# Human uses and indigenous knowledge of edible termites in Vhembe District, Limpopo Province, South Africa

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Termites are a good food source, being rich in proteins, fats, vitamins and many essential mineral nutrients, and thus provide food security for poor households. We report on a survey conducted in the Vhembe District Municipality of Limpopo Province, South Africa, to identify edible termite species and find out how they are harvested, prepared, graded, packaged and marketed. We also looked at the socio-economic factors of the harvesters, marketers and consumers. Using a structured questionnaire, 104 individuals were interviewed from 48 villages. Most of the harvesters were over the age of 60 years but termites are consumed by the whole family. The results of the survey revealed that only three termite species are consumed: soldiers of *Macrotermes falciger* (89.90%), *M. natalensis* (8.08%) and *M. michaelseni* (2.02%). The preferred method of preparation was frying (77.55% of the respondents). At least 80.77% of the respondents indicated that some religions have restrictions on termite consumption but no ethnic restrictions were reported. The income derived from selling termites was estimated to range from ZAR2040 to ZAR17 680 per annum between April 2015 and April 2016. The results of this study showed that edible termites contribute significantly to the livelihoods of many rural families and this indigenous knowledge should be passed on to younger generations. Research on the sustainability of termite harvesting is recommended.

**Significance:**

- Termites are sources of food with high economic and social importance, and are easily accessible by the poor.
- Studies have been conducted on edible termites in many African countries, yet comparatively little is known about edible termites in South Africa.
- Preservation of indigenous knowledge used during harvesting and processing needs to be prioritised.

## Introduction

The consumption of insects by humans is commonly known as entomophagy.[1] Early hominids have been reported to have eaten insects, with termite soldiers and alates of the genus *Macrotermes* being part of their diet.[2,3]

Termites are rich in proteins, vitamins and mineral nutrients.[4] The crude protein content of termites ranges from 20.4% in *Macrotermes bellicosus* (Smeathman) to 35.88% in *Macrotermes nigeriensis* (Sjostedt).[4,5] *Macrotermes bellicosus* alates have been found to be rich in vitamins, with contents of 2.89 $\mu$g/100 g for vitamin A; 1.98 mg/100 g for vitamin B2 and 3.41 mg/100 g for vitamin C.[4] Mbah and Elekima[5] found alates to be high in minerals, namely calcium 21 mg/100 g; phosphorus 1.36 mg/100 g; iron 27 mg/100 g and magnesium 0.15 mg/100 g. In addition to these nutrients, a study conducted by Banjo et al.[4] found that *M. bellicosus* has a carbohydrate content of 43.3%, while Mbah and Elekima[5] found that the oil content of the same termite species is 28.37%. The studies conducted by Phelps et al.[6] in Zimbabwe found that *Macrotermes falciger* (Gerstacker) are very high in energy with 761 kcal/100 g. Termites can therefore provide food security in many poor African countries as they contain essential nutrients, which are often lacking in the diets of people in those countries.[7]

*Macrotermes nigeriensis* alates have been reported by Igwe et al.[8] and Ajayi and Adedire[9] to be consumed as a delicacy in certain parts of Nigeria. People living in Nkoya in the northeastern part of the Western Province of Zambia use termites as an important part of their diets.[10] Chavunduka[11] reported the consumption of termite soldiers of *Macrotermes* species in Zimbabwe. About 14 species of the family Macrotermitidae have been reported to be consumed in sub-Saharan Africa alone, including in some parts of South Africa.[12] The majority of these termite species belong to the genus *Macrotermes*. Of the 12 recognised species of *Macrotermes* that occur in the sub-Saharan Africa region, 9 are commonly eaten and have been recorded from southern Africa.[13,14] These species are all naturally open-woodland or savanna dwellers and all termite castes – queen, soldiers, alates and workers – are eaten.[15,16] In South Africa, Bodenheimer[17] documented the alates of *Macrotermes swaziae* (Full) and *Microhodotermes viator* (Latreille) as edible termite species, while Quin[18] also reported *Odontotermes badius* (Haviland) and *O. capensis* (DeGeer) to be edible.

Harvesting of soldier termites in Uganda was reported to have been done by using wet grass blades or parts of tree pods or bark, by inserting them into the holes of termite mounds that had been opened with a knife.[19] Alates emerge from holes at the mound after the first rains and are caught using light traps suspended over water buckets and basins to collect them as they drop. Bergier[20] indicated that baskets placed upside down over the holes were used in Democratic Republic of Congo to collect the emerging alates.

Termites are killed by drowning, boiling or roasting for a few minutes and are then sun-dried.[10] A study conducted by Niaba et al.[21] in Cote d'Ivoire found that termites prepared for human consumption were either

dried or fresh and prepared through grilling, baking, frying, seasoning or roasting. Botswanan women of San origin prepared the alates of *Hodotermes mossambicus* (Hagen) by roasting.[22]

Comparatively little is known about the use of termites as food in South Africa. The current study was consequently undertaken to document the edible termite species found in the Vhembe District Municipality of South Africa. The study also looked at consumption, harvesting and biomass harvested; processing and marketing of edible termites as an income-generating activity; and, lastly, assessed the contribution of termites to food security.

## Material and methods

### *Study area*

The study was carried out over a period of 12 months (April 2015 to April 2016) in major termite consumption areas in 48 villages in the three local municipalities of the Vhembe District in the Limpopo Province: Thulamela, Makhado and Mutale. These areas were selected because termites are an important food supplement for people living in the district (personal observation).

The Vhembe District Municipality is one of the five districts of the Limpopo Province in South Africa. The district is located at 22°56'S and 30°28'E in the far north and shares borders with Zimbabwe in the north, Mozambique in the east and Botswana in the northwest.[23] According to Mpandeli[24], the average annual precipitation in the Vhembe District is 820 mm, with the rainfall season starting in October and peaking in January–February. Winter starts in May and ends in August. The district has been reported to have extreme temperatures, with maximum temperatures of more than 35 °C during summer months in most parts of the district.[25]

Agriculture is the largest contributor to the district's economy, with small numbers of commercial farmers and predominantly medium- to smallholder farmers cultivating field, tropical and subtropical crops and livestock.[26] Figure 1 depicts the location of the Vhembe District with termite-harvesting mounds and markets where the studies were conducted. A significant portion of the land is arable. The district falls under communal tenure systems, where most of the land legally belongs to the state and is administered by traditional authorities.[27] Most of the villages within the district are rural with a high unemployment rate and the majority of residents, mainly women, are living in poverty and/or depend on government social grants.[28]

## Data collection methods

### *Questionnaires and interviews*

Three sets of structured questionnaires were developed to source the information from the selected harvesters, marketers and consumers. Marketers and consumers were randomly selected. The marketers were interviewed at the markets. The consumers – the buyers of termites – were interviewed at their homes and workplaces. The consumers were randomly selected by approaching people door-to-door at homes and workplaces and by approaching those seen purchasing termites at the markets. Consumers are a separate group and are people who eat termites. Marketers and harvesters also consume termites but were not interviewed as part of the consumer group in Table 1.

A chain referral sampling technique as explained by Biernacki and Waldorf[29] was applied to locate the harvesters through the assistance of the termite marketers at the vendor markets around the study areas. The harvesters were randomly selected from the list provided by the marketers, community members and referrals from other harvesters. Harvesters were interviewed at harvest sites and at their homes. The questionnaire took between 1 h and 1.5 h to complete, depending on how quickly the respondents answered the questions. All the interviews were conducted individually in local languages, i.e. Tshivenda and Xitsonga, with assistance from a Xitsonga fieldworker who is competent in the language.

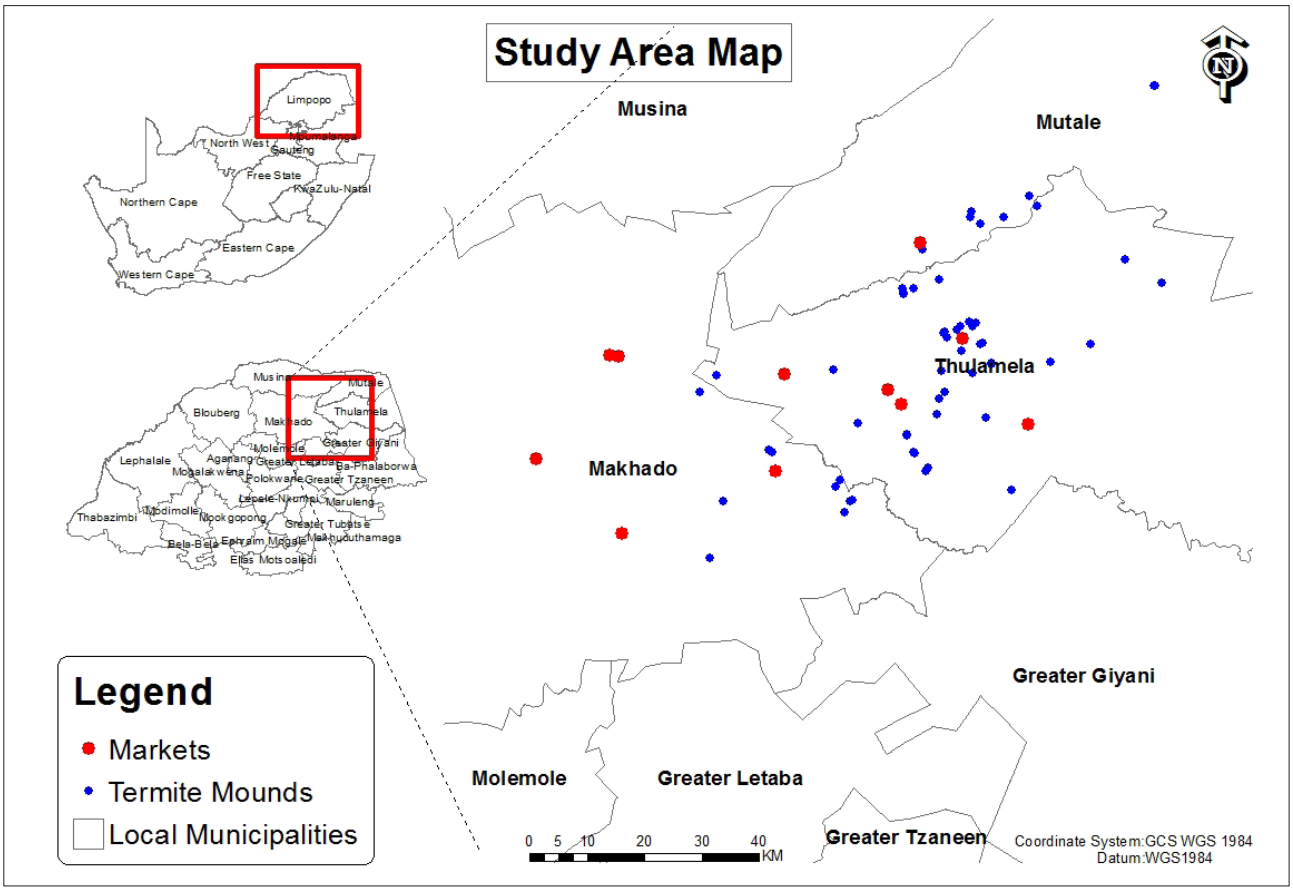


**Figure 1:** Location of the Vhembe District in the Limpopo Province, South Africa (inset) with specific study sites (termite harvesting sites/mounds and markets) indicated. (Enlarged area: 22°49'S to 23°41'S and 29°77'E to 31°02'E).

The consumers', marketers' and harvesters' questionnaires covered the socio-economic characteristics of the respondents, including culture and religion, importance of termites as food, ethnic preferences and prohibitions, uses of termites, frequency and means of termite consumption, species preference, knowledge of termite taxonomy, knowledge of termite abundance and distribution, and knowledge of the role of termites in human nutrition and health. In addition to the above aspects, the marketers' questionnaire also covered marketing, selling prices, marketer's estimated income, what consumers look for before buying, quantity of termites transported per batch, the type and volume of the packaging unit, grading and quality standards (including size, aroma and colour), variability of prices between seasons and volumes sold. Harvesters' questionnaires also covered seasonal availability, distance travelled to harvesting sites, how they know a particular species is edible, how termites are harvested or captured, preparation, preservation, which species are easy or difficult to harvest, how often harvesting occurs, and the quantity of termites harvested or captured in a single harvest.

The study was approved by the Human Research Ethics Committee of the University of the Witwatersrand (protocol number H15/0314).

### *Edible termite surveys*

A total of 62 mounds were randomly selected and sampled with assistance of harvesters in the area. Harvesters were asked to identify mounds in the area from which they were harvesting. The positions of edible termite mounds were recorded using a Garmin GPS 60. At least 10 minor and 10 major soldier castes were collected from each mound and preserved in vials containing 80% ethyl alcohol. These samples were identified to species by the Biosystematics Division of the ARC–Plant Protection Research Institute in Pretoria, South Africa.

## Statistical procedures and data analysis

Statistical Analysis System (SAS), version 9.3 of 2012 was used for the analysis of the descriptive statistics.[30] Data from the questionnaire surveys were analysed separately per municipality for the three local municipalities and also combined (Vhembe District) as the total for the study area. The termite soldiers and alates harvested or captured were determined by recording the number of litres harvested per week, adding this over a period of 12 months. The daily intake of termites was determined by recording the number of cups consumed per household per day and dividing this by the number of household members, and multiplying this by 64.8 grams (a steel cup is equivalent to 64.8 g of termites). The volumes of termites sold annually were determined by recording the number of cups sold per week per month and adding this over a period of 12 months. The rand value of termites was determined using a price of ZAR20 per cup (one steel cup was equivalent to 0.3 L) of termites. Dry weight of termites was determined after sun drying (ready for market). Mapping of the villages and mounds was done using ArcGIS 6.3 software. A chi-square test was used to test for associations between species and local municipalities and between termite types and local municipalities and the proportions of education between harvesters and marketers.[31] Analysis of variance (ANOVA) was used to test the differences between harvesters, marketers and consumers for daily intake.[32]

## Results and discussion

### *Socio-economic characteristics*

The results of the socio-economic data of the termite harvester, marketer and consumer respondents are shown in Table 1. The majority of all respondents to the three questionnaires were female and over the age of 50. However, in Mutale, the age of respondents ranged from 25 to 39 years (47.37%), unlike for the other two municipalities. Most (67.6%) harvesters were over 60 years of age and most (64.5%) marketers were over 50 years of age. The interviews were conducted during normal school hours, which may have affected the availability of the younger age group who would have been in attendance at their educational institutes. In light of that, the results demonstrate that individuals within the district across all ages participate in edible termite activities, be it as a consumer, marketer or harvester. The school-attending children participated only in a limited way, mainly during harvesting. About one third (35%) of the respondents had never attended school, while a large proportion of those that had attended school, had secondary education. A 2x2 chi-square test on the proportions of no versus some education between harvesters and marketers (who eat termites) was significant ($X^2 = 5.25$; d.f. $= 1$; $p = 0.022$) (Table 1). At least 65.5% of the marketers had some form of formal education compared with 26.4% of the harvesters. Tshivenda and Christianity were the most dominant language and religion, respectively, in the district.

A 2x2 chi-square test on the proportions of marketers' education (no versus some) between municipalities was highly significant ($X^2 = 10.83$; d.f. $= 2$; $p = 0.001$) (Table 1). Thus, there was strong association between education status and municipality, as the marketers from Makhado were less educated than those from the Thulamela municipality.

## Termite species diversity and preferences

In all municipalities, we found that most of the respondents were able to identify the major edible termite genera, species and the castes using vernacular names. A 3x2 chi-square test on the proportions of knowledge between the three groups was significant ($p < 0.05$) and the harvester group had 100% knowledge of the termite species, while the consumer group had only 83.3% knowledge and the marketers had 90.3% knowledge. Harvesters and marketers were mainly consistent in providing the vernacular names of termite species as compared to the consumers.

The edible termite species collected from the district belonged to one family of the higher termite species of Termitidae: Macrotermitinae. All of the collected species belonged to the genus *Macrotermes* Holmgren. The fungus-growing termite genus *Macrotermes* has been reported by Roonwal[32] as the most important and widely distributed genus in Africa. The three consumed species collected in the study areas in order of preference were *M. falciger*, *M. natalensis* and *M. michaelseni*. Consumers' most preferred termite option was the soldiers of *M. falciger* (89.90%), *M. natalensis* (8.08%) and *M. michaelseni* (2.02%). *Macrotermes natalensis* and *M. michaelseni* were mainly preferred in Nzhelele (Makhado) and some parts of Mutale where *M. falciger* either is not available or is rarely available. The collection of soldier termites all year round seems to be widespread. The level of consumption of *M. natalensis* and *M. michaelseni* was not large enough for a reliable test and was combined for the chi-square test. A 2x3 chi-square test on the proportions of species consumed per local municipality was not significant ($X^2 = 4.27$; d.f. $= 2$; $p = 0.118$). *Macrotermes falciger* was the most common species collected in Thulamela (51.7%) followed by Makhado (28.1%) then Mutale (20.2%) (Table 2).

*Macrotermes falciger* has larger soldiers than *M. natalensis* and *M. michaelseni*, and was the only species sold at all six surveyed local markets. Harvesters preferred harvesting the major soldiers of *M. falciger* because of their higher demand and harvesters would be able to fill the harvesting buckets more quickly. It was observed that soldier termites were available all year round even though they are scarce in winter months (May to July). The alates were collected during the beginning of the rainy season in October/November in the Vhembe District. Studies conducted by van Huis[12] found that alates are mainly collected during the night and emerge from the holes of the mounds after the first summer rainfall. Meyer[33] found that the alates release of *M. natalensis* in the Kruger National Park occurs mainly during December and February.

Contrary to the findings by Nonaka[22] in studies conducted in Botswana, all the harvesters in the Vhembe District collected more soldiers than the winged reproductives (alates) because they are available all year round, are easy to harvest and are more in demand than alates. This finding substantiates those of Chavunduka[11] who found that major soldiers and alates of *M. falciger* are eaten as food in many parts of Zimbabwe. During the surveys conducted in the Vhembe District, it was reported by consumers that alates can cause stomach disorders.

*Macrotermes natalensis* are smaller than *M. falciger* and the species was not found in any of the markets surveyed. The *M. natalensis* major soldiers are about the size of the ignored minor soldiers of *M. falciger*.

**Table 1:** Socio-economic characteristics of respondents in the Vhembe District, Limpopo Province, South Africa. Data are given as percentages of respondents with the number of respondents in brackets. Not all respondents consumed termites.

| Characteristics | | Local municipality | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Makhado | | | Mutale | | Thulamela | | |
| | | Harvesters | Marketers | Consumers | Harvesters | Consumers | Harvesters | Marketers | Consumers |
| Number of respondents | | 12 | 10 | 10 | 9 | 10 | 16 | 21 | 16 |
| Age (years) | 18 – 24 | | | | | | | | 6.25 (1) |
| | 25 – 39 | | | 50.00 (5) | 22.22 (2) | 70.00 (7) | | 19.05 (4) | 25.00 (4) |
| | 40 – 49 | | 30.00 (3) | 20.00 (2) | | 10.00 (1) | 6.25 (1) | 19.05 (4) | 37.50 (6) |
| | 50 – 59 | 16.67 (2) | 20.00 (2) | 30.00 (3) | 22.22 (2) | 20.00 (2) | 31.25 (5) | 28.57 (6) | 18.75 (3) |
| | >60 | 83.33 (10) | 50.00 (5) | | 55.56 (5) | | 62.50 (10) | 33.33 (7) | 12.50 (2) |
| Gender | Male | | 10.00 (1) | 30.00 (3) | | 20.00 (2) | | | 43.75 (7) |
| | Female | 100.00 (12) | 90.00 (9) | 70.00 (7) | 100.00 (9) | 80.00 (8) | 100.00 (16) | 100.00 (21) | 56.25 (9) |
| Language | Shona | | | | | | | 4.76 (1) | |
| | Tshivenda | 91.67 (11) | 50.00 (5) | 90.00 (9) | 100.00 (9) | 100.00 (10) | 93.75 (15) | 85.71 (18) | 93.75 (15) |
| | Xitsonga | 8.33 (1) | 50.00 (5) | 10.00 (1) | | | 6.25 (1) | 9.52 (2) | 6.25 (1) |
| Religion | African tradition | 50.00 (6) | 20.00 (2) | 20.00 (2) | 66.67 (6) | 10.00 (1) | 25.00 (4) | 19.05 (4) | 18.75 (3) |
| | Christianity | 50.00 (6) | 80.00 (8) | 70.00 (7) | 33.33 (3) | 90.00 (9) | 75.00 (12) | 80.95 (17) | 81.25 (13) |
| | Rastafarian | | | 10.00 (1) | | | | | |
| Educational status | No schooling | 83.33 (10) | 80.00 (8) | | 55.56 (5) | | 56.25 (9) | 19.05 (4) | |
| | Primary schooling | 8.33 (1) | 10.00 (1) | 10.00 (1) | 22.22 (2) | 20.00 (2) | 25.00 (4) | 19.05 (4) | 25.00 (4) |
| | Secondary schooling | 8.33 (1) | 10.00 (1) | 70.00 (7) | 22.22 (2) | 80.00 (8) | 18.75 (3) | 57.14 (12) | 31.25 (5) |
| | Tertiary education | | | 20.00 (2) | | | | 4.76 (1) | 43.75 (7) |

**Table 2:** Termite species, list of castes, corresponding vernacular names and level of consumption of each type in the Vhembe District, Limpopo Province, South Africa. Data are given as percentages of respondents in the district with the number of respondents in brackets.

| Scientific name | Vernacular name | | Level of consumption of each type / species | | | |
|---|---|---|---|---|---|---|
| | | | Local municipality | | District | |
| | Tshivenda | Xitsonga | Makhado | Mutale | Thulamela | Vhembe |
| **Termite species** | | | | | | |
| *Macrotermes falciger* | *Madzhulu a nthwa* | *Tintshwa* | 25.25 (25) | 18.18 (18) | 46.47 (46) | 89.90 (89) |
| *Macrotermes natalensis* | *Madzhulu a nemeneme* | *Timenemene* | 5.05 (5) | 1.01 (1) | 2.02 (2) | 8.08 (8) |
| *Macrotermes michaelseni* | *Madzhulu a nemeneme* | *Timenemene* | 1.01 (1) | 0 (0) | 1.01 (1) | 2.02 (2) |
| **Termite caste** | | | | | | |
| Alates | *Nthwa* | *Tintshwa* | 11.11 (11) | 5.05 (5) | 21.21 (21) | 37.38 (37) |
| | *Nemeneme* | *Tintshwa* | | | | |
| Major soldiers | *Magena* | *Majenje* | 20.20 (20) | 14.14 (14) | 28.28 (28) | 62.62 (62) |
| | *Magege* | *Jendze* | | | | |
| Minor soldiers | *Vhutshembelane* | *Swijenjana* | | | | |
| | *Vhutshemela* | *Jendze* | | | | |

The minor soldiers of *M. natalensis* in Vhembe are quite small, but both major and minor soldiers are harvested and consumed together. These termites are thought to be not as palatable as the *M. falciger* species. *Macrotermes michaelseni* is the least preferred species, was also not available in the market and was detected only twice after direction received from the harvesters. This might be because there were very few mounds of this species in the study area. Although *Odontotermes* spp. and *H. mossambicus* occur in Vhembe and are known to be eaten by humans,[18,22,34] these species were not sold at any of the markets surveyed.

## Termite consumption

The overwhelming majority of the respondents (94.23%) of all ages and genders from three local municipalities consumed termites. The findings by Nyeko and Olubayo[35] on the studies conducted in Uganda found that both male and female respondents of all ages consumed soldiers, alates and workers. A majority (97.96%) of the respondents grew up eating termites. Soldiers of mainly *M. falciger* were the most preferred and regularly consumed in the district followed by alates. A 2x3 chi-square test on the proportions of termite type consumption per local municipality was not significant ($X^2 = 1.67$; d.f. = 2; $p = 0.434$). In all three municipalities, more soldiers (62.62%) than alates (37.38%) were consumed (Table 2). No workers were consumed. Table 3 shows the state in which edible termites are consumed in the district. It was observed that most of the respondents in the district consumed termites as frequently as possible.

The results of this survey show that the termites were eaten fresh (raw straight out of the mound) or were dried or refrigerated. Termites were prepared in a variety of ways: boiled, fried, grilled, roasted and sundried. They were normally eaten with maize meal porridge. At least 77.55% of consumers preferred fried termites mixed with tomato and onions followed by boiled (11.22%), sundried (5.01%), fresh (3.06) and grilled (1.02%). The results of this study also affirm those of Niaba et al.[21] who found that the majority of Ivorians preferred fried termites seasoned with spices. It was observed from this study that fresh termites were consumed by the harvesters while harvesting. The average daily intake of soldier termites per person was 22.27 g (dry weight), with a maximum of 38 g and a minimum of 7.70 g. Termite consumers in the study area indicated that one steel cup (0.30 L) of soldier termites (dry weight) can feed an average of three members of a household daily. A one-way ANOVA was done to test for differences in daily intake between the three groups involved with termites. No significant differences were found at the 5% level. Consumers ate more (23.17 g) than harvesters (21.09 g), but the differences among the three groups were not significant (Table 4).

Most of the respondents rated health benefits or nutrition as the main reason for consumption, as termites were reported to enhance health and ease digestion (Table 3). Of interest, one of the marketers, a qualified retired nurse, stated that termites are high in proteins compared to beef, fish and poultry and that termites are good for breastfeeding mothers as they contain iron. She also stated that termites were used by many households to combat malnutrition in the district. A study conducted in Owerri, Nigeria, by Igwe et al.[8] revealed that *M. nigeriensis* is a good source of proteins, minerals and nutrients and played a significant role in fighting protein energy malnutrition.

**Table 3:** Results of consumption survey from three groups of harvesters, marketers and consumers combined. Data are given as percentages of respondents with the number of respondents in brackets.

| Characteristics | Local municipality | | | District |
|---|---|---|---|---|
| | Makhado | Mutale | Thulamela | Vhembe |
| Number of respondents | 31 | 18 | 49 | 98 |
| **Frequency of termite consumption** | | | | |
| As often as possible | 32.26 (10) | 22.22 (4) | 34.69 (17) | 31.63 (31) |
| Occasionally | 25.81 (8) | 11.11 (2) | 12.24 (6) | 16.33 (16) |
| Once a week | 22.58 (7) | 27.78 (5) | 30.61 (15) | 27.55 (27) |
| Twice a week | 19.35 (6) | 38.89 (7) | 22.45 (11) | 24.49 (24) |
| **Why termites are eaten** | | | | |
| Curiosity | 3.23 (1) | 5.56 (1) | 2.04 (1) | 3.06 (3) |
| Custom | 19.35 (6) | 5.56 (1) | 4.08 (2) | 9.18 (9) |
| Desire | | | 4.08 (2) | 2.04 (2) |
| Enjoyment | 9.68 (3) | | | 3.06 (3) |
| Flavour | 9.68 (3) | 5.56 (1) | 6.12 (3) | 7.14 (7) |
| Nutrition | 38.71 (12) | 61.11 (11) | 63.27 (31) | 55.10 (54) |
| Poverty | 19.35 (6) | 22.22 (4) | 20.41 (10) | 20.41 (20) |
| **Most preferred termite caste** | | | | |
| Alates | 35.48 (11) | 22.22 (4) | 42.86 (21) | 33.73 (36) |
| Soldiers | 64.52 (20) | 77.78 (14) | 57.14 (28) | 63.27 (62) |

**Table 4:** Daily termite intake of three groups associated with termites in the Vhembe District, Limpopo Province, South Africa

| Group | Sample size | Mean intake (g) | Standard error of the mean |
|---|---|---|---|
| Harvesters | 37 | 21.09 | 1.325 |
| Marketers | 31 | 22.55 | 1.435 |
| Consumers | 36 | 23.17 | 1.288 |

In addition to the health benefits derived from consuming termites, it was also observed that some pregnant and lactating women consumed soil from termitaria of the three identified *Macrotermes* species for nutrients and good health. This phenomenon of eating soil is termed geophagy and has health benefits of enhanced maternal calcium status and improved foetal skeletal formation.[36] This corroborates the findings by Saatoff et al.[37] who stated that women in South Africa consumed soil from termitaria. It was also discovered that some babies within the study area were fed soft porridge mixed with ground powder of termite soldiers and alates by their parents who were either termite consumers or marketers. Other anecdotal reports in the study area were that traditional healers used powdered termites in their traditional medicines to cure diseases and injuries. Figueirêdo et al.[38] documented the use of *M. nigeriensis* in Nigeria for the treatment of wounds and illness in pregnant women.

## Termite type preferences and prohibitions

With reference to religion, of the 37 harvesters interviewed, most (63.6%) were Christian – 4 of whom did not consume termites – and the rest were of the African tradition. Similarly, most (86.2%) of the 29 marketers interviewed were Christian – 1 of whom did not consume termites – and the rest were of the African tradition. Most (80.6%) of the consumers interviewed were Christian, one was a Rastafarian, and the rest were of the African tradition. The majority (80.77%) of respondents indicated that some religions have restrictions on termite consumption; they stated that some of the old traditional churches prohibit the eating of termites while the charismatic churches do not. The results of this study support the findings made by Silow[10] that some missionaries condemned the eating of winged termites as a heathen custom and Christians were advised to not eat termites as the practice was non-Christian. A study conducted by Egan[39] in the Blouberg Municipality in the Limpopo Province found that members of the Zion Christian Church were prohibited to eat any insect other than locusts. Vhavenda or Vatsonga clans in the district were reported to not have restrictions on termite consumption.

## Harvesting of edible termites

Harvesting of termites was mostly done by women and in some cases they were assisted by their children. Harvesting of soldier termites occurred all year round in all three municipalities. During harvesting, both the major and minor soldiers were collected. Harvesting of termite soldiers took place most often (29.73%) 3 days a week, followed by 2 days (21.62%) then 4 days and 6 days (13.51%), 7 days (10.81%) and, least often, 1 and 5 days (5.41%) a week. We have shown that harvesters are actively involved in feeding the population and also contributing to the economy of the district. The winged termites were collected after the first rains of the rainy season, mainly in October/November periods. In some of the villages, mainly in the Thulamela Municipality, the alates were also collected until January. The harvesting of the alates was done 2 days (66.67%) and 3 days (33.33%) a week. Reasons given for harvesting termites included: poverty, to get money, high demand of termites in the study area, part of tradition, following parent's tradition, interest and to be kept busy.

The harvesters indicated that the knowledge about which termite species to harvest was indigenous knowledge passed onto them by their parents or grandparents at a very young age or from other harvesters. The harvesters used size, taste and colour of termites as well as the mound type and size to identify the species. According to the harvesters, *M. falciger* is identified by its dark brown/red colour, dark abdomen, big head, large size and good taste, whereas *M. natalensis* are differentiated by a light brown/red colour, thinness, small head, shiny colour and sour taste. *Macrotermes michaelseni* was reported to be similar to *M. natalensis* except that the head of *M. michaelseni* is slightly darker than *M. natalensis*. Low and wide mounds characterise *M. falciger* whereas taller and narrower mounds are those of *M. natalensis* and *M. michaelseni*.

Distance travelled by harvesters to the harvest sites varied between 100 m and 8 km. Most (81.1%) harvesters travelled up to 4 km to harvest sites and many (37.8%) had to travel only up to 2 km. Harvesting took place in the yard, next to roads and in open fields, orchards and mountains. Harvesters raised the issue of safety as a major concern and they often resorted to harvesting in groups for safety reasons.

Harvesting of soldier termites was carried out at any time during the day but more termites were collected in the morning and late afternoon. Soldier termites were collected by inserting grasses or fibres made from trees into the opening of the 'eyes' of the nest and after a short period withdrawing the grass. Eyes are the small openings of the termites' nests. Both the soldier termites and workers who had bitten the grass or fibre were then stripped into the harvesting container. The grass or fibres were either moistened with water or saliva when becoming dry to facilitate grasping. Harvesters usually wrapped grasses or fibres in plastics, put them in empty mealie meal bags and stored them in the shade during harvesting to prevent desiccation. Table 6 gives the names of the various plants used for harvesting soldier termites. Studies conducted in Uganda by Roulon-Doko[40] also described that the women in Uganda lower saliva-moistened grass blades of *Imperata cylindrica* to collect soldier termites. Harvesters used plant leaves in attracting termite soldiers to the mouth of the mound by closing the mouth with leaves (Table 5). All of these plants have putrid and strongly scented leaves which is believed to attract termite soldiers. The most used plant species to harvest termites were the stems of *Cyperus* spp.; ground or pulverised *Nicotiana tabacum* leaves and *Clerodendrum glabrum* leaves were the most widely used plants to attract termites during harvesting (Table 5).

Most of the harvesters indicated that soldiers were easy to harvest because they were available any time, were quick to harvest and many could be harvested from one hole. Alates were reported to be the most difficult to harvest because of the high labour intensity involved, and because they do not emerge on windy days, are sensitive to noise, emerge in the evening (with evening harvesting being a safety concern), are available only after rains and because it takes at least 3 days to harvest them after placing traps. Mounds of *M. natalensis* were also reported to be more difficult to harvest from because the soil is harder than that of *M. falciger* mounds.

Alates were collected after rains using a bucket or pot by digging a hole in the soil at the bottom end of the mound on a steep slope and then placing an empty bucket (without the lid) in the cavity. The hole was covered with sticks and leaves of either banana (*Musa paradisiaca* Linnaeus and *M. sapientum* Linnaeus) or *Peltophorum africanum* (Sond). It was claimed that the leaves of these two plants provide good shade. As alates leave the nest, they roll or fly to the bottom of the hole where they are trapped and collected. A similar harvesting method was reported in Zimbabwe by Chavunduka[11]. The only difference was that in Zimbabwe, the roof was covered with grass and a pot containing water was used. To limit the number of alates flying in an evening, harvesters used pestles to close the openings at the onset of a rainy season. This method is traditionally known as '*u tsivha*' in Tshivenda. Households collected termites for home consumption but the alates were also sold at the market.

Table 6 shows summary statistics of edible termites harvested, marketed and consumed in the Vhembe District. The results show that a minimum of 1 L of soldier termites and 20 L of alates were harvested in a single harvest compared to the highest harvests of 10 L and 40 L, respectively. The soldier termite biomass of *M. falciger* varied from 641.3 g to 642.8 g (fresh weight/litre). These soldiers weigh on average 0.15 g each and these values therefore correspond to approximately 4280 individuals/litre. Harvesting season of the alates lasted a maximum of 4 months depending on rainfall.

**Table 5:** Plants used for harvesting and attracting termites and their extent of use. The values in the table are percentages with actual counts in brackets.

| Botanical name | Common name | Vernacular name (Tshivenda) | Family | Part of the plant used | Extent of use by municipality (actual counts) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Thulamela | Makhado | Mutale | Total (Vhembe) |
| **Plants for harvesting** | | | | | | | | |
| *Cyperus latifolius* Poir | Smooth flat sedge | *Dzhesi* | Cyperaceae | Stems | 7.14 (4) | 8.92 (5) | 5.36 (3) | 21.42 (12) |
| *Cyperus sexangularis* Nees | Bushveld sedge | *Mutate* | Cyperaceae | Stems | 1.79 (1) | 1.79 (1) | 8.92 (5) | 12.50 (7) |
| *Cyperus rotundus* Linnaeus | Nut sedge grass, purple sedge grass | *Mutate* | Cyperaceae | Stems | 19.64 (11) | 12.50 (7) | 3.57 (2) | 35.71 (20) |
| *Plectranthus laxiflorus* Benth | Citronella spur-flower, white spur flower | *Bunganyunyu Sindambudzi* | Lamiaceae | Stems | 0 (0) | 3.57 (2) | 0 (0) | 3.57 (2) |
| *Annona senegalensis* Pers. | African/ wild custard apple | *Muembe* | Annonaceae | Fibres | 7.14 (4) | 1.79 (1) | 1.79 (1) | 10.72 (6) |
| *Musa* spp. Linnaeus | Banana | *Muomva* | Musaceae | Leaves, fibres | 3.57 (2) | 0 (0) | 0 (0) | 3.57 (2) |
| *Agave sisalana* Perrine | Sisal plant | *Tshikwenga Savha* | Asparagaceae | Leaves, fibres | 3.57 (2) | 0 (0) | 0 (0) | 3.57 (2) |
| *Balanites maughamii* Sprague | Torchwood | *Mudulu* | Zygophyllaceae | Fibres | 0 (0) | 1.79 (1) | 0 (0) | 1.79 (1) |
| *Grewia flava* DC | Velvet raisin / wild currant | *Muhwana Murabva* | Malvaceae | Fibres | 0 (0) | 1.79 (1) | 0 (0) | 1.79 (1) |
| *Cocculus hirsutus* (L.) Diels | Broom creeper | *Muzwingwe* | Menispermaceae | Stems | 1.79 (1) | 0 (0) | 3.57 (2) | 5.36 (3) |
| Total | | | | | 44.64 (25) | 32.14 (18) | 23.21 (13) | 100 (56) |
| **Attractants** | | | | | | | | |
| *Clerodendrum glabrum* E. Mey | Tinder wood | *Munukhatshilongwe* | Lamiaceae | Leaves | 11.11 (2) | 22.22 (4) | 0 (0) | 33.33 (6) |
| *Lippia javanica* (Burm. f.) Spreng | Lemon bush | *Musudzungwane Mukundamboho* | Verbenaceae | Leaves | 0 (0) | 16.66 (3) | 0 (0) | 16.66 (3) |
| *Nicotiana tabacum* Linnaeus | Tobacco plant | *Fola* | Solanaceae | Ground or pulverised tobacco leaves | 16.66 (3) | 11.11 (2) | 5.56 (1) | 33.33 (6) |
| *Cannabis sativa* Linnaeus | Marijuana plant | *Mbanzhe* | Cannabaceae | Leaves | 5.56 (1) | 0 (0) | 0 (0) | 5.56 (1) |
| *Plectranthus laxiflorus* Benth | Citronella spur-flower, white spur flower | *Bunganyunyu Sindambudzi* | Lamiaceae | Leaves | 0 (0) | 11.11 (2) | 0 (0) | 11.11 (2) |
| **Total** | | | | | **33.33 (6)** | **61.11 (11)** | **5.56 (1)** | **100 (18)** |

**Table 6:** Summary statistics of edible termites harvested, marketed and consumed in the Vhembe District, Limpopo Province, South Africa (as estimated by the respondents)

| Characteristics | Municipality and district | | | |
|---|---|---|---|---|
| | Makhado | Mutale† | Thulamela | Vhembe |
| **Termite soldiers captured in a single harvest (litres)** | | | | |
| Average | 3.25 | 4.44 | 4.25 | 3.97 |
| Minimum | 1.00 | 2.00 | 2.00 | 1.00 |
| Maximum | 5.00 | 6.00 | 10.00 | 10.00 |
| **Alates captured in a single harvest (litres)** | | | | |
| Average | 40.00 | 20.00 | 35.00 | 33.33 |
| Minimum | 40.00 | 20.00 | 20.00 | 20.00 |
| Maximum | 40.00 | 20.00 | 40.00 | 40.00 |
| **Termite soldiers harvested during peak times per week (litres)** | | | | |
| Average | 13.33 | 15.00 | 23.81 | 18.27 |
| Minimum | 3.00 | 5.00 | 2.00 | 2.00 |
| Maximum | 35.00 | 24.00 | 60.00 | 60.00 |
| **Alates captured during peak times per week (litres)** | | | | |
| Average | 120.00 | 80.00 | 65.00 | 76.66 |
| Minimum | 120.00 | 80.00 | 40.00 | 40.00 |
| Maximum | 120.00 | 80.00 | 80.00 | 120.00 |
| **Volume delivered to the market per consignment (litres)** | | | | |
| Average | 14.00 | – | 22.00 | 19.70 |
| Minimum | 10.00 | – | 5.00 | 5.00 |
| Maximum | 20.00 | – | 80.00 | 80.00 |
| **Volume of soldiers and alates sold daily by marketers (litres)** | | | | |
| Average | 2.40 | – | 4.95 | 4.13 |
| Minimum | 1.00 | – | 1.00 | 1.00 |
| Maximum | 4.00 | – | 20.00 | 20.00 |
| **Volume of soldiers and alates sold annually by marketers (litres)** | | | | |
| Average | 101.00 | – | 111.43 | 108.06 |
| Minimum | 80.00 | – | 30.00 | 30.00 |
| Maximum | 120.00 | – | 260.00 | 260.00 |
| **Daily intake per person (dry weight in grams)** | | | | |
| Average | 25.23 | 22.00 | 20.54 | 22.27 |
| Minimum | 9.00 | 11.00 | 8.00 | 8.00 |
| Maximum | 32.00 | 38.00 | 32.00 | 38.00 |

†*Termites were not sold in Mutale informal markets.*

With the growing population and the mass collection of termites, questions are being raised as to the sustainability of harvesting termites. Indications from the harvesters, based on the yields received per mound, were that they have not noticed any decline in termite availability over the years, even though harvesting has been increasing. Termite harvesters promoted responsible harvesting through mound rotations and protected mounds from destruction. They were concerned about the destruction of mounds in new areas zoned for housing developments.

Farmers and the local community also played their part in protecting the termite mounds. Most of the termite mounds located within the crop fields were not destroyed during ploughing and farmers planted around the mounds. Mounds are considered the property of the family if found near their homes or fields. The permission of that family has to be requested before harvesting can take place. Research into the sustainability of termite harvesting is recommended.

## Preparation and preservation of edible termites

Harvested termite soldiers were killed using boiled or cold water or by roasting and then either sun dried or refrigerated to reduce spoilage. *Macrotermes natalensis* and *M. michaelseni* soldiers were prepared differently because these two species are not as palatable as *M. falciger*. Their preparation for cooking included vigorously whisking them with a natural whisk (a forked, fresh tree branch) in water and then rinsing. The whisking process created foam in the water, which suggests some chemical or toxin was being released and removed. The harvesters believed that whisking was to eliminate the bitter taste of the soldiers of these two species.

## Marketing and economic benefits of edible termites

A total of 13 informal street markets were surveyed in the district: Makhado (8), Thulamela (4) and Mutale (1) (Figure 1). Of these informal markets, 46% sold termites, of which 66.67% were in Thulamela and 33.33% in Makhado. No termites were sold in Mutale informal markets. The vendors in both Thulamela and Makhado municipalities rented space from the municipalities on the side of the road or pavement and no one was registered as a business entity. Sellers also rented space for storage of the termites, other edible insects and dried vegetables. The majority (96.77%) of vendors selling termites were women between the ages of 50 and 60 years. The marketers were not actively involved in any harvesting but only bought termites from harvesters. There were large numbers of sellers in Thohoyandou (Thulamela Municipality) sitting close to one another, resulting in competition for buyers and this led to sellers giving extras to attract more customers. It was observed that customers checked for freshness, presence of legs, cleanliness, species type and oil on alates before they bought. Sellers allowed buyers to taste before buying. Some buyers preferred termites fresh from the mounds.

Termites were graded using a traditional way of sieving according to morphospecies, size and type by harvesters before selling to marketers or consumers. Major soldiers were separated from minor soldiers and workers. Minor soldiers were fed to chickens. The average marketer in the district sold 14, 120 and 367 steel beakers (0.30 L) of termites daily, monthly and annually, respectively. Table 7 shows the number of sellers, volumes sold, and unit weights and prices in South African rands (ZAR) with the standard deviation. The price of termites per steel beaker (0.30 L) was ZAR20. The dry weight of termites per the packaging unit (steel beaker) was 64.8 g. The lowest volume of termites sold daily was 1 L (3.5 steel beakers), which is equivalent to ZAR70, while the highest volume sold daily during peak times was 20 L (70 steel beakers), which equates to ZAR1400. Peak season when termites are most visible and available is normally between October and February. The majority of sellers reported no price fluctuations during the year or between seasons. The quality of the termites did not affect the price. Buyers can purchase soldiers or alates separately in a beaker or combined in a mix. All of the termite sellers sold throughout the year, 6 days a week, working half day on Saturdays. The average income derived from termites was estimated at ZAR292 daily, ZAR2395 monthly and ZAR7348 annually. The lowest annual income from the sale of termites was estimated at ZAR2040 compared with highest annual income of ZAR17 680.

**Table 7:** The number of sellers, volumes sold plus unit weights and prices in ZAR recorded in Vhembe District, Limpopo District, South Africa

| Variable | Quantity | Standard deviation |
|---|---|---|
| Number of sellers selling termites | 31 | |
| Average litres sold per day (estimate by seller) | 4.13 | 4.61 |
| Average litres sold per month (estimate by seller) | 35.23 | 20.52 |
| Average litres sold per year (estimate by seller) | 108.06 | 44.90 |
| Average dry weight of termites in 1 beaker (kg) | 0.0648 | |
| Price per steel mug (ZAR) | 20 | |

According to Statistics South Africa[41], the retail prices of various fresh meats as at the end of January 2017 were: beef chuck (ZAR73.67/kg), beef rump steak (ZAR117.18/kg), pork chops (ZAR78.59/kg), whole chicken (ZAR43.69/kg) and lamb leg (ZAR123.84/kg). The price per kilogram of termites was estimated at ZAR100.00/kg. The retail prices obtained from two local butcheries for dried beef meat, sausages and pork were ZAR329/kg, ZAR320/kg and ZAR430/kg, respectively. Dried lamb and dried chicken were not sold. This comparison indicates that the price per kilogram for termites was more than the price of fresh chicken, beef and pork, but less than that of lamb chops and dried meats. However, 1 kg of termites can feed at least 15 people – far more than 1 kg of fresh chicken, beef or pork and dried meats. In addition, termites can be harvested in the district by anyone at no cost.

Alternative sources of income for sellers of termites were the sales of other edible insects (mopane worms and edible stinkbugs) and vegetables (dried/fresh pumpkin leaves and flowers, *Amaranthus hybridus*, *Cleome gynandra*, dried/fresh *Corchorus tridens*, *Solanum nigrum* and dried *Biden pilosa*). The results of this study indicate that termites are contributing to the socio-economic well-being and food security of the people living in the district. Most of the termite trading took place in Thulamela, with the Thohoyandou Complex the largest provider of termite markets, followed by the Sibasa Complex.

## Conclusion

*Macrotermes* termites play a significant role in food security in many communities in the Vhembe District, thus the indigenous knowledge of harvesting and preparation should be retained. As termites are a protein source and can generate income, promotion of sustainable termite harvesting for food security should be adopted. Further research into the sustainability is required as well as the nutritional value of various termite species. In conclusion, the approach of entomophagy can play a big role in combating the global food crisis. Promoting indigenous knowledge of diets and sustainable harvesting of insects should be taught at schools at an early stage.

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## Authors' contributions

S.R.N. and F.D.D. worked on the original concept of the manuscript. E.C.K. gave valuable scientific inputs during conceptualisation and also provided significant contributions during the editing of the manuscript.

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