Nutrafoods (2021) 1:234-245 DOI 10.17470/NF-021-0031

Original Research

Effects of the cooking of mushrooms (*Cantharellus symoensii*; firifiti) on vitamin C, phenolic compounds and antioxidant activity

Abstract

Thermal treatments may lead to the degradation of phytochemical compounds in foods of plant origin. The selection of cooking methods is key to preventing nutritional losses.

Therefore, the aim of this research was to determine the effects of different cooking methods on vitamin C, phenolic compounds and antioxidant activity in *Cantharellus symoensii* (firifiti).

Frying significantly ($p \leq 0.05$) decreased vitamin C content, but significantly ($p \leq 0.05$) increased total phenolic content, flavonoid content and antioxidant activity. Boiling significantly ($p \leq 0.05$) decreased vitamin C, total phenolic content, flavonoid content and antioxidant activity.

Microwaving resulted in a significant ($p \leq 0.05$) increase in the total phenolic content and antioxidant activity, but significantly ($p \leq 0.05$) reduced vitamin C and flavonoid content. Baking significantly ($p \leq 0.05$) decreased vitamin C and flavonoid content, but significantly ($p \leq 0.05$) increased the total phenolic content. All of the cooking methods decreased the vitamin C content.

The order of DPPH activity was: fried > baked > microwaved > raw > boiled. From the four cooking methods studied, frying was established as being the most effective cooking method for retaining or enhancing mushroom bioactive compounds.

TV Ndlovu[1]

T Reid [2]

B Chipurura [1]

[1]Department of Food, Nutrition and Family Science, University of Zimbabwe, P.O. Box MP 167, Mount Pleasant, Harare, Zimbabwe

[2] Department of Biochemistry, University of Zimbabwe, P.O. Box MP 167, Mount Pleasant, Harare, Zimbabwe

*Corresponding author:
B. Chipurura
bchipurura@gmail.com

Keywords: Cooking, *Cantharellus symoensii*, vitamin C, phytochemical, antioxidant activity

Introduction

Oxidative damage caused by free radicals is the main cause of the development of chronic degenerative diseases such as diabetes, cardiovascular diseases, stroke and cancer [1]. Free radical formation is a natural process, which is linked to metabolism in body cells [2]. Humans have antioxidant defence systems that include enzymes, glutathione and superoxide dismutase. These systems are incapable of totally preventing oxidative damage due to the rise in free radical levels caused by environmental and lifestyle changes. Antioxidants taken in the form of food thereby play a role in preventing oxidative stress. Epidemiological studies, that is, analysis of the distribution and determinants of health and diseases in certain populations, support the consumption of plant food for the prevention of chronic diseases [3]. There is an association between consumption of plant food and prevention of chronic diseases. Plant food is known to be a rich source of bioactive compounds that modulate the body's immune system.

Mushrooms are an example of a plant food that possesses both nutritional and medicinal properties. Mushrooms are edible fungi that have been extensively used since ancient times as food and medicine, especially in Eastern Asian countries. They can be utilized as a functional food to help improve the quality of diet and health. Phytochemicals such as phenolics and flavonoids have been isolated from various edible mushroom species [4].

Fungi produce phenols in response to abiotic and biotic conditions; for instance, infection and low temperature [5]. Polyphenols are complex organic compounds with aromatic rings bearing hydroxyl groups. Examples include quercetin, flavonoids and resveratrol. Interest in phenolic compounds has increased recently as studies have reported their beneficial biological properties [6] and ability to suppress chronic diseases. Polyphenols have chemopreventive, antifungal, bactericidal, anti-inflammatory and pharmacological properties [7]. They are also better antioxidants compared to vitamins [8].

Cooking processes such as baking, frying, grilling, boiling, microwaving, steaming and pressure-cooking cause significant changes to the physical and chemical properties of food [9]. Heat employed in food processing affects the nutritional and health properties of food.
This affects the concentration and bioavailability of bioactive compounds in food. Cooking may increase, decrease or result in no significant change in the antioxidant properties of plant food [10].

Studies have confirmed the antioxidant activity of four *Cantharellus* species from Himalaya and India. *C. fries* had the highest antioxidant activity among the species studied in Himalaya [11, 12]. A comparative study was also carried out to establish the antioxidant properties of mushrooms in the genus *Cantharellus* from Tanzania by Tibuhwa [13]. Despite the various studies focused on quantification of the antioxidant activity of mushrooms, there is a lack of data on the antioxidant activity of Zimbabwean indigenous mushrooms.
For this reason, the research here was aimed at determining the antioxidant activity of *C. symoensii* (firifiti) indigenous to Zimbabwe.
The research also aimed to establish whether different cooking methods have an effect on vitamin C and phenolic compounds in *C. symoensii*, along with its antioxidant activity.

Materials and methods

Reagents

Standards (quercetin and gallic acid) were purchased from Sisco Research Laboratories (Mahastra, India). The DPPH and Folin-Ciocalteu reagent were purchased from Sigma Chemical Co. (St Louis, USA). The methanol used was

purchased from Promark Chemicals (Welman Port). All other chemicals used were of analytical grade and purchased from Associated Chemical Enterprises (South Africa).

Sample procurement and preparation

Fresh mushroom (*C. symoensii*) fruit bodies were purchased from Marondera, Zimbabwe. The samples were transported in polythene bags. The samples were cleaned using tap water followed by distilled water.

The cleaned samples were stored in a refrigerator at -10°C upon arrival in the laboratory, and were later exposed to the different cooking methods.

Cooking methods

Frying

Mushrooms (5 g) were put in a frying pan with 15 ml of hot cooking oil. The mushroom pieces were stirred until they became crisp on the outside and tender on the inside. Excess cooking oil was filtered.

Boiling

Mushrooms (5 g) were placed in a pot with 50 ml of boiling water and boiled for 15 min.

Excess water was drained using a filter paper.

Microwaving

Mushrooms (5 g) were placed in a glass dish and put in a Whirlpool M901 (Sweden) microwave oven for 2 min at 900 watts.

Baking

Mushrooms (5 g) were put in foil paper and placed in an oven for 10 min at 120°C.

Moisture content measurement

Two grams of the differently cooked mushroom pieces were put in a hot air oven at 100°C for 24 hours until a constant weight was achieved.

The percentage moisture content was calculated using the following equation:

$$\text{Moisture content \%} = \frac{(\textit{fresh weight-dry weight})}{(\textit{fresh weight})} \times 100$$

Vitamin C measurement

A ground sample (2 g) was mixed with 25 ml of 5% metaphosphoric acid and the mixture was shaken for 30 min. The mixture was filtered through Whatman number 2 filter paper in a vacuum using a Buchner funnel. From the extraction, 10 ml were pipetted into a conical flask and titrated against dichlorophenol-indophenol.

Extraction of phytochemicals

Three grams each of the cooked samples were ground using a pestle and mortar.

The cooked samples were placed in conical flasks and mixed with absolute methanol.

The mixtures were stirred for 24 hours with a magnetic stirrer and then filtered through Whatman number 1 filter paper. The filtrate was collected in weighed beakers. The filtrate was left to evaporate for 24 hours in a fume hood.

The mass of the extract was obtained by subtracting the mass of the empty container from the mass of the container plus sample.

Absolute methanol was used to reconstitute the dried extracts to a concentration of 20 mg/ml.

Qualitative determination of phytochemicals

Phenols

To 1 ml of extract, 3 drops of ferric chloride were added. A positive result was indicated by a bluish colour. The observed colour intensity was used to determine strongly positive results (+++), positive results (++), weakly positive results (+) and negative results (-).

Flavonoids

To 1 ml of extract, 3 drops of 0.1 N NaOH were added followed by 3 drops of 0.1 M sulphuric acid.

The presence of flavonoids was confirmed by the disappearance of the yellow colour on addition of sulphuric acid [14].

Saponins

To 1 ml of extract, 3 ml of water were added and the mixture was shaken. A persistent foam indicated the presence of saponins.

Tannins

To 1 ml of extract, 3 drops of 2% ferric chloride were added followed by 3 drops of 0.5 M potassium hydroxide.

A red colour confirmed the presence of tannins. The observed colour intensity was used to determine strongly positive results (+++), positive results (++), weakly positive results (+) and negative results (-).

Quantitative determination of phytochemicals

Total phenolic content

To a volume of 50 µl of sample, 950 µl of distilled water were added to make up to a final volume of 1 ml. To this, 500 µl of 10% v/v Folin-Ciocalteu reagent were added followed by 500 µl of 2% sodium carbonate.

After incubation of the reaction mixture at room temperature for 40 min, absorbance was measured at 725 nm using a Biobase BK-D560 UV/visible spectrophotometer.

The total phenolic compounds were expressed as mg gallic acid equivalent per 100 mg of mushroom.

Flavonoid content

To 1 ml of each extract, 4 ml of distilled water were added followed by 2% methanolic $AlCl_3$. After incubating the reaction mixture in a dark cupboard for 15 min, absorbance was measured at 430 nm using a Biobase BK-D560 UV/visible spectrophotometer.

The results were expressed as milligrams quercetin equivalent (mg QE/100 g).

Antioxidant activity

A 0.1 mM solution of methanolic DPPH was prepared. 1 ml of the DPPH solution was added to 3 ml of a series of methanolic extracts of different concentrations (1, 2, 3, 4, 5 mg/ml). Gallic acid was used as a standard control.

The reaction mixture was shaken and left to stand at room temperature for 30 min.

Absorbance was read at 517 nm using a Biobase BK-D560 UV/visible spectrophotometer.

The percentage inhibition was calculated as follows:

$$\text{Percent Inhibition} = [(A_0 - A_1)/A_0] \times 100$$

where A_0 is the absorbance of the control sample and A_1 is the absorbance of the test or standard sample.

Data analysis

All of the analysis was conducted in triplicate. The moisture content, vitamin C, total phenolic content, flavonoid content and antioxidant activity data were expressed as means ± standard deviation. GraphPad Prism 5.03 software was used for plotting the standard curves for total phenolic content and flavonoid content. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) software, version 16. The mean values of the raw, fried, boiled, microwaved and baked samples were analyzed by one-way analysis of variance (ANOVA).

A significant difference between means was accepted at $p \leq 0.05$.

Results and discussion

Moisture content of mushroom samples

There was a significant decrease in moisture content ($p \leq 0.05$) with cooking.

There was no significant difference ($p \leq 0.05$) between the moisture content of fried and microwaved samples. As shown in **Table 1**, the moisture content for raw *C. symoensii* was 87.99 ±

0.02 g/100 g. The result obtained is comparable with the data available in the literature.

Rani and Fernando reported a moisture content of 90.95% in mushrooms [1]. Manzi *et al*. reported the moisture content of mushrooms to be in the range of 85.2% to 47.7% [15].

The high moisture content values observed indicate that mushrooms are a high-moisture food and can easily deteriorate. Preservation methods such as drying, freezing and canning may be employed to increase the shelf life of mushrooms. A decrease in moisture content after the cooking of mushrooms has been reported by Jaworska *et al*. [16].

Correspondingly, Ramírez-Anaya *et al*. obtained similar results when comparing cooked and uncooked vegetables [17]. Heat treatments may have caused the evaporation of water from the cooked samples.

Table 1 Moisture content of mushroom samples

Sample	g/100 g
Raw	87.99 ± 0.02^{a}
Fried	85.74 ± 0.03^{c}
Boiled	84.15 ± 0.04^{b}
Microwaved	85.66 ± 0.03^{c}
Baked	84.06 ± 0.04^{d}

Data are represented as the mean ± standard deviation for three replicates. Means with different superscript letters within the same column are significantly different at $p \leq 0.05$

Vitamin C

A significant decrease in vitamin C ($p \leq 0.05$) was observed with cooking.

The highest percentage decrease was observed in the boiled samples **(Table 2)**.

The vitamin C content of raw *C. symoensii* was 46.41 ± 0.07 mg/100 g. According to Tibuhwa, the vitamin C content of *Cantharellus* species ranges between 60–100 mg/100 g [13]. The lower value obtained in the study may be attributed to vitamin C loss upon exposure to air during grinding before adding metaphosphoric acid. Oxygen in the air leads to oxidation of vitamin C. Moreover, the variation in vitamin C content between that observed here and that reported in the literature [13] may be attributed to the specific environmental conditions in the different ecological regions the mushrooms were exposed to.

A significant decrease in vitamin C ($p \leq 0.05$) was observed with all cooking methods and the boiled sample had the highest percentage loss. This can be explained by the fact that vitamin C is a heat-labile micronutrient and it is easily destroyed by heat. A significant decrease in the vitamin C content of vegetables after thermal treatment processing was also reported by Sreeramulu *et al*. [18], Wallace *et al.* [19] and Mepba *et al.* [20].

Boiled samples had the highest percentage loss in vitamin C among all treatments; that is, 60.85%. This can be explained by the different ways by which the samples were cooked.

In the boiling process, water was added and in the other culinary treatments no water was used for cooking the samples. Vitamin C could have leached into the boiling water during the boiling process.

The water employed in the boiling process could be the main factor contributing to higher losses in the boiled samples. Krehl and Winters also demonstrated very low retention of vitamin C in 12 vegetables cooked with water to cover [21]. Higher water activity is linked with greater loss of vitamin C [22]. The main mechanisms of vitamin C loss include water solubility, mass transfer and heat sensitivity [23].

Similarly, it is well known that boiling is the cooking method with the worst effects on the vitamin C content of foods [23].

The severe loss in vitamin C observed with the boiling method may also be attributed to the long contact time with water and longer cooking times employed in boiling processes. Boiling was carried out for 15 min.

Microwaving, frying and baking methods cooked the samples quickly and this may be explained by the very high temperatures em-

ployed in the three processes.

Temperatures for microwaving and frying could be considerably above the boiling temperature of approximately 100°C. A baking temperature of 120°C was used for the baking process.

After eight min of frying, the samples were crisp on the outside and tender on the inside. It took exactly two min for the microwaved samples to be well cooked and baked samples were well cooked within 10 min.

The severe losses in vitamin C observed may lead to a decrease in the bioavailability of this nutrient in the body. Humans need to acquire vitamin C from the diet since the human body cannot synthesize this vitamin. A lack of vitamin C in the body causes malnutrition disorders such as scurvy.

Table 2 Vitamin C content and corresponding % change after treatment

Sample	mg/100 g	% Change
Raw	46.41 ± 0.07^{a}	0.00
Fried	21.14 ± 0.03^{c}	-54.45
Boiled	18.17 ± 0.05^{b}	-60.85
Microwaved	20.32 ± 0.06^{e}	-56.22
Baked	21.09 ± 0.03^{d}	-54.56

Data are represented as the mean ± standard deviation for three replicates. Means with different superscript letters within the same column are significantly different at $p \leq 0.05$

Phytochemicals

Phytochemical screening revealed the presence of phenols, flavonoids, saponins and tannins in *C. symoensii*, as shown in **Table 3.** These results agree with previous findings with respect to mushroom species from Nigeria and Sudan [24, 25]. The results conform to some extent with those obtained from a study carried out on selected mushrooms from Kenya [26].

For the phenols test, strongly positive results were observed in the fried and baked samples, while a positive result was observed for the microwaved sample and the raw sample. A weakly positive result was observed for the boiled sample. Boiling led to the reduction of phenols in *C. symoensii*. Frying and baking increased the presence of phenols.

The raw sample and the microwaved sample had similar results, implying that microwaving may have slightly increased the phenol content or did not change the levels of phenols present in *C. symoensii.*

For the flavonoid test, positive results were obtained for the raw and fried samples. Frying may have caused a slight increase in the flavonoid content of *C. symoensii* or there may have been no change in the flavonoid content. As weakly positive results were observed for the microwaved and baked samples, the two treatments may have caused a decrease in the flavonoid content. A negative result was obtained for the boiled sample.

This does not mean that boiling necessarily led to the absence of flavonoids. Instead, the flavonoids may have been reduced to very low amounts that could not be determined by sodium hydroxide and sulphuric acid.

For the saponins test, a weakly positive result was observed for the raw sample and strongly positive results were observed for the microwaved and baked samples. A positive result was obtained for the fried sample. Microwaving, baking and frying may have caused an increase in the saponin content of *C. symoensii*. A negative result obtained for the boiled sample may imply that boiling decreased the saponin content to very low levels or it caused the absence of saponins. The increase in saponins observed with the treatments other than boiling may help the body to obtain the beneficial effects of saponins.

Saponins help the immune system in fighting cancers and act to lower cholesterol levels.

Saponin diets may be useful in preventing dental caries and platelet aggregation, and in the treatment of hypercalciuria in humans [27].

For the tannins test, a positive result was obtained for the raw sample. Weakly positive

results were obtained for baking, boiling, microwaving and frying. All of the cooking methods may have caused a decrease in the tannin content of *C. symoensii*. Low levels of tannins in cooked mushrooms are preferred. Tannins have been reported to cause decreases in food intake, growth rate and protein digestibility in animals. Tannins reduce the bioavailability of protein in the body. They bind to proteins to form insoluble complexes [28].

Phytochemical screening was carried out as a preliminary procedure to acquire an overview of the effects of different cooking methods on phytochemical levels in raw and cooked *C. symoensii*. The results of the phytochemical analyses are vulnerable to optical bias, since the naked eye was used to determine results.

Table 3 Phytochemical screening of raw and cooked samples of *Cantharellus symoensii*

Sample	Baked	Raw	Boiled	Microwaved	Fried
Phenols	+++	++	+	++	+++
Flavonoids	+	++	-	+	++
Saponins	+++	+	-	+++	++
Tannins	+	++	+	+	+

+++Strongly positive, ++ positive, + weakly positive, - negative

Total phenolic content

A significant increase in the total phenolic content ($p \leq 0.05$) was observed with frying, microwaving and baking **(Table 4)**.

A significant decrease in the total phenolic content ($p \leq 0.05$) was observed with boiling.

The total phenolic content for *C. symoensii* samples was ranked from high to low as:

fried > microwaved > baked > raw > boiled.

The increase in total phenolic content observed for the fried, microwaved and baked samples could be explained by matrix softening and disruption of cellular components caused by heat treatments, leading to the release of polyphenols. Polyphenols in plants are combined with cell wall constituents and they are also present in the vacuoles and apoplast [29].

Heat treatments also lead to inactivation of polyphenol oxidase and other oxidizing enzymes, which slows phenolic destruction by oxidation upon exposure to the surroundings [30].

Moisture loss during cooking, as indicated by the decrease in moisture content, may also explain the increase in polyphenol content in *C. symoensii* after frying, microwaving and baking. Significant differences in the moisture content ($p \leq 0.05$) between the raw and cooked samples observed in the moisture content analyses may have affected the phenolic content. Moisture loss during cooking, especially frying, leads to the concentration of biomolecules, which may cause an increase in phenolic content [9].

Foods with a high phenolic content help to reduce levels of triglycerides in the body. This helps to prevent degenerative and cardiovascular diseases. Phenolics have important functions, exhibiting anti-inflammatory, antiallergic, antiviral, antibacterial and antithrombotic properties [31].

The decrease in the total phenolic content observed for the boiled samples could be attributed to leaching of polyphenols into the cooking water. The significant decrease in phenolic content ($p \leq 0.05$) observed with boiling is in agreement with the findings of Kettawan *et al*. [32]. These authors reported a significant decrease in the phenolic content of 10 edible mushroom varieties consumed in Thailand after boiling. The authors also observed significant amounts of polyphenols in the cooking water used for boiling [32]. The polyphenol loss observed for the boiled samples may also be explained by the characteristics of *C. symoensii*. The large surface area of *C. symoensii* contributed to by the small fruiting body being directly exposed to the cooking water is susceptible to leaching, which may cause a decrease in polyphenols.

In contrast to the present results, other researchers argue that any cooking process such as boiling, baking, frying or microwaving reduces polyphenol content in selected vegetables [33–35]. Similarly, Reid *et al*. reported a general decrease in phenolic content with cooking of the mushroom *Amanita zambiana* [36].

Differences in the observed results may be due to different temperatures used for the cooking processes. Saad *et al*. reported that temperatures of approximately 100°C and cooking for 15–30 min caused an increase in total phenolic content while temperatures of approximately 121°C and cooking for 15–30 min caused a decrease in total phenolic content [37].

The increase or decrease in phenolic content after cooking also depends on the mushroom used for analysis. Ozturk *et al.* demonstrated a decrease in the total phenolic content of the mushroom *Lactarius deliciosus* after baking but an increase in the phenolic content of the mushroom *Ramaria flava* after baking [38]. The different morphological and nutritional characteristics of the mushrooms may determine the effect of cooking [33].

Table 4 Total phenolic content on a dry matter basis and corresponding % change after treatment

Sample	mg GAE/100 g	% Change
Raw	34.66 ± 0.21^{a}	0.00
Fried	42.54 ± 0.48^{c}	22.74
Boiled	16.32 ± 0.29^{b}	-52.91
Microwaved	40.16 ± 0.32^{e}	15.87
Baked	36.89 ± 0.37^{d}	6.43

Data are represented as the mean ± standard deviation for three replicates. Means with different superscript letters within the same column are significantly different at $p \leq 0.05$

Flavonoids

As shown in **Table 5**, a significant decrease in flavonoid content ($p \leq 0.05$) was observed with boiling, microwaving and baking. The highest percentage decrease in flavonoid content was observed in the boiled samples.

A significant increase in flavonoid content ($p \leq 0.05$) was observed with frying.

The results obtained indicate that cooking may increase or decrease the flavonoid content of *C. symoensii*.

According to Rani and Fernando, cooking has both positive and negative effects on the flavonoid content of edible plant material [1].

In most cases, thermal treatments have destructive effects on flavonoids because they are highly unstable compounds [33].

The increase in the flavonoid content observed in the fried samples may be attributed to the shorter cooking time employed in the frying process, compared to other cooking methods. Frying temperatures are high (approximately 180°C), allowing for rapid heat transfer and a short cooking time [39], and temperatures in food rarely exceed 100°C [40].

These features may bring about better retention of antioxidant compounds together with a greater release of bound molecules caused by matrix disruption at high temperatures.

Cooking could lead to decomposition of polyphenols such as flavonoids bound to dietary fibre plant material by releasing them, and thus, increasing their detection [41].

Flavonoids inhibit the oxidative activity of free radicals, thereby reducing oxidative damage to the body. Oxidative damage is the major cause of chronic degenerative diseases such as diabetes, stroke and cancer [1].

Table 5 Flavonoid content on a dry matter basis and corresponding % change after treatment

Sample	mg QE/100 g	% Change
Raw	13.65 ± 0.60^{a}	0.00
Fried	14.68 ± 0.62^{c}	7.55
Boiled	0.77 ± 0.34^{b}	-94.36
Microwaved	9.76 ± 0.46^{e}	-28.50
Baked	11.84 ± 0.34^{d}	-13.26

Data are represented as the mean ± standard deviation for three replicates. Means with different superscript letters within the same column are significantly different at $p \leq 0.05$

Antioxidant activity

Antioxidant activity expressed as the percentage scavenging activity using the DPPH assay for *C. symoensii* samples was found to be, in decreasing order: fried > baked > microwaved > raw > boiled. There was a significant increase in antioxidant activity ($p \leq 0.05$) with frying, baking and microwaving, as shown in **Fig. 1.** A significant decrease in antioxidant activity ($p \leq 0.05$) was observed with boiling.

The increase in antioxidant activity seen with frying, baking and microwaving could be explained by two mechanisms: (1) disruption of the cell wall and release of antioxidant compounds from insoluble portions of the mushroom, leading to an increase in accessible antioxidant compounds, and (2) the formation of novel compounds with high antioxidant activity due to heat treatment or thermal processing, for instance, Maillard reaction products [9].

The results obtained are consistent with the findings of Roncero-Ramos *et al.* who reported that antioxidant activity increased with thermal treatments such as microwaving in *Lentinula edodes* mushrooms [9].

Antioxidants obtained from the diet such as vitamin E, vitamin C and phenolic compounds play a significant role in protecting the body from oxidative damage. Vitamin E prevents lipid peroxidation of membranes and vitamin C helps to recycle vitamin E radicals generated when vitamin E traps the radicals [42].

The cooking treatments that resulted in an increase in phenolic content, that is, frying, microwaving and baking, also brought about an increase in antioxidant activity.

This could be explained by the fact that polyphenolic compounds may contribute directly to antioxidant activity. Various studies have found a correlation between polyphenol content and antioxidant activity in plant foods [43–45].

An increase in antioxidant activity may be due to an increase in the total phenolic content.

The decrease in antioxidant activity observed with boiling could be explained by a loss of water-soluble antioxidants such as vitamin C into the cooking water. Kettawan *et al.* also reported a significant decrease in antioxidant activity in 10 boiled edible mushroom varieties in Thailand [32].

Since most bioactive compound losses result from boiling, other cooking methods that use less cooking water may be employed when cooking *C. symoensii.*

These other cooking methods include grilling and sautéing.

Conversely, Roncero-Ramos *et al*. also reported a decrease in antioxidant activity in cooked *Agaricus bisporus* mushrooms, especially microwaved samples, using the Trolox equivalent antioxidant capacity assay [9].

These results are not comparable to those obtained here, which suggest that heat treatments such as microwaving, baking and frying can increase antioxidant activity in *C. symoensii*.

It should be considered that different antioxidant assays are based on different principles [46]. A food sample may show high antioxidant activity with a particular assay but not with another assay. The variation in antioxidant activity reported by other researchers and in the present study may be attributable to the different assays used to determine antioxidant activity.

Other studies have also demonstrated that heat treatments can decrease the antioxidant activity of mushrooms. In a study by Ozturk *et al*. baking increased the antioxidant activity of *Ramaria flava* mushrooms and decreased the antioxidant activity of *Lactarius deliciosus* mushrooms [38].

This implies that the effect of cooking on antioxidant activity may depend on the mushroom used for analysis. Differences in the morphology and nutritional characteristics of the mushrooms may have caused the variation between the results observed here and those reported by other researchers.

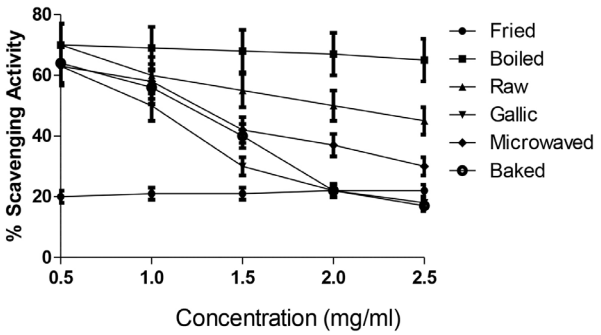

Figure 1 Scavenging effects of methanolic extracts of *C. symoensii* reflected by % decrease in scavenging activity. Data are represented as the means of triplicate determinations ± standard deviation

Conclusion and recommendations

The results from this study show that cooking causes significant changes in vitamin C, phenolic content, flavonoids and antioxidant activity in *C. symoensii*. The boiling process may be considered the worst method for cooking *C. symoensii* since it caused a significant decrease in vitamin C, the total phenolic content and antioxidant activity in *C. symoensii*. Frying was established as the best method for cooking *C. symoensii*. An increase in the total phenolic content, flavonoid content and antioxidant activity was observed with frying. It can be concluded that cooking is not always detrimental to bioactive compounds in *C. symoesii*. If boiling processes are to be used to cook the mushroom, small amounts of water should be used to prevent leaching of bioactive compounds. Frying may be employed in the cooking of *C. symoensii*. When frying processes are used for cooking, small amounts of cooking oil should be used since cooking oil may be associated with other health problems such as cardiovascular diseases. Cooking temperatures during frying should be monitored to prevent very high temperatures, which may cause the formation of harmful Maillard reaction products such as acrylamide. Food scientists should also convey information to the public regarding the best ways to cook *C. symoensii* to reduce bioactive compound loss.

Ethical standards

No studies using human or animal subjects were performed by any of the authors for this article.

Conflict of Interest

The authors declare that they have no conflicts of interest.

Acknowledgements

The authors would like to thank the University of Zimbabwe for funding the study.

References

1. Rani ER, Fernando RRS (2016) Effect of cooking on total antioxidant activity in selected vegetables. Int J Home Sci 2:218–222

2. Arora B (2014) Effect of cooking on antioxidant activity and phenolic content of various species of edible mushrooms of India. Proceedings of the 8th International Conference on Mushroom Biology and Mushroom Products 117:576–581

3. Brito AJ, Sheeba HD, Rathma-Kumar PB (2013) Qualitative and quantitative analysis of phytochemicals in Marsilea Minuta Linn. Int J Pharm Bio Sci 4(1):800–805

4. Zhang M, Cui SW, Chueng PC, Wang KQ (2007) Antitumor polysaccharides from mushrooms: a review on their isolation process, structural characteristics and antitumor activity. Trends Food Sci Tech 18:4–19

5. Islam T, Yu XM, Xu BJ (2016) Phenolic profiles, antioxidant capacities and metal chelating ability of edible mushrooms commonly consumed in China. Food Sci Tech 72:423–431

6. Ramesh C, Pattar MG (2010) Antimicrobial properties, antioxidant activity and bioactive compounds from six wild edible mushrooms of western ghats of Karnataka, India. Pharmacognosy Res 2:107–112

7. Medić-Šarić M, Bojić M, Rastija V, Cvek J (2013) Polyphenolic profiling of Croatian propolis and wine. Food Technol Biotech 51:159–170

8. Podsedek A (2007) Natural antioxidants and antioxidant capacity of Brassica vegetables: a review. LWT Food Sci Technol 40:1–11

9. Roncero-Ramos I, Mendiola-Lanao M, Pérez-Clavijo M, Delgado-Andrade C (2017) Effect of different cooking methods on nutritional value and antioxidant activity of cultivated mushrooms. Int J Food Sci Nutr 68:287–297

10. Miglio C, Chiavaro E, Visconti A, Fogliano V, Pellegrini N (2008) Effects of different cooking methods on nutritional and physicochemical characteristics of selected vegetables. J Agric Food Chem 56:139–147

11. Wani AH, Boda RH, Nisa T, Peer LA (2010) Potential antioxidant activity of some mushrooms growing in Kashmir Valley. Mycopath 8:71–75

12. Kumari D, Reddy MS, Upadhyay RC (2011) Antioxidant activity of three species of wild mushroom genus *Cantharellus* collected from North-Western Himalaya, India. Int J Agric Bio 13:415–418

13. Tibuhwa DD (2014) A comparative study of antioxidant activities between fresh and dry mushrooms in the genera *Cantherellus* and *Afrocantherellus* from Tanzania. Food Nutr Sci 5:212–221

14. De S, Dey YN, Ghosh AK (2010) Phytochemical investigation and chromatographic evaluation of the different extracts of tuber of *Amorphophallus paeoniifolius* (Araceae). Int J Pharmaceut Biol Res 1:150–157

15. Manzi P, Gambelli L, Marconi S, Vivanti V, Pizzoferrato L (1999) Nutrients in edible mushrooms: an inter-species comparative study. Food Chem 65(4):477–482

16. Jaworska G, Pogon K, Bernas E, Duda-Chodak A (2015) Nutraceuticals and antioxidant activity of prepared for consumption commercial mushrooms *Agaricus bisporus* and *Pleurotus ostreatus*. J Food Qual 38:111–122

17. Ramírez-Anaya JP, Samaniego-Sanchez C, Castañeda-Saucedo MC, Villalon-Mir M, Lopez-Garcıa de la Serrana H (2015) Phenols and the antioxidant capacity of Mediterranean vegetables prepared with extra virgin olive oil using different domestic cooking techniques. Food Chem 188:430–438

18. Sreeramulu N, Ndossi GD, Mtotomwema K (1983) Effect of cooking on the nutritive value of common food plants in Tanzania: part 1 – vitamin C in some of the wild green leafy vegetables. Food Chem 10:205–210

19. Wallace PA, Marfo EK, Plahar WA (1998) Nutritional quality and anti-nutritional composition of four non-conventional leafy vegetables. Food Chem 61:287–291

20. Mepba HD, Eboh L, Banigo DEB (2007) Effects of processing treatments on the nutritive composition and consumer acceptance of some Nigerian edible leafy vegetables. Afr J Food Agr Nutr Dev 7(1):1–18

21. Krehl WA, Winters RW (1950) Effect of cooking methods on retention of vitamins and minerals in vegetables. J Am Diet Assoc 26:966–972

22. Laing BM, Schlueter DL, Labuza TP (1978) Degradation kinetics of ascorbic acid at high temperature and water activity. J Food Sci 43:1440–1443

23. Masrizal MA, Giraud DW, Driskell JA (1997) Retention of vitamin C, iron, and β-carotene in vegetables prepared using different cooking methods. J Food Qual 20:403–418

24. Egwim EC, Ellen RC, Egwuche RU (2011) Proximate composition, phytochemical screening and antioxidant activity of ten selected edible mushrooms. Amer J Food Nutr 1:89–94

25. Moglad EHO, Saadabi AM (2012) Screening of antimicrobial activity of wild mushrooms from Khartoum State of Sudan. J Microbiol 2:64–69

26. Wandati TW, Kenji GM, Onguso JM (2013) Phytochemicals in edible wild mushrooms from selected areas in Kenya. J Food Res 2(3):137–144

27. Shi J, Arunasalam K, Yeung D, Kakuda Y, Mittal G, Jiang Y (2004) Saponins from edible legumes: chemistry, processing, and health benefits. J Med Food 7:67–78

28. Chung KT, Wang TY, Huang YW, Lin Y (1998) Tannins and human health: a review. Crit Rev Food Sci Nutr 38:421–464

29. Kalt W (2005) Effects of production and processing factors on major fruit and vegetable antioxidants. J Food Sci 70:11–19

30. Yamaguchi T, Mizobuchi T, Kajikawa R, Kawashima H, Miyabe F, Terao J (2001) Radical scavenging activity of vegetables and the effect of cooking on their activity. Food Sci Technol Res 7:250–257

31. Cook NC, Samman S (1996) Flavonoids: chemistry, metabolism, cardioprotective effects and dietary sources. J Nutr Biochem 7:66–76

32. Kettawan A, Chanlekha K, Kongkachuichai R, Charoensiri R (2011) Effects of cooking on antioxidant activities and polyphenol content of edible mushrooms commonly consumed in Thailand. Pak J Nutr 10:1094–1103

33. Ismail A, Marjan ZM, Foong CW (2004) Total antioxidant activity and phenolic content of selected vegetables. Food Chem 87:581–586

34. Zhang D, Hamauzu Y (2004) Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. Food Chem 88:503–509

35. Turkmen N, Sari F, Velioglu YS (2005) The effect of cooking methods on total phenolics and antioxidant activity of selected green vegetables. Food Chem 93:713–718

36. Reid T, Munyanyi M, Mduluza T (2017) Effect of cooking and preservation on nutritional composition of the mushroom *Amanita zambiana*. Food Sci Nutr 5:538–544

37. Saad ZW, Hashim M, Ahmad S, Abdullah N (2014) Effects of heat treatment on total phenolic contents, antioxidant and anti-inflammatory activities of *Pleurotus Sajor-Caju Extract*. Int J Food Properties 17:219–225

38. Öztürk M, Tel G, Öztürk FA, Duru ME (2014) The cooking effect on two edible mushrooms in Anatolia: fatty acid composition, total bioactive compounds, antioxidant and anticholinesterase activities. Rec Nat Prod 8:189–194

39. Fillion L, Henry CJK (1998) Nutrient losses and gains during frying: a review. Int J Food Sci Nutr 49:157–168

40. Califano AN, Calvelo A (1991) Thermal conductivity of potato between 50 and 100°C. J Food Sci 56:586–587

41. Stewart AJ, Bozonnet S, Mullen W, Jenkins GI, Lean MEJ, Crozier A (2000) Occurrence of flavonols in tomatoes and tomato-based products. J Agric Food Chem 48(7):2663–2669

42. Baydar NG, Zkan GO, Yasar S (2007) Evaluation of the antiradical and antioxidant potential of grape extracts. Food Control 18:1131–1136

43. Gramza AO, Khokar S, Yoko S (2006) Antioxidant activity of tea extracts in lipids and correlation with polyphenol content. Eur J Lipid Sci Technol 108:351–362

44. Kiselova Y, Ivanova D, Chervenkov T, Gerova D, Galunska B, Yankova T (2006) Correlation between the in vitro antioxidant activity and polyphenol content of aqueous extracts from Bulgarian herbs. Phytother Res 20:961–965

45. Ruiz A, Hermosin-Gutierrez I, Mardones C, Vergara C, Herlitz E, Vega M, Dorau C, Winterhalter P, von Baer D (2010) Polyphenols and antioxidant activity of calafate (*Berberis microphylla*) fruits and other native berries from Southern Chile. J Agric Food Chem 58:6081–6089

46. Barros L, Baptista P, Correia DM, Morais JS, Ferreira ICFR (2007) Effects of conservation treatment and cooking on the chemical composition and antioxidant activity of Portuguese wild edible mushrooms. J Agric Food Chem 55:4781–4788