



Research Article

Characterization of Onion (*Allium cepa* L.) Storage Practices in the North and Far North Regions of Cameroon

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Abstract

This study aimed to evaluate onion (*Allium cepa* L.) storage practices and structures in the North and Far North regions of Cameroon. A structured and validated questionnaire was administered to producers who owned storage facilities. The study covered 52 producer facilities in each of the two regions. These producers included individuals, Common Initiative Groups, Cooperative Societies and Cooperatives with a Board of Directors. The results showed that individual growers are the primary producers (60.58%). The five onion varieties known in these regions are Goudami (adopted by 100% of respondents), Chagari, Violet of Galmi, alongside more marginal varieties such as Belami and Safari. Storage warehouses consisted predominantly of construction sites (38.46%). Temperatures range between 36 and 40°C in 26.92% of facilities in the North and between 31 and 35 °C in 55.77% of facilities in the Far North. Humidity levels were higher (31 to 50%) in 98.07% of facilities in the North whereas very low levels (10 to 20%) in 82.69% of cases in the Far North. The lack of measurement is more common in the Far North (7.7%) than in the North (1.0%). Constructions sites and Rudu were the most vulnerable, with losses reaching up to 42.99% and 32.56%, respectively. Producers were willing (96.15%) to adopt modern storage technologies such as controlled atmosphere storage, to safeguard stocks for periods exceeding four months. This work provided information for managing technical and technological conditions in onion storage facilities and paves the way for the introduction of modern preservation technologies.

Keywords

Allium cepa L., Storage, Post-harvest Losses, Northern Regions, Cameroon

1. Introduction

The onion (*Allium cepa* L.) is a widely consumed crop globally [1, 2]. It is also considered an essential cash crop in savannah zones, particularly among vegetable crops. In Cameroon, this crop is experiencing significant growth with an average production of 310,831 tonnes [3]. It is ranked as the second cash crop after cotton, in the northern part of the country [4]. The main production hub is located in the northern part (Far North, North and Adamawa regions) accounting for over

85% of national production [5] and benefiting from a dry tropical climate [6].

However, the consumption and marketing of these products are limited by significant post-harvest losses. These losses are estimated at between 18% and 40%, depending on the harvest season [4, 7]. They have a direct impact on the economic well-being of rural households obliging producers to sell quickly after harvest to avoid bulb deterioration [6]. Numerous studies

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have focused on reducing these losses, as current storage facilities are not always efficient or effective in preserving onions. This situation has sparked research interest in alternative preservation technologies and methods. Post-harvest bulb drying is commonly used to extend the shelf life of onions. The use of drying both in Cameroon and elsewhere (Burkina Faso, Algeria) as a method to reduce losses and preserve nutrients in whole bulbs has been documented [8-14]. Spatial and logistical arrangements within storage facilities have also been employed to mitigate post-harvest [15, 16]. Despite these measures, the reduction of storage losses remains unsatisfactory. Another approach would be to gain a combined understanding of the technical parameters (temperature, relative humidity, wind speed, gas composition within the storage space, onion sterility) and technological factors (onion type, moisture content, temperature, final onion quality) associated with traditional storage facilities in order to develop more effective solutions.

Some studies have focused on evaluating traditional storage techniques in the Sahel region, such as the Rudu in Niger and in Cameroon [6, 7]. However, these works did not address other types of storage facilities, nor did they provide a technical description of the storage facilities. To the best of our knowledge, few studies have addressed the descriptive characterization of storage facilities in the North and Far North regions of Cameroon. It is therefore essential to document current practices in order to identify critical points in the post-harvest chain. The aim of this study is to evaluate the characteristics of storage facilities and associated losses through a descriptive analysis. Specifically, the study seeks to identify onion storage structures categories and stored varieties, assess losses by structure type and provide a technical description of the storage facilities. This could reveal the limitations of traditional storage facilities owned by producers, as well as the potential for these producers to adopt innovative techniques.

2. Material and Methods

2.1. Survey Instruments and Methodology

Some thermodynamic measurements of the storage struc-

tures were carried out. The ambient temperature (T) and relative humidity (RH) were determined in situ using a *TFA Dostmann* digital thermo-hygrometer. Furthermore, a structured and validated questionnaire was administered face-to-face to producers who owned storage facilities.

2.2. Study Area and Sampling

The study was conducted over two-month period (April-May 2024) in the major production basins of the North and Far North regions (Figure 1). In the North region, the study covered the Benoue, Mayo Louti and Mayo Rey divisions, specifically the localities of Garoua 1, 2 and 3, Pitoa, Demsa, Bibemi, Bachehou, Figuil, Guider and Lagdo. As for the Far North region, the divisions involved were Diamare, Logone and Chari, Mayo Tsanaga, Mayo Sava and Mayo Kani. Here, the study was carried out in the localities of Kousseri, Mora, Koza, Maroua, Miskine, Gazawa and Kaele (Doumrou and Guereme). The North region has a Sudanian climate. It extends between 8 ° and 10 ° North latitude and 12 ° and 16 ° East longitude, with an average altitude ranging steadily between 200 and 600 m. The Far North region is characterized by a Sudan-Sahelian climate. It is situated between 10 ° and 13 ° North latitude and, 14 ° and 16 ° East longitude, with an average altitude generally ranging between 200 and 450 m. A sample of 104 producers was selected and distributed evenly (52 per region). Those who took part in the study were: individuals, Common Initiative Groups (CIG), Cooperative Societies (COOPS) and Cooperatives with a Board of Directors (COOP-BD) that possessed storage facilities.

The questionnaire covered general information about the respondent (name, type of organization, gender, region, division, village), knowledge of onion cultivation practices (varieties grown, area, soil type, yield, post-harvest losses, plant diseases), the marketing chain, onion storage (type of facility, storage duration, losses) and storage facility characteristics (capacity, ventilation system, average temperature, wind speed, onion arrangement and loss rates due to sprouting and rotting).

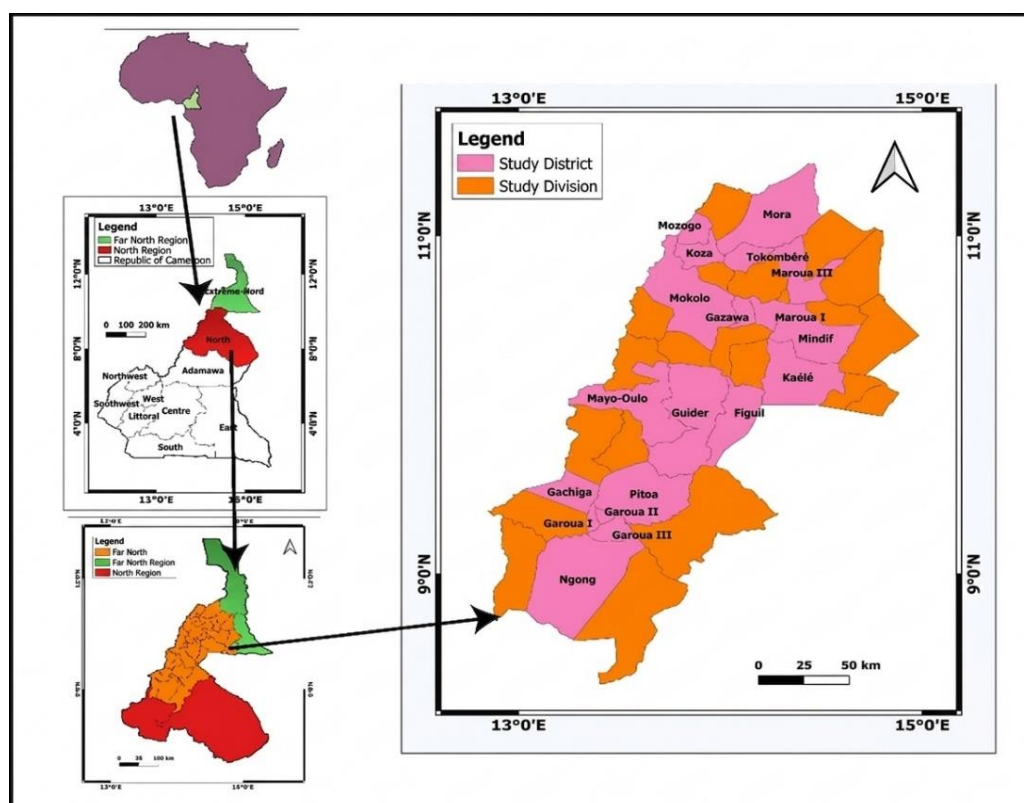


Figure 1. Demarcation of the study area by region.

2.3. Data Collection and Statistical Analysis

An approach in three phases was adopted: an exploratory survey (March), a descriptive phase during storage (April-May) and a final assessment of losses. Qualitative and quantitative variables were entered into Microsoft Excel 2016 and analyzed using SPSS software (version 22). The latter was also used to determine correlations between variables. Results are presented as frequencies, means and standard deviations. Significant differences between regions were assessed using Pearson's Chi-square test at a significance level of $p < 0.05$.

3. Results

3.1. Socio-Economic Characteristics and Variety Choices

3.1.1. Categorization of Production and Storage Organizations

Figure 2 shows the types of organizations involved in onion production and storage in the North and Far North regions. They consist of individual producers (60.58%), Common Initiative Groups (CIG) up to 18.27%, Cooperative Societies (COOPS) at a proportion of 8.65% and Cooperatives with a Board of Directors (COOP-BD) for 12.50%. Individual initiatives dominate the sector (63 out of 104 units), although

structured organizations (COOP-BD) cultivate larger areas (often exceeding 3 hectares). The Far North region has 1.17 times as many individual producers and 2.25 times as many COOP-BD as the North region. Conversely, CIG and COOPS are 2.16 and 2 times more numerous in the North than in the Far North, respectively. COOPS are the least represented, with only 3 units in the Far North.

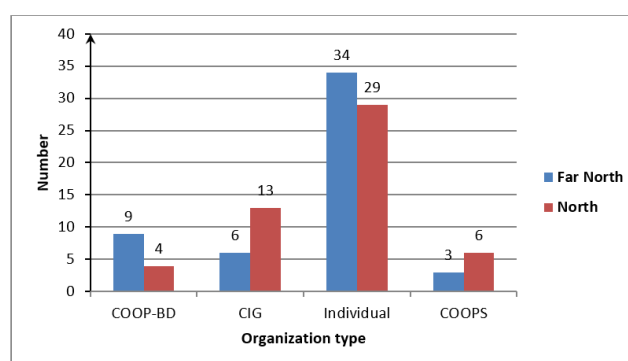


Figure 2. Type of organization by region.

3.1.2. Diversity of Cultivated Varieties

There are five varieties of onion in the North and Far North regions of Cameroon (Table 1). In general, the Goudami variety is adopted by all surveyed farmers (100%), followed by Violet of Galmi (52.88%) and Chagari (16.34%). On the other

hand, the Belami and Safari varieties are the least cultivated.

Table 1. Onion varieties grown in the North and Far North.

Variety	Number		Total (n=104)	Percentage (%)
	Far North (n=52)	North (n=52)		
Goudami	52	52	104	100
Violet of Galmi	28	27	55	52.88
Chagari	9	8	17	16.34
Belami	1	1	2	1.92
Safari	1	1	2	1.92

The different varieties exhibit varied physical properties (Figure 3). The Goudami variety serves as the reference variety.

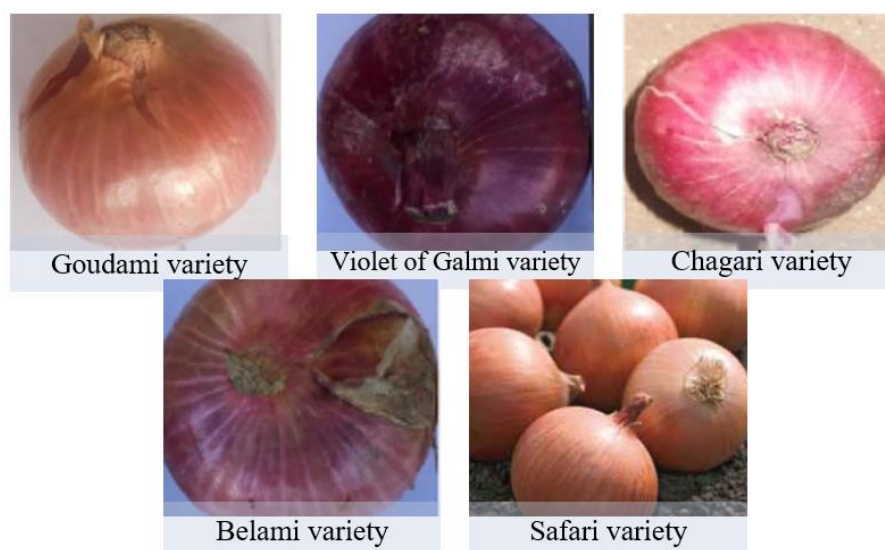


Figure 3. Bulbs of cultivated onion varieties showing various colours.

3.1.3. Physical Description of Storage Facilities

Five type of storage facilities were observed (Figure 4). A distinction is made between store types such as construction sites, granaries, sacks, Rudu and Reseda (Table 2). Construction site accounts for 32.69% in the North and 44.23% in the Far North, Rudu represents for 34.62% in the North and 23.08% in the Far North, and finally, Reseda accounts for 32.69% in the North and 19.23% in the Far North. This distribution

yields overall percentages of 38.46%, 28.85% and 25.96% for these three types of facilities, respectively. The construction sites are buildings under construction where the bulbs are stored. Onions are also stored in sacks or granaries while awaiting sale at markets. Rudus are elevated huts or silos, circular or rectangular in shape, made of straw and millet stalks, with an opening for loading and unloading the onions. Resedas are improved storage structures built from local materials, including banco (local raw earth mixed with straw).



Figure 4. Different types of storage facilities.

Table 2. Distribution of storage facilities by region.

Type of facilities	Region		Total (n=104)	Percentage (%)	P-value
	Far North (n=52)	North (n=52)			
Construction site	23	17	40	38.46	0,033
Rudu	12	18	30	28.85	
Reseda	10	17	27	25.96	
Granarie	4	0	4	3.85	
Sack	3	0	3	2.88	

Furthermore, construction materials significantly influence ($p < 0.05$) the thermal and thermodynamic regulation of buildings. Indeed, each material possesses a specific thermal and thermodynamic signature (thermal conductivity, thermal resistance, emissivity, specific heat capacity, thermal diffusivity, dynamic transfer characteristics) [17, 18]. Understanding

these materials makes it possible to comprehend and even predict their thermal behavior [19]. Table 3 presents the materials used to construct the storage structures. It shows that these materials consist of concrete (59.61%), earth bricks (35.58%) and, wood and straw (4.81%). Concrete is the dominant material, used primarily for high-capacity storage facilities (>20 tonnes).

Table 3. Distribution of construction materials for storage facilities.

Material	Region		Total (n=104)	Percentage (%)	P-value
	Far North (n=52)	North (n=52)			
Concrete	36	26	62	59.61	0,013
Earth brick	12	25	37	35.58	
Wood/Straw	4	1	5	4.81	

3.2. Descriptive Analysis of Post-Harvest Losses

3.2.1. Storage Facilities and Loss Rates

Loss rates by type of storage facility are presented in Table 4. It shows that losses are classified into two groups: quantitative and qualitative; with the average storage duration directly influencing these parameters. It is observed that germination

is non-existent in short-term storage structures (granary and sack). It becomes a major problem only in construction site type storage facilities, where it reaches 9.82%. Storage in construction site (33.17%) and Rudu (31.03%) facilities shows the highest rates of rot, even though the storage period is less than three and a half months. Quality losses manifest as tissue softening and discoloration of the outer scales.

Table 4. Average loss rates observed according to storage facility type.

Type of facility	Cause of losses		Storage duration (months)
	Germination (%)	Rotting (%)	
Construction site	9.82	33.17	3.23
Rudu	1.53	31.03	3.15
Reseda	1.03	22.89	5.03
Granary	0.0	20.75	4.37
Sack	0.0	15.75	2.37

3.2.2. Factors Contributing to Losses

According to the producers surveyed, the primary causes of losses fall into four categories (Table 5): climatic factors, biological factors, cultivation and post-harvest practices, and inadequate storage facilities.

Table 5. Loss factors by region.

Factor	Identified cause	Region		Total (n=104)	Percentage (%)
		Far North (n=52)	North (n=52)		
Climatic or environmental	Heat	48	46	94	90.38
	Humidity	30	17	47	45.19
Biological	Diseases	30	16	46	44.23
	Pathogenic attacks	0	1	1	0.96
Cultivation and post-harvest practices	Poor agricultural practices	6	3	9	8.65
Inappropriate storage areas	Insufficient space	1	3	4	3.84

3.3. Thermo-Hygrometric Characterization of Storage Facilities

A mastery of physical characteristics and the psychological and cultural disposition of producers regarding technological innovations are crucial for successful onion storage. These factors directly impact post-harvest loss rates, bulb quality,

and the financial profitability of both producers and storage facility owners. To the best of our knowledge, this is the first time such a study, examining both physical parameters and the adoption of technological innovation, has been conducted on producer-owned storage facilities in the North and Far North regions of Cameroon.

3.3.1. Average Storage Facility Temperature by Region

Figure 5 shows the average temperatures for the types of facilities in the North and Far North regions. The results reveal marked thermal disparities between the two regions. The North shows a wider temperature distribution, ranging from 25 °C to 40 °C, with a significant proportion (26.92%) exposed

to very high temperatures (36–40 °C), a range not observed in the Far North. Conversely, temperatures in the Far North are predominantly concentrated in the 31–35 °C range (55.77%), which could reflect thermal stability but also prolonged exposure to high temperatures. The rate of failure to measure temperature in storage facilities is higher in the Far North (8.7%), which may reflect limitations in monitoring or measuring equipment.

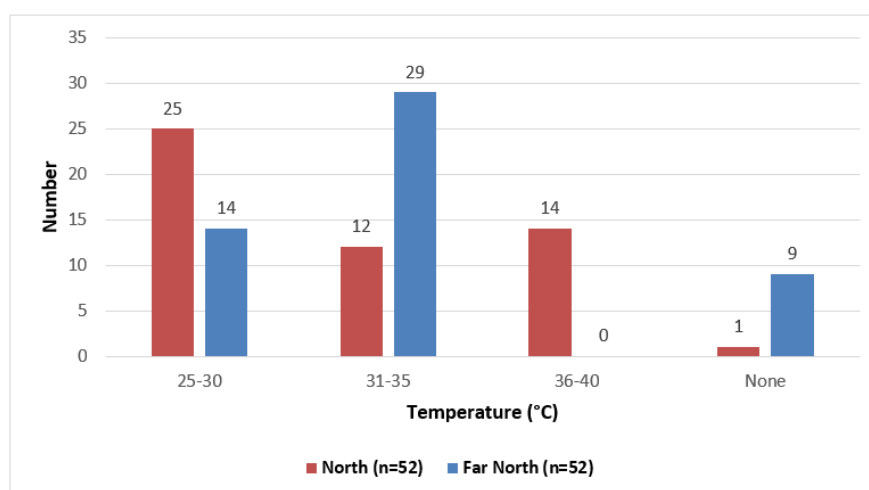


Figure 5. Average temperature by types of facilities and region.

Table 6. Correlation coefficients between causes and degradation properties.

	Germination	Rotting	Facility	Temperature	Humidity
Rotting	-0.401				
Facility	0.008	-0.243			
Temperature	0.168	-0.385	-0.155		
Humidity	0.034	-0.313	0.082	0.484	
Duration	0.872	-0.361	-0.131	0.284	0.1

3.3.2. Average Humidity Levels in Storage Facilities by Region

In the Far North, the majority of observations (82.69%) fall within the lowest humidity range (10–20%), whereas this

same range is entirely absent in the North (Figure 6). Conversely, the North region exhibits higher humidity levels, specifically in the range 31–40% (76.92%) and 41–50% (21.15%), reflecting more humid climatic conditions. Furthermore, the absence of measurements is more frequent in the Far North (7.7%) than in the North (1.0%).

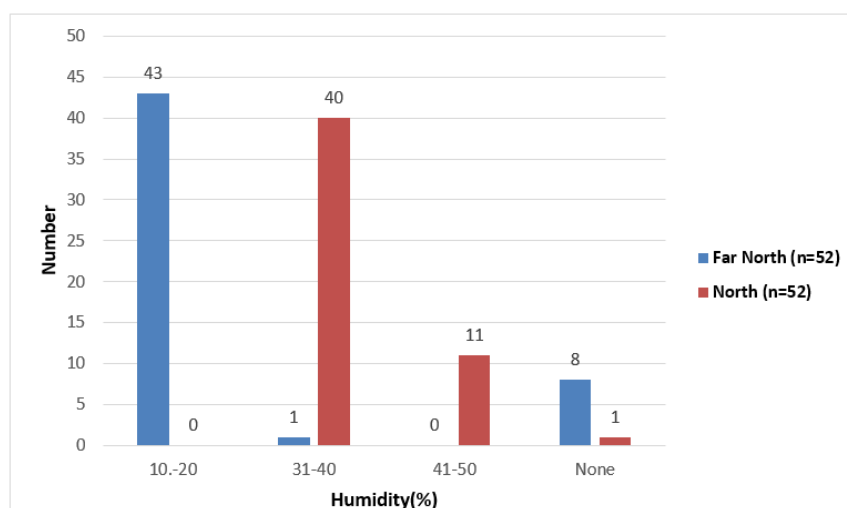


Figure 6. Average humidity by region.

3.3.3. Perception of Technological Innovation

Modern storage technologies, including controlled atmosphere systems, cannot succeed without farmer buy-in. They must offer improved preservation at a low investment cost, require simplified operational expertise and ensure long-term

profitability. Acceptance of controlled atmosphere technology was assessed following a technical presentation (Figure 7). Almost all respondents (96.15%) were willing to adopt the technology, with no significant difference between the North and Far North regions ($P = 0.308$).

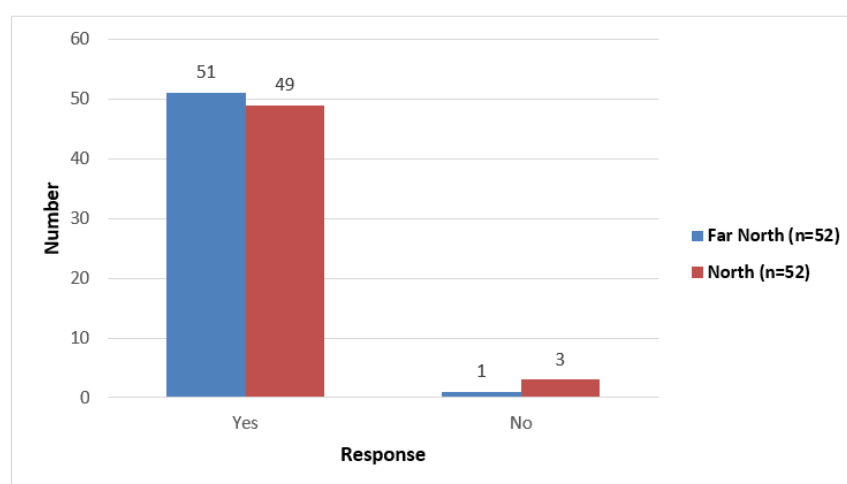


Figure 7. Acceptability of the Controlled Atmosphere.

4. Discussion

The fact that most producers in these two regions are small-holders likely could explained why individual operators make up the largest proportion. The recent establishment of producer groups [7] may also account for the low percentage of such groups. Although the North region has a higher number of producers [1], the greater presence of individual operators in the Far North can be attributed to the fact that this region has more small-scale producers who frequently engage in

post-harvest storage for later sale. Indeed, this region is further removed than the North region from key market outlets such as Southern Cameroon, the Central African Republic, Congo-Brazzaville, Gabon and Equatorial Guinea [7]. Furthermore, MINEPIA/DESA [20] had already reported a 29.7% increase in production in the Far North, compared to 4.2% in the North. This situation appears to confirm the rise in the number of small-scale producers in the Far North. However, the prevalence of individual initiatives suggests a level of fragmentation that may limit access to the substantial investments required for more efficient storage structure [4]. Furthermore,

the higher number of COOP-BD in the Far North region may be attributed to greater experience's with collective organization. The producer's federation had more members in the Far North (200) than in the North (80) [4]. However, despite their potential, they remain a minority. The low proportion of individual operators in the North could likely explain the higher level of grouping into CIG and COOPS.

The observation that the Goudami variety is adopted by all surveyed farmers, followed by Violet of Galmi and Chagari, and that the Belami and Safari varieties are the least cultivated, aligns with existing literature [7, 12, 21] regarding the main onion varieties in northern Cameroon. Goudami is the most widely cultivated variety due to its heat tolerance. It adapts exceptionally well to the intense heat of the Grand-North regions, thanks to its high dry matter content [11]. It also offers very high yields, superior storage qualities and better resistance to diseases and pests [1]. Conversely, the Violet of Galmi, even though it is appreciated for its organoleptic qualities, it is highly susceptible to losses. This duality is common in the Sahelian zone, where producers weigh the high market value of the Violet of Galmi against the climate resilience of the Goudami [22]. The Belami and Safari varieties are the least cultivated due to their low market profitability. Indeed, they have poor storage qualities (prone to post-harvest rot), low yields, and demanding soil and fertilizer requirements.

The Goudami variety has globular bulbs ranging in color from straw-yellow to ochre and is favored for its productivity and suitability for traditional storage. The Violet of Galmi variety is highly prized on the market, characterized by its intense purple skin and flattened or globular shape. While renowned for its pungent taste, it is more susceptible to rotting in humid conditions. As for the Chagari variety, although known to 86.52% of stakeholders, it is less widely cultivated. It resembles the Goudami variety but differs slightly in color and storage characteristics. Finally, the marginal varieties Belami and Safari are present but each accounts for less than 5% of the cultivated area.

The results on physical description of storage facilities corroborate the findings regarding the organizational categorization of the value chain, which identifies individual growers as the largest group of producers. Indeed, lacking dedicated storage facilities, small-scale producers use construction sites, granaries and sacks to store onions prior to sale. The predominant use of the construction site and the rudu reflects the enduring reliance on traditional natural ventilation methods. The Rudu and Reseda are recognized as improved storage structures that extend the shelf life to up to six months, compared to only two to three months for bulk ground storage [4, 22]. These results also confirm the prevalence of small-scale producers who engage in storage activities in the Far North region compared to the North region.

The predominant use of concrete for large-capacity storage facilities poses a thermal challenge, with temperatures exceeding 36 °C in the North. This situation runs counter to technical recommendations advocating for materials with high thermal

inertia or insulation systems to prevent the heating of the bulbs, as high temperatures drastically reduce commercial shelf life by promoting desiccation and respiratory metabolism [22, 23].

The high rates of germination and rotting observed in the construction site and Rudu storage facilities are likely caused by high temperatures and humidity levels combined with the piling of bulbs, which restricts airflow between them. Indeed, in these facilities, onions are stacked in large quantities. This arrangement tends to trigger the end of the dormancy period, leading to rapid sprouting and rotting. Within three months, the rate of rotting becomes very high, particularly if the bulbs are not sorted regularly.

The lack of germination observed in onions stored in sacks and granaries can be attributed to the bulb's dormancy (vegetative rest), unsuitable storage temperatures (too cold or too hot), or a lack of ventilation and excessive humidity, factors that trigger rotting rather than germination. This confirms that confinement and poor ventilation are the primary catalysts for fungal diseases [23]. However, in the case of Reseda storage units, the germination of the onions could be attributed to their natural emergence from dormancy. This process is itself promoted by favorable temperature and humidity conditions (temperatures between 5 and 25 °C combined with high humidity). Indeed, RECA-Niger [24] reported temperatures in the range of 25–30 °C and humidity levels of 10–15% within Reseda style stores. This emergence from dormancy may also be attributed to the prolonged storage period (5–6 months), which eventually breaks the bulbs' natural dormancy [22, 25, 26]. Correlation analysis indeed indicates that the germination rate is strongly correlated with storage duration ($R = 0.872$). Although these loss rates are lower than the overall estimates of 20–40% for West Africa [27], they confirm that fungal and bacterial diseases remain the primary obstacle to bulb preservation.

Overall, lower loss rates due to rotting (9.1%) and germination (5.5%) were reported by Housseini Djida *et al.* [15]. The difference in percentages compared to our values is attributable to the fact that those authors stored the samples in a farmer's storage facility. The bulbs were spread out on straw mats and sorted regularly.

As far as factors contributing to losses are concerned, climatic factors include excessive heat, humidity, and unexpected rainfall. Regarding biological factors, the specific issues are germination and diseases (rot). Issues identified in cultivation practices include early harvesting, improper drying and the mixing of healthy and damaged bulbs. Regarding storage facilities, the noted shortcomings include poor ventilation, overloading, water infiltration and a lack of structural soundness. Field observations align with the losses due to germination and rotting recorded in the various types of facilities. It is also observed that excessive heat is the primary cause of loss in the North (46 stores representing 88.46%) and the Far North (48 stores representing 92.30%), representing an overall figure of 90.38%. Humidity also contributes to losses in the North (32.69% for 17 stores) and the Far North (57.69% for

30 stores), accounting for an overall proportion of 45.19%. The third cause is a biological factor which is disease, representing 30.77% of stores in the North and 57.69% in the Far North, for an overall rate of 44.23%. Causes related to cultivation practices, bulb biology, and storage facilities were cited by Housseini Djida *et al.* [15] in their study of post-harvest losses in the Violet of Galmi variety. These various causes have also been documented by other researchers [6, 25, 27].

The p-value of 0.000 confirms that these differences on the thermal disparities between the two regions are statistically significant, suggesting that climatic conditions vary markedly between the two regions, with direct implications for agricultural practices, product preservation, and post-harvest loss management. Furthermore, average temperatures in the construction site (32.68 °C), Reseda (33.67 °C) and Rudu (28.91 °C) structures are high. These data, combined with poor aeration, corroborate the findings regarding germination and rotting rates in these types of storage structures. This observation is reinforced by the correlations between causes of loss and degradation parameters (Table 6). The table shows that temperature ($R = -0.385$) and humidity ($R = -0.313$) are significantly and negatively correlated with rotting. Thus, warmer and more humid climates with good aeration could reduce losses due to rotting.

A marked difference in humidity levels is observed between the Far North and North regions, with a P-value of 0.000 indicating a statistically significant association. Low relative humidity in the Far North promotes weight loss, corroborating the idea that humidity control is just as crucial as temperature control. Furthermore, the marked desiccation observed in the Far North, driven by very low relative humidity, confirms that the air's moisture deficit is a factor in mass loss just as decisive as temperature in arid zones [23]. The overall mean relative humidity values are 26.74% for construction sites, 32.25% for Reseda and 25.69% for Rudu. These values, combined with poor air circulation, are favourable to germination and rotting observed in these types of storage structures. Correlation analysis (Table 6) is consistent with these relative humidity figures. Specifically, temperature and humidity are positively correlated ($R = 0.484$), meaning that a warmer storage area could tend to be more humid. This situation indicates that additional technical and technological measures are essential to extend the onion storage period beyond four months.

The slightly higher acceptance rate in the Far North aligns with the greater number of cooperatives with boards of directors in that region compared to the North. In general, this trend highlights that, despite the deep-rooted nature of traditions, producers recognize the limitations of current structures for securing stocks beyond four months. Moreover, this predisposition towards adoption aligns with trends observed among African smallholders who, faced with significant losses, are increasingly willing to invest in innovative cooling or storage technologies [28]. However, this willingness to adopt such technologies could be hindered by economic barriers and high investment costs, which are frequently cited as the primary

obstacle to modernizing horticultural value chains in sub-Saharan Africa [4, 29]. To the best of our knowledge, this is the first time that the characterization of producer-owned onion storage facilities in the North and Far North regions, as well as the potential acceptance of controlled-atmosphere technology, has been studied.

5. Conclusion

The objective of this study was to evaluate the characteristics of producer-owned storage facilities in the North and Far North regions of Cameroon. The findings revealed four categories of producers, with private individuals predominating at 60.58%. The Goudami onion variety is universally adopted (100%), followed by Chagari and Violet of Galmi. The main storage facilities used are construction sites (38.46%), Rudu (28.85%) and Réséda (25.96%). Germination is a major issue in construction site type facilities, reaching a rate of 9.82%. Storage in construction site (33.17%) and Rudu (31.03%) shows the highest rates of rotting. Losses are driven by heat (90.38%), humidity (45.19%), and diseases (44.23%). Temperatures range between 36 and 40 °C in 26.92% of facilities in the North and between 31 °C and 35 °C in 55.77% of facilities in the Far North. Humidity levels are higher in 98.07% of facilities in the North, whereas very low levels are observed in 82.69% of cases in the Far North. Producers are willing (96.15%) to adopt modern technologies to secure stocks for periods exceeding four months. These results indicate that warmer and humid storage facilities with good aeration could reduce losses and further extend the storage life of onions.

To the best of our knowledge, this is the first time that these parameters and the adoption of technological innovation have been studied in the North and Far North regions using storage facilities owned by producers. This work provides information for managing technical and technological conditions in onion storage facilities and paves the way for the introduction of modern preservation technologies.

Abbreviations

CIG	Common Initiative Groups
COOPS	Cooperative Societies
COOP-BD	Cooperatives with a Board of Directors

Author Contributions

Soumeiya Halimatou: Data curation, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing

Gilles Bernard Nkouam: Conceptualization, Data curation, Investigation, Methodology, Software, Supervision, Validation, Writing – original draft, Writing – review & editing

Jacques Bikai: Data curation, Formal Analysis, Methodology, Software, Supervision, Validation, Writing – original

draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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