care should be taken in handling vegetables and fruits which include thorough washing of fruit and vegetables before consumption.

3.2 Effect of the Storage Conditions on the Proximate Composition of Carrot and Green Pepper

The proximate composition of carrot and green pepper at different storage temperature as shown in Table 1. The value of moisture content to be 85.19% and 95.02% for carrot and green pepper respectively and this is in accordance with the study [46]. At room temperature, a reduction of moisture content occurred in both carrot and green pepper. In many horticultural products, a reduction of more than 5% would cause loss of freshness, witting appearance and even loss of commodity values [45].

The value of protein for carrot and green pepper shows that carrot and green pepper does not contain much protein but can still be used as protein food supplement. The value for carrot ranged from 1.02% - 2.64% for carrot and 0.98% - 2.80% for green pepper, which is higher than the result obtained [47]. The lipid content at room temperature reduced significantly while it showed a slight reduction at cold storage. The losses might be narrowed to the fact that fats are rich in unsaturated fatty acids which is liable to oxidation degradation [48]. In this study the ash content for carrot is 3.030% and I.33% for green pepper which is higher compare to the Brazilian Table of Food Composition 2001. Carbohydrates and fibre are relatively low (6.71% and 2.89%) compared to the work reported [49]. The value of carbohydrates was 31 g and fibre was 29.3 g.

Table 1. Proximate composition of the various samples stored at different condition

Sample identity	Moisture (%)	Ash (%)	Carbohydrates (%)	Protein (%)	Lipid (%)	Fibre (%)
Carrot room temperature on day 2	82.54	1.21	4.62	1.07	1.21	2.37
Carrot room temperature on day 8	73.69	1.18	4.22	1.02	0.26	1.98
Green pepper RM temp on day 2	95.02	1.33	6.10	1.13	0.37	1.17
Green pepper RMemp on day 8	87.97	1.29	6.06	2.80	0.28	1.16
Carrot refrigeration temperature on day 2	85.19	3.030	3.26	2.64	1.52	2.89
Carrot refrigeration temperature on day 8	83.62	3.03	2.93	2.51	0.90	1.59
Green pepper refrigeration temperature on day 2	91.10	1.030	6.71	1.19	0.75	1.59
Green pepper temperature on day 8	91.50	1.03	5.59	0.98	0.64	1.53

3.3 Effect of Storage Temperature on the Quality of Carrots and Green Pepper

Quality of carrot and green pepper is affected by water loss during storage, which depends on the temperature and RH of the storage conditions and this is similar to the study [54,55]. Hardenburg *et al*. [56] stated that storage under minimum temperature is the most efficient way to maintain quality of fruits and vegetables as a result of its effects on reducing respiration rate, ethylene production, ripening, senescence, and rot development. Higher temperature increases the vapour pressure difference between the fruit and the surrounding, which is the driving potential for faster moisture transfer from the fruit to the surrounding air and this is in accordance to this present study.

4. Conclusions

Based on the findings of this study, storage temperature has a better impact in retarding the respiration rate, weight loss and decay, while maintaining the fruit firmness and general quality. The higher the temperature ranges the faster the rate of spoilage. It can as well be stated that refrigeration storage condition is a better method of storing green-pepper and carrot.

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Conflict of Interest

There is no conflict of interest.

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