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# Economic Potential and Value Chain of Wild Edible Mushrooms and Cultivated Mushrooms from the Virunga National Park and Surrounding Area in the Democratic Republic of Congo

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## Abstract

A substantial body of research has been conducted with the objective of enhancing the understanding of Non-Timber Forest Products (NTFP) in Central Africa. A significant proportion of the studies focus on medicinal plants, in contrast to those that examine food products. Nevertheless, studies on edible wild mushrooms as NTFPs and cultivated mushrooms, on their economic potential and value chains in the Great Lakes Region, remain scarce and largely absent for some NTFPs. In light of the aforementioned considerations, the present study aims to examine the economic potential and value chain of the production sector of wild edible mushrooms (WEM) and cultivated mushrooms (CM) within the Virunga National Park (PNVi) and its surrounding areas in North Kivu, Democratic Republic of the Congo (DRC). To this end, a sample of 432 respondents was selected, distributed equitably among the actors of the Goma-Kitshanga-Mweso value chain, the Goma-Rutshuru chain, the Beni-Mutwanga chain, and the Beni-Mangina chain. A digital questionnaire consisting of open and closed questions was administered, and observations were carried out concurrently. The quantities of mushrooms sold were weighed and photographed. The results demonstrated that, when the eight-

month fruiting period of wild and cultivated mushrooms was considered as a single year for all actors within the value chain, a picker could sell 6.1 kg at $2 and earn $12. A seller could sell 16 kg at $4 and earn $64, while a grower could sell 502 kg at $3 and earn $1506. Consequently, the CM grower generates a significantly higher profit than other participants in the value chain, despite the expenses he incurs. Ultimately, the domestication of WEM, highly prized by the local population of the Virunga National Park, has the potential to enhance their household incomes, as evidenced by the findings of this study.

## Keywords

Economic Potential, Cultivated Mushrooms, Value Chain, Wild Edible Mushrooms, Virunga National Park, North Kivu

## 1. Introduction

For more than a decade, a decline in the level of development has been observed in almost 25 countries. The majority of which, are in sub-Saharan Africa [1] [2]. Moreover, more than half of Africans live in absolute poverty, failing to meet common indicators of human well-being, including access to adequate food [3] [4]. Unfortunately, this situation persists and is getting worse. Indeed, the recent World Hunger Index report shows that "Around 733 million people faced hunger in 2023, or one in eleven people worldwide and one in five in Africa" [5]. According to the same report, the DRC is one of 36 countries in the world with a severe level of hunger (GHI) ($20.0 \leq 34.9$). The country occupies 123$^{th}$ place on the list of 127 countries whose GHI was calculated using data for the period 2019-2023 [6]."

However, the DRC has abundant geological resources, including critical and/or strategic minerals, an immense hydrographic network, a mega-biodiversity, and a wealth of natural resource [7]. And a host of other advantages that are expected to facilitate efforts to achieve the 2030 sustainable development goals are remarkable [8]. However, the country is struggling to make adequate use of these resources. This situation is largely due to the virtual non-existence of the value chains inherent in the DRC's gigantic natural resources [9]. This is particularly true in the biodiversity sector, which generates and helps maintain numerous eco-system services essential to human well-being and economic development [10].

The mycological component of this forest biodiversity of the DRC, constitutes Non-Timber Forest Products (NTFPs) of capital importance, both from a nutritional and economic point of view [11]. However, seasonality in the appearance of these is a limiting factor for their availability, often random and concentrated over a few weeks a year, mainly in the rainy season [12]. From the above, one question has been raised in this study: is there an economic potential for WEM and CM that would constitute a value chain between actors living in the vicinity of the ViNP? In the same vein, the cultivation of wild edible mushrooms (WEM) could prove to be a profitable activity for African farmers in general and those in the DRC in particular [13].

However, although over 300 species of WEM have been recorded in tropical Africa [14] very few of them have been cultivated. Trials to cultivate three strains of three species of edible lignicolous fungi (*Pleurotus cystidiosus O.K. Miller*, *Lentinus cladopus Lév*. and *Marasmius buzungolo Singer*) have been successful in Kisantu, *DRC* [15]. According to Mpulusu *et al.* [16], nine strains of edible wild mushrooms have been domesticated in Kinshasa with encouraging results. These are: *Auricularia cornea*, *Auricularia delicata*, *Marasmiellus inoderma*, *Lentinus brunneofloccosus*, *Lentinus squarrosulus*, *Nothopanus hygrophanus*, *Pleurotus flabellatus*, *Pleurotus cystidiosus*, *Schizophyllum commune.* Nevertheless, these trials and results remain insufficient. The picking is a widespread phenomenon in the DRC and may even become an economic activity [17].

However, in the protected areas (PAs) covered for the most part by the DRC's forests, the WEM sector, like all other NTFP sectors, is often confronted with several regulatory, institutional and organizational constraints; as well as picking practices that are sometimes destructive and unsuitable [18]. However, regulated harvesting in PAs and the soilless cultivation of WEM would contribute not only to the sustainable management of PAs, but also to increasing the income of local residents in the ViNP [19]. This is why it is becoming imperative to define a strategy for organization and promotion of the WEM value chain found in this region [20].

Cooperation between the various key players: research institutions, forestry administration, local communities and the private sector, would contribute to improving knowledge for better natural resource management and the valorization of WEM [21]. It has also been recognized that the development of forest mycetes is hampered by a lack of knowledge about this biodiversity [22]. The need to remedy this shortcoming justifies the intensification of scientific research that has been undertaken through the African Great Lakes Region Mycologists' Network (MycoRGL) [23].

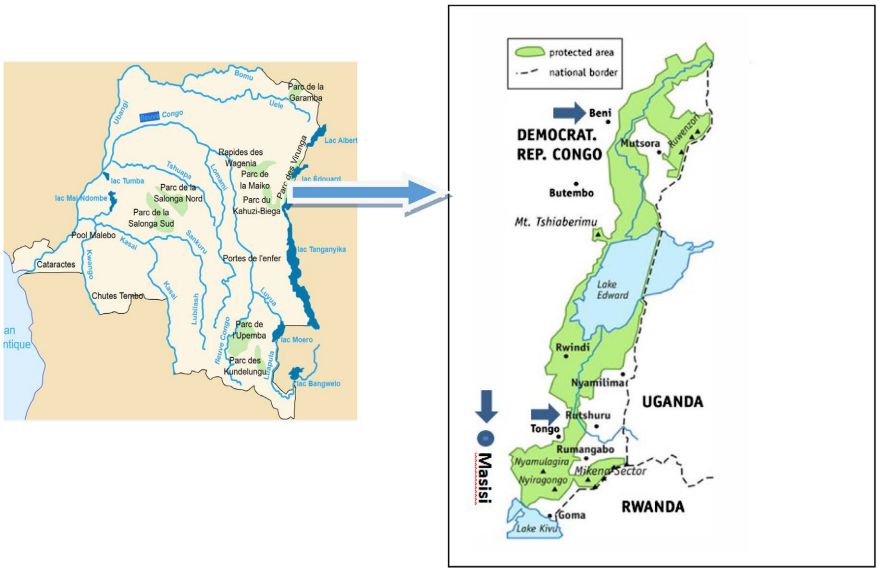
This network, which was created with the support of RBINS-CEBioS in partnership with the Jardin Botanique Meise (JBM), also involves several institutions from the DRC, Burundi and Rwanda [24]. Its ambition is to study mycetes and promote their potential socio-economic uses in- and *ex-situ*, for the benefit of local populations [25]. The results already obtained consist mainly of mycological inventories [26]. Investigations into the socio-economic aspects associated with WEM in the Albertine Rift are insufficient [27].

The results of the above-mentioned investigations allow us to hypothesize that there is an economic potential for WEM and CM that would constitute a value-added chain for players in the vicinity of the ViNP. It is for this reason that, in order to verify this hypothesis, the present study was undertaken, with the aim of describing, analyzing and collecting information on the harvesting, cultivation, marketing and consumption of WEM in Virunga National Park and its surrounding.

## 2. Study Area and Methods

### a) Study area

Figure 1 shows the three territories in which this study was carried out. Beni territory, along two of its main roads (Beni-Mutwanga and Beni-Mangina); Ruthsuru territory (Goma-Rutshuru route); Masisi territory (Goma-Kitshanga-Mweso axis).




NB: The Arrows indicate surveyed areas.

Figure 1. Description of the study area. *Source*: https://fr.wikipedia.org/wiki/G%C3%A9ographie_de_la_r%C3%A9publique_d%C3%A9mocratique_du_Congo#/media/Fichier:Parcs_rdc.svg, https://www.berggorilla.org/en/gorillas/protected-areas-for-gorillas/virunga-national-park/.

The ViNP is divided into southern, northern and central sectors. The southern sector includes the active Nyiragongo and Nyamuragira volcanoes to the west and the extinct Mikeno, Karisimbi, Visoke and Sabyinyo volcanoes to the east. It extends to the east with the Parc National des Volcans in Rwanda and the Gorilla Game Reserve in Uganda. The Central sector is formed by the Rwindi-Rutshuru alluvial plain [28]. This plain, with an average altitude of 983 m, is bordered to the west by the Mitumba range (average altitude 2000 m) and limited to the east by the Ishasha river. This boundary is conventional, and the same type of landscape extends into neighbouring Virunga National Park [29].

The northern and central sectors are separated by Lake Edouard, an immense water reserve covering an area of around 225,000 ha, located at an altitude of 916 m [30]. The northern sector is essentially made up of the Semliki plain, a river that empties the waters of Lake Edouard into Lake Albert and originates at Ishango [31]. The open savannahs of the south are gradually being replaced by the large equatorial rainforest of the middle Semliki. This plain is squeezed between the western ridge of the Graben and the Congolese face of the Ruwenzori, an ancient, violently elevated mountain whose highest peak (Pic de Margueritte, 5119 m) dominates the plain [32]. The three sectors were surveyed in three territories

(Masisi, Rutshuru and Beni).

**b) Sample selection**

Given that WEM are part of NTFPs and that NTFPs are periodic and located in non-specific places, and that the population is not known, the sample size was calculated using FISHER's formula [33].

$$n = \frac{t^2 * p * (1-p)}{d^2} * f$$

where n = Sample size, $t$ = Reduced confidence interval (1.96), $p$ = Proportion of desired estimator (0.5), $f$ = Non-response ratio (1.1), $d$ = Margin of error (0.05). Replacing each term by its value, the solution was as follows [34]:

$$n = \frac{(1.96)^2 * 0.5 * (1-0.5)}{(0.05)^2} * 1.1;\ n = \frac{0.9608}{0.0025} * 1.1;$$

$$n = 384.32 * 1.1;\ n = 384.32 * 1.1 = 422.752 - 432$$

The above formula was used to determine the number of people to be surveyed, *i.e.* 432 people who took part in this study. Multi-stage cluster sampling makes it possible to survey a limited area while preserving the representativeness of the sample at national (or local) level [35]. The diagram below was used to distribute the various respondents from the target population along the different routes (axes) that were covered.


Table 1 shows the distribution of respondents according to the different links involved in value chain activities. Respondents were evenly distributed across all links. These links are: pickers, growers, sellers and consumers. Each link comprised 108 respondents. However, for the consumer link, there was another subsample, made up of 65 respondents, in order to identify the types of mushrooms consumed, including: wild edible mushrooms, cultivated mushrooms and mushrooms sold in tins. Gatherers are men and women who take the time to go in search of wild edible mushrooms in or around Virunga National Park. Cultivators are those who grow edible mushrooms in their own homes. They may also be institutions (schools, universities, associations or cooperatives) that engage in this activity. Sellers, on the other hand, are those who buy from pickers and growers and resell at the market or along roads and footpaths. Consumers are those who come to the market to buy wild edible mushrooms and cultivated mushrooms. The respondents' selection criteria took into account the location of each actor in the value chain. Gatherers were met at the exits of their picking sites (*i.e.* at the exit of the ViNP, along the main village tracks and at the exits of areas reputed to have large quantities of wild edible mushrooms. Farmers were contacted in their workplaces. Vendors were contacted at markets and supermarkets. Consumers were met at their homes.

**Table 1.** Distribution of respondents in the different axes considered.

| | | Respondent links | | | | |
|---|---|---|---|---|---|---|
| **Territory** | **Road axis** | **Pickers** | **Cultivators** | **Sales** | **Consumers** | **Total** |
| Rutshuru | Goma-Rutshuru | 27 | 27 | 27 | 27 | **108** |
| Masisi | Goma-Kitshanga-Mweso | 27 | 27 | 27 | 27 | **108** |
| Beni | Beni-Mutwanga | 27 | 27 | 27 | 27 | **108** |
| | Beni-Mangina-Kantine | 27 | 27 | 27 | 27 | **108** |
| **Total** | | **108** | **108** | **108** | **108** | **432** |

Source: Field surveys, April 2022.

**c) Data collection**

Two types of balance were used: a digital balance to measure small quantities to within 1 kg, and another to weigh larger quantities. The camera was used to take pictures and facilitate the knowledge and classification of the various WEM species. The Kobocollect application was used to manage the survey questionnaire on tablets and android phones. Information on the most popular species on the markets, the quantity sold per day, price variations by species, purchase and transport costs were recorded. Data on the destination of the WEM' collection, the quantity collected per day and the costs associated with this activity were also taken.

The identification of WEM was facilitated by the determination key found on the website: http://www.efta-online.org/.

It lists 10 species of edible wild mushrooms found in and around ViNP.

Two species of mushroom are cultivated around Virunga National Park, but one species of *Agaricus bisporus* is grown more in Rwanda than in the DRC. The species most widely cultivated in the DRC is *Pleurotus ostreatus* (http://www.efta-online.org/) commonly known as Pleurot.

**d) Data analysis**

Data were processed using SPSS 26 and Excel 2013. Descriptive statistics were presented, and means comparison tests were performed using t-student tests at the 5% significance level. Qualitative values are expressed as percentages, and differences were tested using $Chi^2$ tests [36]. Profit margins (PM) were obtained by deducting the Cost of Goods Sold (COGS) from the Selling Price (SP) of the product (PM = SP − COGS) [37]. Costs related to marketing expenses per unit of measurement were calculated as the ratio of expenses related to each function or service to the quantity of product sold or covered by said function(s) or service(s) [38]. Since no fixed investments are made, fixed costs are zero for pickers, and the profit margin is equal to the net margin [39]. As for growers, there has been investment in a few tools and structures, including mushroom houses, substrate preparation barrels and ordinary scales. The investments made by oyster mushroom growers helped to calculate fixed costs (FC) by estimating depreciation. The estimation of fixed costs led to estimates of Net Margins (NetM) [40]. Net Margins were calculated by deducting total oyster mushroom production costs from the

gross product (GP) in value terms, or by deducting fixed costs from gross profit margins [41]. Depreciation has been calculated by taking into account the purchase price of each tool or the cost of each structure in relation to their lifespan. The Net Margin is given mathematically by the following formula: NetM = PM − (VC + FC) or NetM = PM − FC (Am) in Fc; Where NetM = Net Margin, GP = Gross Product, VC = Variable Cost, FC = Fixed Cost, PM = Profit Margin, D = Depreciation [42]. For pickers, the average cost of picking time per picker was calculated by converting into Congolese francs the time spent picking in or around ViNP for all pickers divided by the number of pickers. The average spreading cost per seller was found by taking into account the sum paid on the place used during spreading, as well as some materials used during spreading, for all sellers, divided by the number of sellers. For the average cost of transport and communication, the procedure was the same as for the previous cost calculation. The same strategy for calculating costs was used for the growers. These average costs were used to calculate the intermediate consumptions of the value chain actors, apart from the purchase costs for picking WEM and cultivating CM.

## 3. Results

### 1) Demographic and socio-economic characteristics of respondents

In view of Table 2 below, all the variables relating to the socio-economic characteristics of the respondents produced significant differences at the 5% probability level. However, young people aged 18 - 35 are more represented in all links of this value chain than older people, with a percentage of 52 to 70; p = 0.000. For the gender variable, men are more likely (59%) to gather WEM than women (41%). For culture, Women come first (54%) versus (46%); (p = 0.000) for men. For the marital status of respondents, married people are more represented in all value chain actors (p = 0.000) at the 5% significance level, with a percentage ranging from 64.8 to 83. In terms of education, state graduates were more likely to be involved in mushroom cultivation (36%). Those who have not finished primary and secondary school are well represented in all value chain actors at a percentage between 4 and 33 with (p = 0.000).

Table 2. Demographic and socio-economic characteristics of respondents.

| Variables | Modality | Cultivator n =108 | Picker n = 108 | Sales n = 108 | Consumer n = 108 | $\chi^2$ | p-Value |
|---|---|---|---|---|---|---|---|
| | | % | % | % | % | | |
| Age | 18 - 35 | 51.9 | 54.0 | 70.4 | 57.4 | 370.00 | 0.000* |
| | 36 - 55 | 39.8 | 38.1 | 23.1 | 33.3 | | |
| | 56 - 65 | 4.6 | 6.5 | 6.5 | 6.5 | | |
| | 66 - 70 | 3.7 | 1.4 | 0.0 | 2 | | |
| | Over 70 | 0.0 | 0.0 | 0.0 | 0.8 | | |
| Gender | Male | 46.3 | 59 | 90.7 | 65.7 | 40.33 | 0.000* |
| | Female | 53.7 | 41 | 9.3 | 34.3 | | |

**Continued**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Territory | Beni | 50 | 50 | 50 | 50 | 334.690 | 0.000* |
| | Rutshuru | 25 | 25 | 25 | 25 | | |
| | Masisi | 25 | 25 | 25 | 25 | | |
| Civil status | Single | 16.7 | 17.3 | 26.8 | 17.6 | 664.370 | 0.000* |
| | Married | 83.3 | 82.0 | 64.8 | 76.9 | | |
| | Divorced | 0.0 | 0.7 | 2,8 | 3.7 | | |
| | Separate | 0.0 | 0.0 | 5.6 | 1.8 | | |
| Level of education | No studies | 5.6 | 26.6 | 19.4 | 25.9 | 133.023 | 0.000* |
| | Unfinished primary | 3.7 | 20.9 | 32.6 | 17.6 | | |
| | Primary School Certificate | 3.7 | 7.9 | 13 | 10.2 | | |
| | Unfinished high school | 29.6 | 33.1 | 14.6 | 23.1 | | |
| | State Diploma | 36.1 | 9.4 | 14.8 | 20.4 | | |
| | Graduation | 6.5 | 0.7 | 5.6 | 1.9 | | |

* = Significant at 1%.

**2) Average quantities of WEM and CM harvested, picked, sold and consumed by value chain players**

Table 3 shows that a picker can harvest an average of 78 kg of WEM in the short season (March to May), while the long rainy season allows him to harvest a lot, averaging over 130 kg (September to January). However, the farmer can harvest an average of 359 kg during the crop cycle. The average quantity consumed varies according to the link in the value chain in which the actor is located. However, it turns out that two links (pickers and growers) consume the same

Table 3. Average quantities of mushrooms produced, harvested, sold and consumed by value chain player.

| *Designation* | *Picker* | *Cultivator* | *Sales* | *Consumer* |
|---|---|---|---|---|
| Average quantity produced or picked per season in Kg | 78 (short season) and 130 (long season) | 359 | 0.0 | 0.0 |
| Average quantity sold in kg per season or cycle | 2.3 | 251.5 | 6 | 0.0 |
| Average consumption per household in Kg/day | 5.2 | 5.2 | 0.1 | 2.8 |
| Quantity purchased per customer/day in Kg | 0.0 | 0.0 | 0.0 | 2.8 |
| Average price $kg^{-1}$ in Fc | 4556 | 6913 | 10394.2 | 10394.2 |

Source: Field surveys, April 2022.

quantity of mushrooms per household (5 kg). The seller, on the other hand, consumes only 0.1 kg, for fear of abusing his business. The average price of the quantity sold per kg for WEM is 4556 Fc, around 2 US$ at the rate of 2300 Fc/1US$. CM are sold at an average price of 6913 Fc, around US $3, with a difference of US $1 between pickers and growers. Vendors selling WEM from pickers and growers sell at an average price of 10,394 Fc, around US $5.

**3) Trade in WEM and CM in North Kivu and their circuits**

Table 4 shows that there are three types of mushroom available on the markets of North Kivu: wild edible mushrooms, cultivated mushrooms (*Pleurotus* spp.) and canned mushrooms. CM (*Pleurotus* spp.) can be found everywhere in markets, hotels and supermarkets in North Kivu province. As for wild edible mushrooms, they can be seen in markets and sales outlets when they appear. Packaged mushrooms, on the other hand, are more visible in supermarkets, hotels and restaurants in the major towns of North Kivu province. The 65 respondents (Table 4) from hotels, restaurants, supermarkets, markets, street vendors, grower-sellers and picker-sellers were part of the 432 respondents who made up the sample size for this study.

Table 4. Types of mushrooms marketed by sales system.

| *Sales system* | *Wild edible mushrooms* | *Wild edible mushrooms-Cultivated mushrooms-Canned mushrooms* | *Wild edible mushrooms-cultivated mushrooms* | *Total* |
|---|---|---|---|---|
| Hotels with restaurants | 3 (2B and 1Mu) | 6 (3G and 3B) | 2 (1G and 1B) | 11 |
| Supermarkets | - | 10 (5G and 5B) | 5 (3G and 2B) | 15 |
| Markets | 12 (4B, 4M and 4R) | - | - | 12 |
| Street vendors | 10 (4G, 4B and 2Mu) | - | 7 (2B, 2G, 1Mu, 1Mw, 1Ma-k) | 17 |
| Picker-seller | 5 (1M, 2B, 1Mu and 1R) | - | - | 5 |
| Grower-seller | - | - | 5 (2B, 2G, 1Kiw) | 5 |
| Total | 30 | 16 | 19 | 65 |

**Legend:** B: Beni, M: Masisi, R: Rutshuru, Mu: Mutwanga, Ma-k: Mangina-Kantine, Kit: Kitshanga, Kiw: Kiwanja, Mw; Mweso, G: Goma, numbers refer to respondents interviewed in the various markets, Source: Field surveys, April, 2022.

**4) Distribution of wild edible mushrooms and cultivated mushrooms in and around ViNP**

The results in Table 5 show that, given that no fixed investments have been made by the players in the value chain, the profit margin (PM) is equivalent to the net margin for the pickers. It is explained by the costs and selling prices charged by the players in this value chain. Whereas the results in Table 6 show that the Profit

Margin is different from the Net Margin for growers only. This situation is explained by the fixed costs incurred by growers in depreciating tools and structures, unlike the other links in the value chain. Table 5 and Table 6 show that all players in the value chain achieve positive value added and profit margins, albeit unevenly.

**Table 5.** Estimated profit margin for WEM value chain players (quantity in Kg, amount in Fc) in April 2022.

| *PM element* | *Pickers and sellers* | *Local merchants* | *Intermediaries* | *Market vendors in Beni and Goma* | *Street vendors in Beni and Goma* | *Supermarkets in Goma and Beni* |
|---|---|---|---|---|---|---|
| Average quantity purchased (AQP) | 0.00 | 5.97 | 35.00 | 72.00 | 23.00 | 14.00 |
| Purchase price (PP) | 0.00 | 4555.56 | 10394.18 | 15200.00 | 20300.00 | 25200.00 |
| Purchase cost (AQP*PP) (A) | 4555.56 | 27181.66 | 363796.16 | 1094400.00 | 466900.00 | 352800.00 |
| Average cost of picking time (1) | 1000.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Average spreading cost (2) | 500.00 | 500.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Average communication cost (3) | 0.00 | 0.00 | 600.00 | 700.00 | 1200.00 | 800.00 |
| Average cost of transport (4) | 0.00 | 1800.00 | 2000.00 | 0.00 | 1500.00 | 0.00 |
| Intermediate consumption (IC) (1) + (2) + (3) + (4) (B) | 1500.00 | 2300.00 | 2600.00 | 700.00 | 2700.00 | 800.00 |
| Total WEM operating expenses = Total Cost of Goods Sold (TCGS) (A + B) | 6055.56 | 29481.66 | 366396.16 | 1095100.00 | 469600.00 | 353600.00 |
| Average quantity sold (AQS) | 2.30 | 5.97 | 35.00 | 72.00 | 23.00 | 14.00 |
| Unit cost (UC) = Total Cost (TC)/AQS | 2632.85 | 4941.03 | 10468.46 | 15209.72 | 20417.39 | 25257.14 |
| Average Selling Price (ASP) | 4555.56 | 10394.18 | 16300.00 | 20300.00 | 25600.00 | 30500.00 |
| Value added (A − B) | 3055.56 | 24881.66 | 361196.16 | 1093700.00 | 464200.00 | 352000.00 |
| PM per kg = (ASP − UC) | 1922.71 | 5453.14 | 5831.54 | 5090.28 | 5182.61 | 5242.86 |

Source: Our surveys, April 2022.

**Table 6.** Estimated profit margin for CM value chain players (Quantity in Kg, amount in Fc).

| *Profit margin component* | *Cultivator salesmen* | *Local merchants* | *Intermediaries* | *Market vendors in Beni and Goma* | *Street vendors in Beni and Goma* | *Supermarkets in Goma and Beni* | *Hotels and restaurants in Beni and Goma* |
|---|---|---|---|---|---|---|---|
| Average quantity purchased (AQP) | 0.00 | 251.47 | 730.00 | 1250.00 | 450.50 | 30.00 | 15.00 |
| Purchase price (PP) | 0.00 | 6912.96 | 10394.18 | 15200.00 | 20300.00 | 25200.00 | 30500.00 |
| Purchase cost (AQP * PP) (A) | 10394.18 | 1738416.63 | 7587748.48 | 19000000.00 | 9145150.0 | 756000.00 | 457500.00 |
| Average spreading cost (1) | 0.00 | 500.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cost per man-day/Boot (2) | 531.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Average seed cost (blanc)/boot (3) | 586.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Average cost of substrate and material/boot (4) | 4725.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Continued**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Average cost of transport (5) | 0.00 | 1800.00 | 2000.00 | 0.00 | 1500.00 | 0.00 | 0.00 |
| Average communication cost (6) | 0.00 | 0.00 | 600.00 | 700.00 | 1200.00 | 800.00 | 850.00 |
| Intermediate consumption (IC) (1) + (2) + (3) + (4) + (5) + (6) (B) | 5844.06 | 2300.00 | 2600.00 | 700.00 | 2700.00 | 800,00 | 850.00 |
| Total WEM operating expenses = Total Cost of Goods Sold (TCGS) A + B | 16238.24 | 1740716.63 | 7590348.48 | 19000700.00 | 9147850.0 | 756800.00 | 458350.00 |
| Average quantity sold (AQS) | 125.74 | 251.47 | 730.00 | 1250.00 | 450.50 | 30.00 | 15.00 |
| Unit Cost (UC) = Total Cost/AQS | 129.15 | 6922.11 | 10397.74 | 15200.56 | 20305.99 | 25226.67 | 30556.67 |
| Average Selling Price (ASP) | 4600.00 | 9200.96 | 12500.00 | 18300.00 | 28200.00 | 35500.00 | 45600.00 |
| Value added (A − B) | 4550.12 | 1736116.63 | 7585148.48 | 18999300.00 | 9142450.0 | 755200.00 | 456650.00 |
| PM per kg = (ASP − UC) | 4470.85 | 2278.85 | 2102.26 | 3099.44 | 7894.01 | 10273.33 | 15043.33 |
| Average Depreciation (AD) | 269.78 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Average Net Margin (ANetM) = PM − AD | 4201.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Source: Our surveys, April 2022; bundle or boot: Moistened substrate packaged in a polyethylene bag, cylindrical in shape, often weighing 2 kg, on which the mushrooms germinate.

## 4. Discussion

### 4.1. Demographic and Socio-Economic Characteristics of Respondents

Table 3 shows that all variables related to the socio-economic characteristics of the respondents produced significant differences at the 5% probability level. This shows that the sale and consumption of WEM and CM were influenced by these different characteristics. With regard to age, it can be seen that the 18 - 35 age group represents a high percentage, ranging from 52% to 70%; p = 0.000, compared with other age groups for all players in the WEM and CM value chain. This shows that, in the area surveyed, young people are more active in this value chain than older people. These results are justified by the fact that young people still have the strength to travel through forests and mountains to gather WEM, but also for entrepreneurial initiatives related to mushroom cultivation.

For the gender variable, men (51%) are more likely to pick WEM than women (40%). This can be explained by the fact that some men may pick WEM on their hunting trips. For example, the Bahatsa and Mwenda pygmies in Beni and others make this their main activity. These two categories of men (those who pick passing WEM during the hunt and those who make it their main activity) are increasing their number of pickers, while women have only one category of pickers. For cultivation, however, the opposite is true. Women come first (54%) versus (46%); (p = 0.000) for men.

This is justified by the fact that it's an activity that takes place very close to home, where women can perform it while doing other household chores. For this

reason, men are more likely to sell WEM and cultivated mushrooms (91%) than women (9%), and consume them a lot (66% vs. 34%), as they are part of their subsistence diet in some of the areas surveyed (Bahatsa). These results run counter to those of Härkönen M. [43] who stated that it is mainly women and children who gather WEM, although men do take them home if they happen to find them in Tanzania. However, Boa E. [44] states that in Mexico, Bhutan and Siberia, families and individuals of both sexes may pick WEM, but it is women who sell them at market. Nevertheless, the Boa, *op.cit* goes on to show that in the Indian state of Madya Pradesh, whole families are involved, but women are more active. In Yunnan, China, however, it's the men who are most interested in picking. With regard to the marital status of respondents, married people are more represented in all value chain actors ($p = 0.000$) at the 5% significance level, with a percentage ranging from 2.8 to 83. This can be explained by the fact that married respondents are concerned not only with their own lives, but also with the lives of their offspring. As a result, they engage in all activities that can increase the ratio in their homes. These results are in line with article 447 paragraphs 1 and 2 of the Congolese Family Code, which stipulates that spouses contribute to household expenses according to their abilities and status. The pecuniary aspects of this obligation are governed by the provisions relating to matrimonial property regimes [45].

For the level of education variable, state graduates are more involved in mushroom cultivation (36%). These results corroborate those of Mattia *et al,* [46] who find that higher levels of education in Europe increase the likelihood of being a WEM picker or CM grower in the recreational sense. On the other hand, those who have not finished primary and secondary school are well represented in all value chain actors at a percentage between 4 and 33 with ($p = 0.000$). This can be justified by the fact that the entities surveyed that are favorable to WEM do not have many schools that would encourage value chain actors to continue their studies.

### 4.2. Average Quantities of WEM Harvested, Picked, Sold and Consumed by Value Chain Players

Table 4 shows that a picker can gather an average of 78 kg of WEM during the short rainy season (March to May), while the long rainy season allows him to gather considerably more, averaging 130 kg (September to January). These results are no further from Aguilar [47] who revealed that in Mexico, up to 1,759 kg per ha of WEM can be produced in a good year. Yields in other countries are usually much lower, around 100 kg or less per ha. Nevertheless, the farmer can harvest an average of 359 kg during the crop cycle. These results corroborate those of Sénéchal, [48]; Mercier, [49] who stipulated that, the yield can be 590 kg per bundle (made from crop haulms) or log (log of a wood) per log life of 5 years or 118 kg per year. In addition Mukito *et al.* [50]; Owona and Manirakiza [51] reported that the best yields were obtained with *Pleurotus ostreatus* 2125, 969 and 2153 (strains) grown on a substrate consisting of *Pennisetum* supplemented with avocado stone crush at a rate of 30% (yield varying between 33 and 38%) and 40% (yield varying

between 34 and 36%).

The average quantity consumed varies according to the link in the value chain in which the actor is located. However, two links (pickers and growers) consume the same quantity of mushrooms per household (5 kg). This can be explained by the fact that they can easily find mushrooms without having to buy them, unlike the consumer link, who finds mushrooms for a fee and consumes around 3 kg per household. Vendors, on the other hand, consume only half a kg, for fear of abusing their business. These results corroborate those of Dimitrova [52] who mentions that in the Russian-Siberian Federation, populations pick 15 to 100 kg in a year and consume 80 to 90 percent of it directly. However, he also states that in Malawi, the average consumption of *Termitomyces schimperii* has been estimated at 30 to 35 kg per household per year. Estimating 8 months of WEM production over the whole year, and the average of 30 - 35 kg being 32 kg, the consumption per monthly harvest is 4 kg of *Termitomyces schimperii* in Malawi. This is not far off the *Termitomyces microcarpus* consumption of 5 kg per household in our study area.

The average price of the quantity sold per kg for WEM is 4556 Fc, around US $2 at the rate of 2300 Fc/US$1. CM are sold at an average price of 6913 Fc, around US $3, *i.e.* a difference of US $1 between pickers and growers. Vendors who sell WEM from pickers and who also sell CM from growers sell at an average price of 10,394 Fc $kg^{-1}$ around 5 US$. There is a significant difference of US $3 between pickers and sellers, and US $2 between growers and sellers. Sellers sell CM and WEM at almost the same price, depending on the species. These results corroborate those of André De Kesel who stated that red-orange chanterelles (*Catharellus* spp.) are sold at a higher price (average in January = 5.5 US$ $kg^{-1}$) than yellow-white chanterelles (*Catharellus* spp.) (average in January = 3.9 US$ $kg^{-1}$) in Haut-Katanga province.

They also mentioned that the market price of two categories of chanterelle is highest in January, and gradually and significantly decreases until April. This phenomenon is contrary to that of the study area, where the price is low during the rainy seasons (September-February) and rises gradually during the dry seasons when WEM are scarce (March-August). For chanterelles, the average price fluctuates between US $1.7 ± 0.7 and US $2.8 ± 0.6 on rural and urban markets respectively. Nevertheless, Martinez *et al.* [53] reveal that the quality of WEM has a significant effect on the prices obtained. Strong local demand for wild edible mushrooms guarantees good market prices, but only a small number of gatherers sell their food products directly. More generally, they sell to traders who sell to the market at two or three times the price. This reality was observed in the survey area, where vendors earn almost twice as much as pickers and growers. To sum up, considering only the 8-month fruiting period of WEM and CM as a year for all players in the value chain (picker, grower and seller), it was found that a picker can sell 6.1 kg at a price of $2 and have $12. As for the seller, he can only sell 16 kg at a price of $4 and earn $64. The farmer can sell 502 kg at $3 and earn $1506. It's quite clear that the CC grower makes a lot more profit than the other players

in the value chain.

### 4.3. Trade in WEM and CM in North Kivu and Their Circuits

Table 4 shows that there are three types of mushroom available on the markets of North Kivu: wild edible mushrooms, cultivated mushrooms (*Pleurotus* spp.) and mushrooms packaged in tins. CM (*Pleurotus* spp.) can be found everywhere in markets, hotels and supermarkets in North Kivu province. As for wild edible mushrooms, they can be seen in markets and sales outlets known to consumers and retailers at the time of their appearance (statement given by the guide (Guide Osee Mulembwa de Mutwanga, April, 2021; and Soro [54]. Packaged mushrooms, on the other hand, are more likely to be found in supermarkets, hotels and restaurants in the major towns of North Kivu province. There are even fewer mushroom growers in Goma to be able to flood the city with oyster mushrooms.

According to guide Osée Mulembwa, Congolese cross the border between the DRC and Uganda to sell these WEM. Some Ugandans also return home with WEM harvested in the DRC. As for the Rwandans, they are known to supply WEM and CM, cfr our 2022 surveys at the small and large barriers in the town of Goma (cfr Figure 2 of the WEM and CM distribution circuit). These oyster mushrooms are sold along the main road, at the Birere, Alanine and Kibabi markets [55].

However, wild edible mushrooms reach the major towns and cities (Goma, Beni and Butembo) via a long distribution circuit. Nonetheless, pickers bring them to households in the vicinity of the ViNP or the picking site (**Figure 2**). Local traders can then either sell them in retail outlets or at local markets [56]. Mushrooms sent to households are intended for self-consumption or for sale to local traders and intermediaries [57]. The latter take them to the Alanine market in Goma, or to the Birere or Kibabi markets from Minova, or to the mountains above Sake (Busheka and Mitumbala) or Rutshuru. The most common species in Sake is *Termitomyces rubustus*. In Masisi territory, wild edible mushrooms are sold at the Kitshanga, Minova, Sake and Mweso markets. The most dominant species are *Termitomyces microcarpus and Termitomyces robustus*; other species are sporadic. In Rutshuru territory, edible wild mushrooms are sold mainly at the Kiwanja market from neighboring villages (Kinyandonyi, Katemba, etc.), as well as in Rutshuru center. In Beni territory, the main market for wild edible mushrooms is in Beni ville. These wild edible mushrooms come from other major centers and neighboring villages (Mutwanga, Bahatsa, Beni-Mbau and Mangina-Kantine, among others). These large centers can easily supply the town of Beni, and even the town of Goma and neighboring Uganda (according to Mutwanga Guide Osee Mulembwa). In addition to wild edible mushrooms, the towns of Beni and Butembo have *Pleurotus ostreatus* growers who produce large quantities compared with other towns mentioned above. This gives the town the opportunity to produce large quantities of WEM and CM compared with other areas visited. The supermarket supplying Goma with tinned mushrooms is Kin-Marché, which has more than three outlets in Goma (Supermarché des Indiens). These supermarkets are the source of supply

for street vendors, hotel-restaurant managers and supermarkets in Goma (Figure 2). Other supermarkets stock small quantities on a sporadic basis.

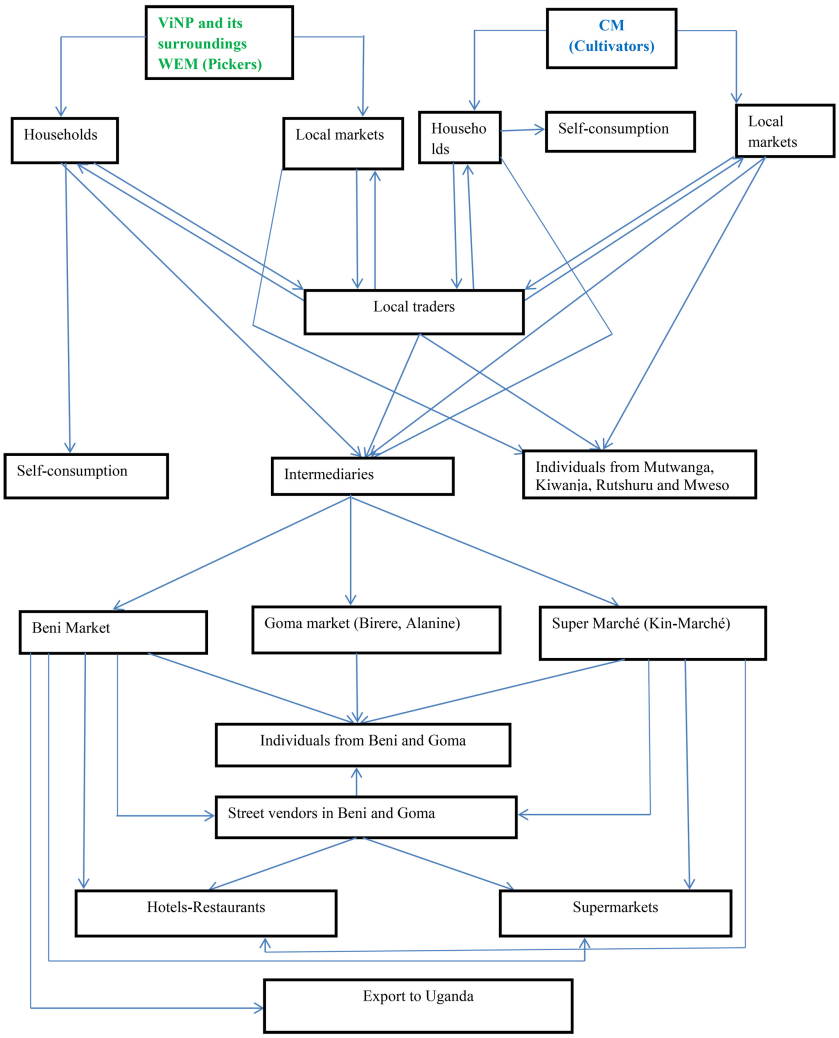



Figure 2. Distribution circuit of WEM and CM. Source: Field surveys, April 2022.

## 4.4. Estimated Profit Margin for WEM and CM Value Chain Players

The results in Table 5 shows that, given that no fixed investments have been made by the players in the value chain, the profit margin (MB) is equivalent to the net margin. The results in Table 6 show that the profit margin differs from the net margin for growers only [58]. This situation is explained by the fixed costs incurred by growers in depreciating tools and structures, unlike the other links in the value chain [59]. These same results in Table 5 and Table 6 reveal that all value chain actors achieve positive value added and profit margins, albeit unevenly. However, value chain players in CM earn more than those in WEM, despite the costs incurred. This is due to the fact that some consumers scorn the consumption of WEM in favor of CM, on the grounds that the latter are clean and well produced under acceptable and well-known conditions. Consequently, they

buy them at a slightly higher price than WEM whose origin and possible toxicity are unknown (Guide Osee Mulembwa de Mutwanga, Avril, 2021). Nevertheless, starting from the charges incurred, traders in the local markets of Masisi, Rutshuru, Mutwanga, Mangina and Kantine bear lower charges for WEM and CM than sellers in Beni and Goma in the larger towns. However, it is the latter that stand out with their higher profit and net margins. This phenomenon is interpreted by upwardly revised prices charged by Beni and Goma sellers for WEM and CM, which is made possible by the existence of higher purchasing power and the arguments given to WEM and CM by certain tribes as luxury foods. In any case, local pickers, growers and traders are forced to charge a lower price, accessible to the rural population that makes up the majority of their clientele. What's more, as there are no effective methods of preserving WEM and CM in Masisi, Rutshuru, Mutwanga, Mangina and Kantine, apart from sun-drying, which only takes place when the day is sunny, sellers strive to sell their entire offer at the end of the day.

## 5. Conclusion

This research assessed the economic potential of the wild edible mushroom and cultivated mushroom value chain in and around the Virunga National Park (ViNP) in North Kivu, DRC. Results from the survey showed that a picker can sell an average of 2.3 kg per season at a price of 4556 Fc (approx. 2 US$) $kg^{-1}$ at an exchange rate of 2300 Fc/1US$. Whereas the CM grower can sell 251 kg/boot life cycle or crop cycle at 6913 Fc (approx. 3 US$) $kg^{-1}$. As for the seller, he can easily sell 6 kg on average per season at a price of 10,394 Fc (around 4.5 US$) $kg^{-1}$. It can be seen that, among these three players in the value chain, the one who can earn more than the others is the grower, because he sells a large quantity at an affordable price despite having to bear many costs. So the larger the quantity he sells, the more income he earns, compared with a local vendor who sells a smaller quantity at a lower price. The WEM and CM marketing circuit extends to neighboring countries such as Uganda and Rwanda. All players in the value chain generate added value, a positive profit margin and net margin, albeit unevenly. The domestication of WEM prized by the local population of the Virunga National Park could help improve their household incomes.

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## Credit Authorship Contribution Statement

Jean Pierre Habineza Mpunga: Data collection, Writing—original draft, Investigation, Formal analysis. Edson Niyonsaba Sebigunda: Supervision, Investigation,

Formal analysis. Chantal Shalukoma: Revised the paper. Philippe Lebailly: Revised the muniscript. Fabio Berti: Revised the muniscript. Constantin Dushimimana: Investigation, Formal analysis and paper revision. François Muhashy Habiyaremye: Revised the muniscript and Coordonated the Ares project. Philippe Burny: First supervisor, Investigation, Formal analysis, Revised the paper. Baudouin Michel: Supervision, Investigation, Formal analysis.

## Declaration of Competing Interest

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

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