ISSN: 2224-0616
Int. J. Agril. Res. Innov. Tech. 12(2): 36-40, Dec 2022
DOI: https://doi.org/10.3329/ijarit.v12i2.64075

OPEN ACCESS
Available online at https://ijarit.webs.com
https://www.banglajol.info/index.php/IJARIT

Evaluation of nutritional, anti-nutritional and mineral content of amaranths species grown in Gamo and Konso zone, Southern Ethiopia

Wasihun Wale Eyesa*, Tuma Ayele Yadda, Ermais Dureto Badebo and Melese Lema Tessema

Received 4 July 2022, Revised 31 October 2022, Accepted 22 December 2022, Published online 31 December 2022

A B S T R A C T

Amaranth (*Amaranthus* sp.) is an underutilized pseudo-cereal with excellent nutritional and functional properties. The nutritional compositions, anti-nutritional and mineral content of two Amaranth species were evaluated by using standard procedures. Completely Randomized Design (CRD) was used for nutritional, anti-nutritional and mineral content with two treatments and five replications. The nutritional compositions of *Amaranthus cruentus* and *Amaranthus hypochondriacus* were shown a significant difference ($p<0.05$) in mean scores excepting moisture content. Phytate and oxalate content of *A. cruentus* and *A. hypochondriacus* were shown a significant difference ($p<0.05$), but tannin content did not show a significant difference ($p<0.05$). The calcium, iron and zinc content of *A. cruentus* and *A. hypochondriacus* were shown a significant difference ($p<0.05$) in mean, scores. The Amaranth grain species were rich in crude protein, fat and fiber as compared to common cereal grains (maize, sorghum, rice, teff and wheat). *A. cruentus* and *A. hypochondriacus* can contribute minerals such as calcium, iron and zinc, which are very important for human nutrition. The results of the current study indicate that *A. cruentus* and *A. hypochondriacus* can provide better nutritional values and mineral content with a minimum value of anti-nutrients that are very important to minimize binds and block the absorption of certain minerals, such as iron, zinc and calcium. Using *A. cruentus* and *A. hypochondriacus* alone and with other cereals should be encouraged and recommended for consumption to increase the nutritional composition of diets and decrease food security problem in a study areas.

Keywords: Amaranth species, Anti-nutritional, Mineral contents, Nutritional compositions

South Agricultural Research Institute, Arba Minch Agricultural Research Center, P.O. Box: 2228, Arba Minch, Ethiopia

*Corresponding author's email: wasihunwale2011@gmail.com (Wasihun Wale Eyesa)

Cite this article as: Eyesa, W.W., Yadda, T.A., Badebo, E.D. and Tessema, M.L. 2022. Evaluation of nutritional, anti-nutritional and mineral content of amaranths species grown in gamo and konso zone, Southern Ethiopia. *Int. J. Agril. Res. Innov. Tech.* 12(2): 36-40. https://doi.org/10.3329/ijarit.v12i2.64075

Introduction

Amaranthus belongs to the *Amaranthaceae* family. Genus *Amaranthus* is easy to grow, nutrient rich and has the potential to contribute to the growing nutritional needs of many low income people because of its high protein content, superior protein quality, high content of essential fatty acids and micronutrients (Venskutonis and Kraujalis, 2013). It is a pseudo cereal with excellent nutritional and functional properties, high tolerance to arid conditions and poor soils, resistance to drought, pests and ability to adapt to environments that are not conducive to conventional cereals (Capriles *et al.*, 2008). Amaranthus are highly nutritious; both the grain and leaves are utilized for human as well as for animal feed (Mustafa *et al.*, 2011). The crop has high levels of protein and minerals as compared to the commonly utilized cereal grains such as millet, sorghum, rice, wheat, and corn (Mustafa *et al.*, 2011). It has a balanced content of essential amino acids and unsaturated fatty acids. Moreover, it have an excellent amino acid profile with of lysine and sulfur containing amino acids that are lacking in cereals and legumes, respectively (Amare *et al.*, 2015). Amaranth was declared as one of the promising crops to feed the global population (Mekonnen *et al.*, 2018). Amongst other green leafy vegetables and cereals, Amaranthus species are regard as storehouse for vital vitamins such as vitamin C, B6, folate and carotene (Musa *et al.*, 2011).

In addition to its nutritive value, amaranth grain contains bioactive compounds with health promoting effects, (Karamac *et al.*, 2019). The potential of the amaranth species appears to be enormous and promising, making its exploration for health purposes and industrial applications imperative. Studies have shown that regular consumption of Amaranthus has the potential (Karamac *et al.*, 2019) to reduce cholesterol level, benefit people suffering from hypertension, and cardiovascular disease (Olaoye *et al.*, 2007; Kolawole and Sarah, 2009).

Lacks of nutrition and food security problems are reflecting in malnutrition and hunger, which are affecting many developing countries such as Ethiopia. Despite government and non-government efforts to address the problem of food security and malnutrition, there have been poor research studies on nutrient rich and underutilized pseudo cereal such as Amaranthus species in southern Ethiopia. Even though amaranth is of varying importance to human health and nutrition, consumption in southern Ethiopia is not well known. These could be due to lack awareness of nutritional value, anti-nutritional and mineral content. Hence, the current study was conducted to evaluate nutritional, anti-nutritional and mineral content of amaranth species grown in Gamo and Konso Zones, Southern Ethiopia to reduce nutrition and food security problems in a study area.

Materials and Methods

Sources of study materials

Amaranths species (*A. hypochondriacus* and *A. cruentus*) were collected from Gamo and Konso zone, Southern Ethiopia.

Preparation of Amaranth sample flours

Amaranth flour was prepared according to the procedure of Emire and Arega (2012) and Mugalavai (2013) with some modifications. Amaranth species seed was manually screened and air-selected to be free from chaff, dust and other impurities. The grains of amaranths were sun-dried and milled into flour by using a stainless steel miller to pass through 0.5 mm mesh screen. Finally, amaranths flour was packed in airtight polythene bags and stored at room temperature (25°C) until it was needed for nutritional, anti-nutritional and mineral content analysis.

Experimental design

Completely randomized design (CRD) was used to analyze nutritional, anti-nutritional and minerals contents of amaranths species samples with five replications.

Determination Nutritional Content

The moisture, crude protein, fat, and ash content of amaranthus species samples were determined in triplicate according to the standard analytical methods AOAC (1995) and AOAC (2005). The fiber content of the samples was determined by using the official method of AOAC (2000). Digestion, filtration, washing and drying and combustion were used analysis of fiber content of amaranthus samples. The carbohydrate content of amaranth species samples were determined by subtracting the sum of the percentages of moisture, crude protein, crude fat and ash content from 100 (Mathew and Saleh, 2006). Carbohydrate (%) = 100 − (Protein + Fat + Ash + Moisture content). The energy content of amaranth species samples was by multiplying percentages of crude fat, crude protein, and carbohydrate by factors of 9 kcal/g, 4 kcal/g and 4 kcal/g, respectively (Shrestha and Noomhorm, 2002), and expressed in calories. Energy Content (kcal/g) = (9 x Fat) + (4 x Protein) + (4 x Carbohydrate).

Determination of Anti-nutritional content

Concentrated phytate content was determined using the method used by Norhaizan and Faizadatul (2009). The phytate content was calculated by dividing the measured value of phytic acid by molecular weight (240) of phytic acid. Tannin content was determined by the method of Burns (Burns, 1971; Anonymous, 1971) as modified by Maxson and Rooney (Arias *et al*., 2003), using catechin as the tannin standard. Oxalate was analyzed using the method originally employed by Ukpabi and Ejidoh (Ambecha, 2006) in which the procedures include three steps: digestion, precipitation, and permanganate titration.

Mineral contents

The contents of Ca, Zn and Fe in foods were measured by atomic absorption spectrophotometer (AAS) according to the method of (Hernandez *et al*, 2004). A 5g sample was placed in a previously weighed porcelain crucible and heated. The resulting white ash was weighed, dissolved in 3ml of concentrated nitric acid and diluted with distilled water in a 25ml calibrated flask. The solution then was used to determine Ca, Zn, and Fe. Standard stock solution of iron, zinc and calcium was prepared from AAS grade chemicals (Sigma, USA) by appropriate dilution.

Data analysis

Nutritional, anti-nutritional and mineral contents of two amaranths species were subjected to analysis of variances (ANOVA) and analyzed using SAS software version 9.2 (SAS lnc., Gary, NC). Least significance difference (LSD) between means were attained at ($p<0.05$) by using fisher LSD methods. The results were expressed as mean separations.

Results and Discussion

Nutritional composition of A. cruentus and A. hypochondriacus species

The moisture content of *A. hypochondriacus* and *A. cruentus* species had not shown significant difference ($p<0.05$) in mean scores. The moisture content of two amaranths species was closely related to the reported values of 10.3% by Escudero *et al*. (2004). The moisture content of two amaranth species obtained in this study were lower than the moisture content reported value of 11.3% by Caselato-Sousa and Amaya-Farf´an (2012). Such low moisture content of flours prevents microbial activity and extends the shelf life of the flours (Mosha and Vicent, 2005).

Table 1. Result of nutritional composition of *A. cruentus* and *A. hypochondriacus* species seed.

Treatment	Nutritional Composition						
	Moisture	Ash	Fat	Protein	Fiber	Carbohydrate	Energy
A. hypochondriacus	10.17[a]	3.52[a]	7.15[b]	15.59[a]	4.28[a]	63.57[b]	380.91[b]
A. cruentus	10.32[a]	3.13[b]	7.21[a]	14.48[b]	4.03[b]	64.86[a]	382.25[a]
LSD ($p<0.05$)	0.26	0.29	0.05	0.57	0.08	0.25	0.74
CV (%)	1.13	1.16	0.86	0.13	1.79	1.08	4.67

The ash content of two amaranth species had shown a significant difference ($p<0.05$) in mean scores. Similar ash contents (3.4 and 3.3%) were reported for amaranths grains by Escudero *et al.*, (2004) and Cai *et al.* (2004), respectively. The ash contents of two amaranths species are slightly close to the ash contents (2.7-3.0%) reported in grain tef (Bultosa, 2016). The ash content of a food material is an indication of the high amount of minerals in the food product, as ash content is indicative of the amount of minerals contained in any food sample (Olaoye *et al.*, 2007).

The fat content of two amaranth species were shown the significant difference ($p<0.05$) in mean scores. The fat content obtained in current study was closely related to fat value 7.2% reported (Cai *et al.*, 2004). The protein content of two amaranth species had shown a significant difference ($p<0.05$) in mean scores. This study was slightly related with amaranth grain protein contents were reported 16.6% (Cai *et al.*, 2004). Some of the earlier works also found that amaranth grain are good sources of high quality proteins compared to the protein contents found in grains of common cereal crops (8 to 12%) Koehler and Wieser (2013). The fiber content of two amaranths species had shown the significant difference ($p<0.05$) in mean scores. The fiber content obtained from current study was closely related to the value 4.1% (Cai *et al.*, 2004), but lower than the fiber content 5.8% reported by (Emire and Arega, 2012). The fiber content in amaranths is higher than common cereal grains: rice, maize, sorghum and wheat.

The energy content of two amaranth species had shown a significant difference ($p<0.05$) in mean scores. The energy content obtained for two amaranth species are higher than 251 kcal/100g reported by Emire and Arega (2012). The energy contents of current study are slightly similar to the value 371 kcal/100g reported by Caselato-Sousa and Amaya-Farf´an (2012) on studies conducted on amaranths grains. Energy values of two amaranth species obtained are higher than for tef grains (336 kcal/100g) (Bultosa, 2016).

Mineral Content of A. cruentus and A. hypochondriacus species

The Calcium content of *Amaranth hypochondriacus* and *A. cruentus* species was significantly different ($P<0.05$) in mean scores. Calcium typical value of 159 mg/100g (Caselato-Sousa and Amaya-Farf´an, 2012) and 153 mg/100g (Schakel *et al.*, 2004) were reported for amaranth grains. Adequate Ca is important for bone and tooth structures development, muscle functioning, blood clotting and to reduce the incidence of osteoporosis (Gharibzahedi and Jafari, 2017).

Table 2. Result of mineral content of *A. cruentus* and *A. hypochondriacus* species.

Treatment	Mineral content (mg/100g)		
	Calcium	Iron	Zinc
A. hypochondriacus	159.15[a]	32.58[a]	2.85[b]
A. cruentus	157.13[b]	24.94[b]	2.93[a]
LSD ($p<0.05$)	0.24	0.62	0.06
CV (%)	0.56	0.93	0.37

The iron contents of two amaranth species had shown significant difference ($p<0.05$) in mean scores. The iron content (32.58) of *A. hypochondriacus* was higher than iron content (24.94) of *A. cruentus*. The Fe content obtained in both amaranthus species is higher than the higher range (3.6 to 22.5 mg/100g) reported by Kachiguma *et al.* (2015). The Fe content found in amaranth grains are almost similar to the Fe content reported in grain tef (Bultosa, 2016; Saini *et al.*, 2016).

Zinc contents of two amaranth species had shown significant difference ($p<0.05$) in mean scores. The Zn content obtained in this study was almost similar to the typical value 2.87 mg/100g (Caselato-Sousa and Amaya-Farf´an, 2012). The Zn values found in two amaranths species higher as compared to the range 0.53-1.20 mg/100g reported by Kachiguma *et al.* (2015) for amaranth grains. The Zn content obtained in two amaranth species are also lower than the Zn content (3.7 mg/100g) reported for grain tef (Temesgen and Bultosa, 2017).

Anti-nutritional content of A. cruentus and A. hypochondriacus species

Phytate content of two amaranths species had shown significance difference ($p<0.05$). Phytate contents of *A. hypochondriacus* and *A. cruentus* were lower than values obtained for wheat (4.17 g/100g), rice (4.28 g/100g), Barley (4.03 g/100g) and Oat (2.77 g/100g) (Satinder *et al.*, 2011). Phytic acid is known as an anti-nutrient because it binds and blocks the absorption of certain minerals, such as iron, zinc, calcium, and manganese.

Table 3. Result of anti-nutritional content of *A. cruentus* and *A. hypochondriacus* species.

Treatments	Anti-nutritional contents (mg/100g)		
	Phytate	Tannin	Oxalate
A. hypochondriacus	1.45[a]	0.13[a]	0.07[a]
A. cruentus	1.19[b]	0.15[a]	0.04[b]
LSD(p<0.05)	0.24	NS	0.35
CV (%)	5.31	2.95	4.28

Tannin content of two amaranths species had not shown significance difference (p>0.05) in mean scores. Tannin values obtained in this study were lower than values recorded for wheat (0.29 g/100g), Barley (0.34 g/100g) and Oat (0.62 g/100g); but higher than 0.07 g/100g obtained for rice (Satinder *et al*., 2011). Tannin content of *A. hypochondriacus* at current study is slightly agreed with results of Gorinstein *et al.* (2008) who recorded tannin content of 0.12g/100g of *A. hypochondriacus*. Oxalate contents of two amaranth species had shown significant difference (p<0.05) in mean scores.

Conclusions and Recommendations

Based on the results obtained in this study, amaranth (*A. hypochondriacus* and *A. cruentus*) are contained better amount of protein, moisture, carbohydrate, fat, ash and energy that could provide nutrients to reduce malnutrition. *A. hypochondriacus* and *A. cruentus* contains minerals especial calcium, zinc and iron which could important for bone strength, stabilize immune and reduce anemic conditions respectively. Phytate, oxalate and tannin content obtained in *A. hypochondriacus* and *A. cruentus* are less than to compare with common cereals that are very important to minimize binds and block the absorption of certain minerals, such as iron, zinc and calcium. Using *A. cruentus* and *A. hypochondriacus* alone and with others cereals should be encouraged and recommended for consumption to increase the nutritional composition of diets and decrease food security problem of Ethiopia.

Acknowledgement

We would like to thanks South Agricultural Research Institute, Arba Minch Agricultural Research Center for financial support, guidance and facilitating of all necessary materials since proposal initiated until final paper write up of this study. Our heartfelt thanks also go to School of Nutrition, Food Science and Technology, Hawassa College of Agriculture, Hawassa University for permitting laboratory analysis of samples.

References

AOAC. 1995. Association of Official Analytical Chemists. Official methods of analysis 15th edition. Washington DC, U.S.A. pp. 40-49.

AOAC. 2000. Association of Official and Analytical Chemists. Official Methods of Analysis, 17th edition, Washington DC, U.S.A. pp. 24-28.

AOAC. 2005. Official Methods of Analysis, Association of official Analytical Chemistry, 16th edition, Washington DC, U.S.A. p.19.

Amare, E., Mouquet-Rivier, C., Servent, A., Morel, G., Adish, A. and Haki, G.D. 2015. Protein quality of amaranth grains cultivated in Ethiopia as affected by popping and fermentation. *Food Nutr. Sci.* 06(01): 38–48. https://doi.org/10.4236/fns.2015.61005

Ambecha, O. 2006. A Teaching material on Root and Tuber Crops Production and Management. MSc Thesis, Department of Horticulture, Jimma University College of Agriculture and Veterinary Medicine, Ethiopia. pp. 48-58.

Anonymous. 1971. Tannic acid gain. Food Cosmetol Toxicol. In: Toxicants naturally occurring in foods. 3rd edition. National Academy of Sciences, Washington DC, U.S.A. p. 112.

Arias, M.T.G., Pontes, E.A., Fernandez, M.C.G. and Muniz, F.J.S. 2003. Freezing/ boiling/frying of sardine fillets. Influence of slow and quick defrosting on protein quality. *J. Sci. Food Agric.* 83: 602–608. https://doi.org/10.1002/jsfa.1366

Bultosa, G. 2016. Teff: Overview. In: Wrigley, C. W., Corke, H., Seetharaman, K. and Faubion, J. (Eds.) Encyclopedia of Food Grains, 2nd Edn., Elsevier Ltd., Oxford, UK, pp. 209-220. https://doi.org/10.1016/b978-0-12-394437-5.00018-8

Burns, R.E. 1971. Method of estimation of tannin in the grain sorghum. *Agron. J.* 63: 511-519. https://doi.org/10.2134/agronj1971.00021962006300x

Cai, Y.Z., Corke, H. and Wu, H.X. 2004. Amaranth. In: Wrigley, C., Corke, H. and Walker, C. E. (Eds.) Encyclopedia of Grain Science, Elsevier Ltd., Oxford, UK. pp. 1-10. https://doi.org/10.1016/b0-12-765490-9/00001-x

Capriles, V.D., Coelho, K.D., Guerra-Matias, A.C., Arêas, J.A.G. 2008. Effects of processing methods on amaranth starch digestibility and predicted glycemic index. *J. Food Sci.* 73(7): H160–H164. https://doi.org/10.1111/j.1750-3841.2008.00869.x

Caselato-Sousa, V.M. and Amaya-Farf´an, J. 2012. State of knowledge on amaranth grain: a comprehensive review. *J. Food Sci.* 77(4): R93-R104. https://doi.org/10.1111/j.1750-3841.2012.02645.x

Emire, S. and Arega, M. 2012. Value added product development and quality characterization of amaranths (*Amaranths caudatus* L.) grown in East Africa. *African J. Food Sci. Tech.* 3: 129–141.

Escudero, N.L., De Arellano, M.L., Luco, J.M., Gim´enez, M.S. and Mucciarelli, S.I. 2004. Comparison of the chemical composition and nutritional value of *Amaranthus cruentus* flour and its protein concentrate. *Plant Foods Human Nutri.* 59: 15-21. https://doi.org/10.1007/s11130-004-0033-3

Gharibzahedi, S.M.T. and Jafari, S.M. 2017. Review: The importance of minerals in human nutrition: Bioavailability, food fortification, processing effects and nano-encapsulation. *Trends Food Sci. Tech.* 62: 119-132. https://doi.org/10.1016/j.tifs.2017.02.017

Gorinstein, S., Lojek, A., Cízhacek, M., Pawelzik, E., Delgado, L.E. and Medina, O.J. 2008. Comparison of composition and antioxidant capacity of some cereals and pseudo cereals. *Int. J. Food Sci. Tech.* 43: 629-637. https://doi.org/10.1111/j.1365 2621.2007.01498.x

Hernandez OM, Fraga JMG, Jimenez AI, Jimenez F & Arias JJ (2004). Characterization of honey from the Canary Islands: determination of the mineral content by atomic absorption spectrophotometer. J Food Chem 93:449-458.

Kachiguma, N.A., Mwase, W., Maliro, M. and Damaliphetsa, A. 2015. Chemical and mineral composition of Amaranth (*Amaranthus* L.) species collected from central Malawi. *J. Food Res.* 4(4): 92-102. https://doi.org/10.5539/jfr.v4n4p92

Karamac, M., Gai, F., Longato, E., Meineri, G., Janiak, M.A., Amarowicz, R. and Peiretti, P.G. 2019. Antioxidant Activity and Phenolic Composition of Amaranth (*Amaranthus caudatus*) during Plant Growth. *Antioxidants* 8(6): 173. https://doi.org/10.3390/antiox8060173

Koehler, P. and Wieser, H. 2013. Chapter 2: Chemistry of cereal grains. In: Gobbetti, M. and Gänzle, M. (Eds.) Handbook on Sourdough Biotechnology. Springer, New York. pp. 11-45 https://doi.org/10.1007/978-1-4614-5425-0_2

Kolawole, E.L. and Sarah, O.A. 2009. Growth and yield performance of *Amaranthus cruentus* influenced by planting density and poultry manure application. *Notulae Botanicae Horti Agrobotanici ClujNapoca* 37(1): 195–199.

Norhaizan, M.E. and Faizadatul, A.W. 2009. Determination of phytate, iron, zinc, calcium contents and their molar ratios in commonly consumed raw and prepared food in Malaysia. *Malaysian J. Nutri.* 15(2): 213-222.

Mathew, B.K. and Saleh, B.B. 2006. Selected physicochemical properties of flour from the root of African Fan Palm (*Borassus aethiopum*). *Int. J. Food Propert.* 9(4): 701-713. https://doi.org/10.1080/10942910600575641

Mekonnen, G., Woldesenbet, M., Teshale, T. and Biru,T. 2018. *Amaranthus caudatus* production and nutrition contents for food security and healthy living in Menit Shasha, Menit Goldya and Maji Districts of Bench Maji Zone, South Western Ethiopia. *Nutr. Food Sci. Int. J.* 7(3): 1–7.

Mosha, T.C.E. and Vicent, M.M. 2005 Nutritional quality, storage stability and acceptability of home-processed ready-to-eat composite foods for rehabilitation undernourished preschool children in low-income countries. *J. Food Proces. Preserv.* 20(29): 331-356. https://doi.org/10.1111/j.174-4549.2005.00032.x

Mugalavai, V.K. 2013. Effect of Amaranths maize flour ratio on the quality and acceptability of ugali and porridge (Kenyan cereal staples). *ARPN J. Agril. Biol. Sci.* 8: 1–12.

Musa, A., Oladiran, J.A., Ezenwa, M.I.S., Akanya, H.O. and Ogbadoyi, E.O. 2011. Effect of heading on some micronutrients, antinutrients and toxic substances in *Amaranthus cruentus* grown in Minna, Niger State, Nigeria. *American J. Food Nutr.* 1(4): 147–54. https://doi.org/10.5251/ajfn.2011.1.4.147.154

Mustafa, A.F., Seguin, P. and Gelinas, B. 2011. Chemical composition, dietary fibre, tannins and minerals of grain amaranth genotypes. *Int. J. Food Sci. Nutr.* 62(7):750–754. https://doi.org/10.3109/09637486.2011.575770

Olaoye, O.A., Onilude, A.A. and Oladoye, C.O. 2007. Breadfruit flour in biscuit making: effects on product quality. *African J. Food Sci.* 18: 20-23.

Saini, R.K., Nile, S.H. and Keum, Y.S. 2016. Food science and technology for management of iron deficiency in humans: A review. *Trends Food Sci. Tech.* 53: 13-22. https://doi.org/10.1016/j.tifs.2016.05.003

Satinder, K., Savita, S. and Nagi, H.P.S. 2011. Functional properties and anti-nutritional factors in cereal bran. *J. Food Agro Ind.* 4(2): 122-131.

Shrestha, A.K. and Noomhorm, A. 2002. Comparison of physico- chemical properties of biscuits supplemented with soy and kinema flours. *Int. J. Food Sci. Tech.* 37(4): 361-368.https://doi.org/10.1046/j.1365-2621.2002.00574.x

Temesgen, A. and Bultosa, G., 2017. Physicochemical characteristics and nutrient composition of three grain amaranth species grown in Hirna, Eastern Ethiopia. *East African Journal of Sciences*, *11*(1), pp.17-26.

Venskutonis, P.R. and Kraujalis, P. 2013. Nutritional components of Amaranth seeds and vegetables: A review on composition, properties, and uses. *Comprehen. Rev. Food Sci. Food Safe.* 12(4): 381-412. https://doi.org/10.1111/1541-4337.12021