



Ethnopharmacological communication

Bitterness values for traditional tonic plants of southern Africa



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ABSTRACT

Ethnopharmacological relevance: Bitterness values have been determined for southern African plant species that are traditionally used as tonics (*imbizas* or *'musa-pelo*) to alleviate the symptoms of stress and a variety of ailments related to the digestive system.

Aim of the study: To measure and present, for the first time, the bitterness values of 15 of the best-known and most widely used tonic plants in southern Africa in order to find a rationale for their traditional use in improving appetite and treating digestive ailments.

Results: Most of the plants were found to be very bitter, with bitterness values comparable to those reported for internationally well-known bitter tonics such as *Artemisia absinthium* L. and *Gentiana lutea* L.

Conclusions: The relatively high bitterness values obtained for all of the plants indicate that their alleged value in improving digestion and appetite may at least be partly ascribed to the bitter tonic (*amarum*) effect, i.e., the stimulation of gastric juices via the *nervus vagus*. It may be interesting to examine the chemical compounds responsible for the bitter taste, as well as the possible links between bitterness and the anecdotal anti-stress properties ascribed to these species.

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1. Introduction

The use of bitter tonics such as myrrh and wormwood is an ancient practice believed to have beneficial effects on appetite and digestion. Modern examples of bitter tonics include *Gentiana lutea* L. and the herbal preparation known as Swedish Bitters (which contains *Gentiana lutea* and other ingredients such as *Aloe ferox* Mill., *Commiphora myrrha* L. and *Harpagophytum procumbens* DC. (Van Wyk and Wink, 2004). *Aloe ferox* is also an ingredient of *Lewenssens*, one of the best-selling traditional herbal products in South Africa (Van Wyk et al., 2009). Bitterness is believed to be responsible for the so-called *amarum* effect which promotes the flow of saliva, gastric juices and bile (Burger and Wachter, 1998; Van Wyk and Wink, 2004) and thus enhances the function of the digestive system. Bitter extracts or substances (presumably all) are also known to act on the cardiovascular system by decreasing the heart rate and cardiac stroke volume (Schulz et al., 2001). Examples of plant extracts known to decrease cardiac stroke volume include gentian, hops, bitter orange, rhubarb and wormwood (Schulz et al., 2001).

Swedish Bitters, *Lewenssens* and at least 15 species of indigenous plant species are widely used as tonics or *imbizas* in traditional medicine in southern Africa (Van Wyk and Gericke, 2000). According to Ngubane (1977), *imbiza* is the generic Zulu name for all forms

of purgatives, normally herbal preparations of a single plant or mixtures of plants given orally or as enemas to improve general health. Van Wyk and Gericke (2000) define *imbizas* as “strengthening plant combinations which are believed to play a significant role in maintaining health and vigour”. The Zulu word *imbiza* refers to the traditional Zulu cooking pot in which decoctions were made (L. Posthumus, personal communication to BEvW). Furthermore, the term *'musa-pelo* is used for 17 different species of shrubby legumes (Fabaceae) in the Sotho culture, traditionally used to treat anxiety, stress and grief (Moteetee and Van Wyk, 2007). The term *'musa-pelo* means “to turn the heart around”, signifying the grief and stress relieving properties of these plants, most of which are bitter-tasting.

The aim of this short paper is to present bitterness values for 15 of the most widely used traditional tonic plants of southern Africa.

2. Materials and methods

2.1. Procedure for obtaining bitterness values

Bitterness is usually quantified with a so-called bitterness value, which is available for European traditional tonics, including gentian and absinth (Wagner and Wiesnauer, 1995; European Pharmacopoeia, 2005a). The European Pharmacopoeia (2005b) defines bitterness value as “the reciprocal of the dilution of a compound, a liquid or an extract that still has a bitter taste”. It is

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determined by comparison with quinine hydrochloride, of which the bitterness value is set at 200 000.

The procedure used here is an adaptation of the methods prescribed by the World Health Organisation (2002), the European Pharmacopoeia (2005b) and followed by various researchers, e.g., Katsuragi et al. (1997) in which human volunteers do the tasting. The study was approved by the Ethics Committee of the University of Johannesburg. Healthy male or female volunteers over the age of 18 years were screened first for their ability to taste bitterness using 0.100 g of quinine hydrochloride R (obtained from Merck) dissolved in *Bonaqua still* drinking water and diluted to 100 mL. *Bonaqua still* is high quality commercial drinking water purified by reverse osmosis and reconstituted with normal salts found in drinking water. This solution was diluted 100 times and constituted the stock solution (S_1) with a concentration of 0.01 mg/mL. Nine different dilutions ranging from low to high were prepared (in tubes) from solution S_1 and were used to obtain the “bitterness tasting ability” of the enrolled participants as described by Olivier (2012) following the standard procedures of the World Health Organisation (2002) and the European Pharmacopoeia (2005b). In the choice of participants we attempted to provide for most of the variables that may affect bitterness perception, such as race (44% black, 56% white), gender (65% female, 35% male) and age (48% in age group 18 to 25, 29% 26 to 35 and 23% 36 to 50).

The bitterness taste testing of the 15 medicinal plant extracts was conducted in a similar way: 1 g of dried ground plant sample was extracted by adding 100 mL of boiling drinking water and leaving it to stand overnight. The filtrate was diluted 100 times for the very bitter plants (Table 1). This stock solution (S_2) with a concentration of 0.1 mg/mL has a dilution factor (DF) of 10 000. Nine different dilutions were prepared from solution S_2 and were used together with solution S_2 (undiluted) to obtain the “bitterness value” through bitterness tasting. As each individual has a different level of bitterness tasting ability, a correction factor, k , is used for each member of the panel:

$$k = n/5.00 \quad (n = \text{mL of } S_1 \text{ in the 10 mL tube}).$$

Bitterness value is calculated for each panel member according to the formula:

$$\frac{\text{DF}_{S_2} \times k}{\text{mL } S_2 \text{ in tube which still has a bitter taste} \times 0.1}$$

2.2. Plant material

Plants samples and voucher specimens are listed in Table 1. Authorities for scientific names are not repeated elsewhere in the text.

3. Results

Bitterness values for the 15 species (Table 1) were variable and ranged from 11 556–720 000 (*Aloe ferox*) to 600–14 400 (*Withania somnifera*).

4. Discussion

It is clear from the results that the species investigated can all be classified as bitter tonics. The highest bitterness values (> 10 000) were obtained for *Aloe ferox*, *Artemisia afra*, *Dicoma capensis*, *Sutherlandia microphylla* and *Vernonia oligocephala* (in order of decreasing bitterness). These plants are traditionally known to be very bitter (Van Wyk et al., 2009; Olivier, 2012), but comparative data on bitterness were hitherto unavailable for all but one species

(*Harpagophytum procumbens*). This internationally known product has a reported bitterness value of ca. 6000 (Hänsel and Tyler, 2001). Seven of the 15 species have average bitterness values exceeding 6000. The leaves of *Artemisia afra* have a very high bitterness value of 7200–84 000, comparable to that of *Artemisia absinthium*, which has a reported bitterness value of 10 000–25 000 (Wagner and Wiesenauer, 1995; European Pharmacopoeia, 2005a; Lachenmeier, 2007). It should be noted that the average bitterness value of aloe lump (*Aloe ferox*) is much higher because it is an exudate and not a crude extract.

The extreme variability in bitterness (Table 1), as reflected in the range and standard deviation provided for each species, probably results from the complexity of the extracts and less masking or interfering molecules in those with narrow ranges. The variation in *Aloe ferox* is particularly noteworthy. Bitter taste may be masked by compounds producing tastes such as saltiness, sweetness, sourness and astringency by competing for receptor sites (Reinberger, 2006; Ley, 2008). Some compounds (such as phospholipids) are known to selectively inhibit bitterness without affecting others tastes (Katsuragi et al., 1997). Genetic (Bufe et al., 2005; Behrens and Meyerhof, 2006), physiological (Prutkin et al., 2000; Bufe et al., 2005) and hormonal (Prutkin et al., 2000) variation also causes differences in bitter taste perception. Taste preferences may further be learnt through cultural familiarity with certain foods, herbs and beverages (Reinberger, 2006). Lastly, sensitivity to bitterness may vary in the same person from day to day because of fatigue, smoking, or after eating strongly flavoured food (World Health Organisation, 2002). The variation in taste results per species emphasizes the importance of a standardized method and a correction factor for each participant. It is evident that bitterness taste testing does not provide absolute values and must therefore be reported as ranges, as suggested by Wagner and Wiesenauer (1995). Other methods of taste evaluation (including bitterness), such as using artificial taste sensors (Kataoka et al., 2008) may be considered for future studies.

The physiological effects associated with bitter taste are summarized as the *amarum* effect, where the taste buds are stimulated and the secretion of saliva, gastric juices and bile promoted through taste stimuli via the *nervus vagus* (Borgia et al., 1981; Gebhardt, 1997; Öztürk et al., 1998; Sternini, 2007). The *amarum* effect is relatively well studied in the extremely bitter *Gentiana lutea* (bitterness value of 10 000–30 000; Wagner and Wiesenauer, 1995) but the southern African bitter tonics have not yet been studied in this context.

Additional effects such as antibacterial, antifungal, antioxidant and hepatoprotective properties have also been observed for bitter substances, apart from digestive stimulation (Kondo et al., 1994; Kusar et al., 2006). Certain bitter substances are also postulated to have a potential immunological influence as well by decreasing the sIgA-level in the saliva of patients with inflammatory gastrointestinal diseases (Zimmermann et al., 1986). According to Traditional Chinese Medicine, bitter substances “have draining and drying functions, i.e., they are used for clearing Heat, purging Fire, treating constipation, resolving dampness, or lowering the rebelling qi, and may preserve Yin” (Wu, 2005). “Heat” is a term used to describe irritability and other aggressive behaviours, which could lead to increased heart rate due to stress. Schulz et al. (2001) reiterated this finding when he reported that bitter substances act on the cardiovascular system, decreasing the heart rate and cardiac stroke volume. *Astragalus membranaceus* Bunge, *Panax ginseng* C.A. Mey. and *Eleutherococcus senticosus* (Rupr. & Maxim.) Maxim. are all bitter, and are known immunostimulants and adaptogens (Van Wyk and Wink, 2004; Wu, 2005). It is therefore likely that the southern African traditional tonics have numerous other pharmacological effects, as indicated by the diversity of traditional and modern uses, which are presented in detail by Olivier (2012).

Table 1
Bitterness values for 15 South African tonic plants. Voucher specimens are all in JRAU, the herbarium of the Department of Botany and Plant Biotechnology at the University of Johannesburg. Abbreviations of collectors: BEVW=B.-E. van Wyk, DKO=D.K. Olivier, MLS=M.L. Swartz.

| Plants | Bitterness values obtained | | | |
|--|--------------------------------|----------------------|----------------|--|
| | Total no. of taste results (n) | “Not bitter” Results | Range | Bitterness value ^a (mean ± standard deviation) |
| <i>Agathosma betulina</i> (Bergius) Pillans. Leaves and twigs Voucher no: DKO 53 | 11 | 2 | 1 440–14 400 | 4 859 ± 6 093 |
| <i>Aloe ferox</i> Mill. Lump Commercial sample (ex B-E van Wyk) | 13 | 4 | 11 556–720 000 | 78 254 ± 34 021 |
| <i>Arctopus monacanthus</i> L. Root Voucher no: BEVW 4141(a) | 7 | 1 | 1 600–21 600 | 5 407 ± 7 760 |
| <i>Artemisia afra</i> Jacq. ex Willd. Leaves Voucher no: DKO 35(a) | 11 | 2 | 7 200–84 000 | 26 393 ± 29 759 |
| <i>Balanites maughamii</i> Sprague Bark Voucher no: DKO 70 | 8 | 1 | 1 800–14 400 | 4 211 ± 2 019 |
| <i>Dicoma anomala</i> Sond. Root Voucher no: BEVW 4032 | 7 | 1 | 8 000–12 000 | 8 330 ± 1 421 |
| <i>Dicoma capensis</i> Less. Leaves and twigs Voucher no: DKO 58(a) | 9 | 2 | 8 000–72 000 | 14 531 ± 2 135 |
| <i>Harpagophytum procumbens</i> DC. ex Meisn. Root Voucher no: MLS 1 | 7 | 0 | 1 440–14 400 | 4 359 ± 9 375 |
| <i>Hypoxis hemerocallidea</i> Fisch. C.A. Mey & Avé-Lall Tuber Voucher no: DKO 71(a) | 10 | 4 | 1 800–14 400 | 2 615 ± 4 963 |
| <i>Muraltia heisteria</i> (L.) DC. Leaves and twigs Voucher no: BEVW 4194 | 11 | 2 | 1 680–14 400 | 5 594 ± 5 778 |
| <i>Sutherlandia microphylla</i> (L.) R.Br. Leaves and twigs Commercial sample (ex CA Albrecht) | 8 | 1 | 9 333–37 333 | 14 123 ± 2 711 |
| <i>Vernonia oligocephala</i> (DC.) Sch. Bip. Leaves Voucher no: DKO 48 (a) | 6 | 0 | 8 000–12 000 | 10 032 ± 1 317 |
| <i>Warburgia salutaris</i> (G.Bertol.) Chiov. Leaves Commercial sample (ex R Stewart) | 6 | 0 | 1 600–8 400 | 3 425 ± 2 543 |
| <i>Withania somnifera</i> (L.) Dunal Roots Voucher no: DKO 37(b) | 13 | 5 | 1 600–14 400 | 2 456 ± 1 075 |
| <i>Ziziphus mucronata</i> Willd. Leaves Voucher no: DKO 46(b) | 9 | 3 | 8 400–12 000 | 6 410 ± 1 323 |

^a Mean value calculated from all the taste results obtained per plant, where “not bitter” results were assigned a zero value for bitterness value calculation. According to the European Pharmacopoeia (2005b), an average value obtained from six participants is sufficient for an accurate result and standard deviation (SD) was calculated for the six closest results obtained per plant. Where results were very variable, more samples were tasted until at least six repeatable results were obtained. One person never tasted the same species twice.

5. Conclusion

This study confirmed that all 15 traditional tonic plants examined are bitter-tasting. Five of them are extremely bitter, with average bitterness values above 10 000 (*Aloe ferox*, *Artemisia afra*, *Dicoma capensis*, *Sutherlandia microphylla* and *Vernonia oligocephala*). Four are very bitter, with bitterness values between 5000 and 10 000 (*Arctopus monacanthus*, *Dicoma anomala*, *Muraltia heisteria* and *Ziziphus mucronata*). The remaining six are moderately bitter, with values between 2000 and 5000 (*Agathosma betulina*, *Balanites maughamii*, *Harpagophytum procumbens*, *Hypoxis hemerocallidea*, *Warburgia salutaris* and *Withania somnifera*). The results suggest that the traditional uses of these plants may at least be partly ascribed to the bitter tonic (*amarum*) effect. Future studies should focus on identifying the chemical compounds responsible for the bitter taste and the possible relationship between bitterness

and pharmacological activity of the constituents, in particular anti-stress and cardiovascular effects.

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