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Medicinal foods and beverages among Maasai agro-pastoralists in northern Tanzania

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ABSTRACT

Ethnopharmacological relevance: Pastoralist Maasai populations of east Africa use several different wild plants as dietary and medicinal additives in beverages (soups and teas), yet little is known about how the plants used and the rationales for use compare and contrast across different Maasai beverages, including how gender specific dietary and health concerns structure patterns of intake.

Aim of the study: We investigated three Maasai beverages: *almajani* (tea or herbal infusion); *motorí* (traditional soup); and *okiti* (psychoactive herbal tea). In order to build knowledge about the cultural functions of these Maasai food-medicines and their incidence of use we also investigated use rationales and self-reported frequencies of use. We conclude by examining gender differences and the possible pharmacological antimicrobial activity of the most frequently used plants.

Materials and methods: Research was conducted in 2015, with a population of semi-nomadic agropastoralist Maasai residing in northern Tanzania. Data were collected using key informant interviews, plant collections, n = 32 structured surveys, and n = 40 freelist interviews followed by a literature review to determine the known antimicrobial activity of the most used plants.

Results: We identified 20 plants that Maasai add to soup, 11 in tea, and 11 in the psychoactive tea, for a total of 24 herbal additives. Seven plant species were used in all three Maasai beverages, and these clustered with 10 common ailments. Based on self-reports, women use the beverages less frequently and in smaller amounts than men. There were also several gender differences in the plants that Maasai add to *motorí* and their associated use rationales.

Conclusions: There are several intersections concerning the plant species used and their associated rationales for use in *almajani*, *motori*, and *okiti*. Moving outward, Maasai beverages and their additives increasingly involve gender specific concerns. Female use of food-medicines, relative to men, is structured by concerns over pregnancy, birth, and lactation. The frequent consumption of herbal additives, many of which contain antimicrobial compounds, potentially helps modulate infections, but could have other unintentional effects as well.

1. Introduction

1.1. The food-medicine continuum

In traditional cultures plant use is multicontextual with no apparent distinctions between foods and medicines. Plants that are important sources of calories, proteins, and essential nutrients, for example, might also be used for their pharmacological (Etkin and Ross, 1982; Johns, 1990; Moerman, 1994; Etkin, 2006; Billing and Sherman, 1998), including cognitive (e.g. Bourgeois et al., 2014; Kennedy and Wightman, 2011), benefits. It was this insight that led Etkin (1996) to propose studying "ingestibles" as opposed to just foods and medicines. Plants that are consumed for both their dietary and curative effects are now commonly referred to as *food-medicines* or the *food-medicine continuum* (Pieroni and Price, 2006).

Perhaps nothing illustrates the food-medicine *continuum* better than

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one of the most important criteria used to select dietary and medicinal plants—bitter taste. In many traditional cultures bitter taste is used to denote a plant's pharmacological potential, such that a plant with a very strong bitter taste is used only as medicine, whereas a plant that lacks bitterness, or has only a slight bitter taste, might be used as only food, or as both food and medicine (Brett, 1998; Brett and Heinrich, 1998; Pieroni et al., 2002). Taste is therefore one mechanism that humans employ to determine where on the food-medicine continuum a particular plant belongs. Aside from bitterness, use of food-medicines is structured by taste preferences, ethnomedical and dietary beliefs and practices, local ecological knowledge, and availability of resources (Pieroni and Price, 2006).

Ethnobotanists have argued that food-medicines are an important adaptive biocultural response to diseases (Etkin and Ross, 1982; Jackson, 1996; Johns, 1999) and as such they played an important role in the origin of human medicine (Johns, 1990; Huffman, 1997, 2001; Júnior et al., 2015). This perspective articulates well with the argument made by researchers studying animal self-medication, or zoopharmacognosy (Rodriguez and Wrangham, 1993), in which exploitation of plant secondary compounds (i.e. defensive toxins and other bioactive compounds not directly involved in primary metabolism) is viewed as an adaptive homeostatic response to environmental and reproductive challenges (e.g. Glander, 1994; Hart, 2005, 2011; Villalba and Provenza, 2007; Raubenheimer and Simpson, 2009; Ponton et al., 2011; Forbey et al., 2013). In their review, Forbey et al. (2009) proposed that in addition to the nutritional benefits of plant ingestion, exploitation of plant secondary compounds helps an herbivore (including human) to alleviate the costs of parasitic infection, avoid predation, moderate thermoregulation, increase alertness, and enhance reproduction. One of the strengths of food-medicine research has been elucidating the positive effects of ingested plant foods on things like pathogen infections and chronic illness (e.g. Etkin and Ross, 1982; Johns, 1990, 1999; Lindeberg et al., 1994; Etkin, 1996, 2006; Lockett et al., 2000; Pieroni and Price, 2006; Lindeberg, 2010; Leonti, 2012; Vandebroek and Balick, 2014; Jennings et al., 2015). There is, however, less attention paid to other potential adaptive benefits (or consequences) of ingesting plants.

One exception is the growing body of literature focused on how knowledge and use of food-medicines is structured by gender specific concerns over sexual health and reproduction (e.g. van Andel et al., 2014). In Africa alone, women frequently use herbal remedies to manage a range of issues involving menstruation, pregnancy, childbirth, and lactation (Veale et al., 1992; Steenkamp, 2003; Malan and Neuba, 2011; Yemele et al., 2015; Towns and Van Andel, 2014, 2016). Use of food-medicines might also provide important nutritional benefits during pregnancy and lactation (e.g. Lockett et al., 2000). However, many bitter tasting plants are also toxic and/or have antinutritional effects—they are associated with energetic and metabolic costs, induce physiological aversions such as nausea and vomiting, and some are neurotoxins that disrupt central nervous system signaling. Many plant toxins also disrupt fetal development (i.e. they are teratogens). When pregnant and lactating females consume food-medicines, they therefore risk exposing their fetuses and breastfeeding children to these compounds. Fortunately, females possess biocultural mechanisms that enhance their ability to detect and avoid toxins, especially during pregnancy and lactation (Hagen et al., 2013; Roulette et al., 2016). These include heightened metabolism of plant toxins (Yang et al., 2012), heightened sensitivity to the aversive properties of plant secondary compounds like bitter taste (Bartoshuk et al., 1995; Prutkin et al., 2000), pregnancy sickness (e.g. Profet, 1992; but see Flaxman and Sherman, 2000; Fessler et al., 2002), and food preferences and avoidances (Placek and Hagen, 2015). Despite the growing body of research demonstrating that food-medicines provide important nutritional and medicinal benefits during pregnancy and lactation, few studies have considered that female patterns of use might also be influenced by concerns over the health of the fetus or breastfeeding child. One notable exception is Lockett et al. (2000), who found that Fulani women in West Africa consume wild plants to reduce labor time and pains and to increase breast milk production but that bitter tasting plants are avoided in the belief that they are harmful to the fetus.

1.2. Maasai food-medicines

Maasai are nomadic and semi-nomadic pastoralists who inhabit southern Kenya and northern Tanzania. Primarily cattle herders, many groups have adopted agriculture, sell livestock, milk, and beadwork, and engage in labor migration (Nestel, 1989; Homewood, 2008; Homewood et al., 2009; McCabe et al., 2014). Traditionally, more than 60% of their caloric intake comes from fats in animal foods, such as fresh and fermented milk, meat, and blood (Nestel, 1989).

Maasai also collect and use several wild plant species for firewood, building supplies, medicines, foods, and herbal additives. Fruits, tubers, and roots, for example, are an important part of the diet of women and of young men taking care of animals away from the "bomas," the local English and Swahili term for the enclosed settlement or compound, called nkang in Maa (Maundu et al., 2001).[1]

Maasai use wild plants therapeutically in infusions (called *tumuka*) and tonics (called *teyera*), which are made of the roots, bark, fruits, and/or seeds of shrubs infused or decocted in water or animal fat. Indeed, Maasai recognize that all trees and shrubs can be used as medicines, and the same term, *olcani* (singular), is used to refer to both a tree/shrub (and firewood) and plant medicinals (Mol, 1978; Jacobs, 1963). Like their Samburu relatives (Bussmann, 2006; Fratkin, 1996) and Kenyan Sekenani Valley Maasai (Bussmann et al., 2006), Maasai of the eastern Serengeti ecosystem of northern Tanzania believe that pollutants or irritants block or inhibit digestion, causing sicknesses. Thus, infusions and tonics are consumed for their emetic, purgative, and/or diuretic effects to help "cleanse" the body of pollutants.

Maasai also consume a variety of beverages to which different wild edible and medicinal plants are added (also called "dietary additives", i.e. Johns et al., 1999; Parker et al., 2007). Maasai infuse or decoct a number of different wild plants into tea-like beverages, which are consumed almost daily. There are also a number of different plants that are added to soups to promote healing, build strength and weight, and aid digestion. This paper focuses on three different Maasai soups and teas (see Fig. 1): *almajani*—a drink made of commercial tea, sugar, and milk; *motorí*—a blood-based medicinal soup; and *okiti*—a psychoactive herbal tea. (Hereafter we use "beverages" to refer to Maasai soups and teas, "wild plants" or "herbal additives" to refer to the plants that Maasai add to beverages, and "food-medicine" to refer to both Maasai beverages and herbal additives. For a discussion of other Maasai beverages, e.g. milk and mead [honey beer] see Ibrahim, 2001.)

Almajani, the term Maasai use to refer to "tea" (also called *chai*, a Persian loan word used in Swahili) is usually made with commercial black (oxidized, or "fermented") tea (*Camellia sinensis* [L.] Kuntze), milk, and sugar. During the drought season the tea is made without milk and is called *orangi*. Commercial tea is a relatively new introduction as reflected in borrowed terms that Maasai use: '*majani*' is Swahili for 'leaves' (e.g. tea leaves) and "*rangi*" is Swahili for color (e.g. for black tea without milk). In both cases, Maasai add several pleasant tasting and medicinal wild plants to the tea. They consume tea recreationally on practically a daily basis, and it has become an important (neo)traditional part of social interaction.

Motorí is a medicinal soup consumed with meat or when one is sick. It is made with the boiled fat and blood of cows, sheep, and goats, which are mixed with medicinal herbs to aid digestion and prevent or treat diseases. The consumption of *motorí* is thus accompanied by the

[1] Maasai also occasionally chew the myrrh, resins and gums of *Commiphora* spp., and the inner resin and mature galls of some *Acacia* spp. (Leguminosae) for their flavor, water content, and to pass time (Johns et al., 1999; Maundu et al., 2001).

Fig. 1. Maasai medicinal beverages *almajani*, *motori*, and *okiti*. (a) cup of *almajani.* Photo taken inside Maasai *nkang*; b) pot of *motori* cooking on open fire. Photo taken during *orpul*; c) roots infused in water to make *okiti*. Photo taken during *orpul*.

slaughter, and consumption, of livestock (the fat of which are important for making *motorí*). In one of the only studies to systematically explore Maasai soup additives, Johns et al. (1999) identified about 20 plants that Maasai add to soups throughout Kenya and Tanzania. Johns et al. (2000) argue that Maasai herbal additives could have an antioxidant function and thus might help prevent cardiovascular disease (see also Johns et al., 1999; Mann et al., 1964; but see Berger et al., 2012). Parker et al. (2007) found that two Maasai herbal additives, *Olinia rochetiana* (Oliniaceae) and *Warbugia ugandensis* Sprague (Canellaceae), contain bioactive compounds that are antiviral against the measles virus *in vitro*. This herbal antiviral use suggests that plants that Maasai in other regions use might also contain bioactive compounds with antimicrobial effects and that their frequent use in e.g. Maasai beverages could help modulate infections.

Okiti is a psychoactive and medicinal "tea" that men consume to increase their aggression and to feel brave. Men make it with the roots and bark of plants, which they place in water, boil, let cool, and then drink. Our informants also sometimes call it *kiloriti*, which refers to the most preferred psychoactive plant, *olkiloriti* (*Acacia nilotica* L. [Leguminosae]). In this paper, we use *okiti* to refer to the psychoactive tea, and *olkiloriti* to refer to the plant, *A. nilotica,* as this is the most common way that Maasai in our study community referred to these, respectively. Boys start using *okiti* after they enter the *moran* warrior stage (i.e. after they are circumcised, around 16 years of age, Hodgson, 2001). Sindiga (1994), data from Holford-Walker (1951) reported nineteen plants used as stimulants by Maasai, although only eleven botanical names were provided and it was not clear if the plants were used in *okiti*, *motorí*, or both. Lehmann and Mihalyi (1982) argue that the moran warriors' use of psychoactive plants contributed directly to their reputation as fierce warriors. Overuse of the stimulants, however, can result in *em boshoma*, "a state of hyperexcitement [that inflicts] the warriors, and also the young, powerful and healthy men" (Merker, 1910:185–187), as well as *aduku*, a state of calmness or introvertedness, and *nkirakira*, what Fratkin calls "a state of muscular spasms and seizure among warriors" (1975:27). Merker (1910) points out that married men, girls, and women do not use the stimulants at all, or only in very limited amounts.

1.3. Specific aims

In this study, we examine Maasai knowledge and use of wild plants that are added to soups and teas. Although exploratory, we address three gaps in the literature on Maasai herbal additives and beverages and the food-medicine continuum more generally.

First, previous research on Maasai beverages has not made clear distinctions between the different soups and teas being investigated (e.g. Lehmann and Mihalyi, 1982; Sindiga, 1994; Johns et al., 1999). Therefore, we know very little about how these beverages compare and contrast in terms of the plants used, known pharmacological effects, and Maasai rationales for use. We therefore examine intersections between *okiti, motorí,* and *almajani* in terms of the plants used and the reasons for use. This is possibly also the first report of herbal additives that Maasai add to commercial tea. Moreover, in light of evidence indicating that Maasai in other regions use plants with antiviral activity against the measles virus (Parker et al., 2007) we also examine the antimicrobial and anti-helminthic efficacy of Maasai herbal additives with reference to the pharmacological analyses reported in the literature.

Second, little is known about gender differences in use of Maasai food-medicines, despite the fact that use of food-medicines is likely to be influenced by a) strict cultural rules that dictate the diets of Maasai men and women and b) sex-specific requirements for managing reproductive and sexual health. In this paper, we therefore examine the plants used, rationales for use, and frequency of use of beverages, across gender.

Finally, research on food-medicines has typically focused on the nutritional benefits of medicines and/or the pharmacological benefits of foods. However, there is much less research on the pharmacological and/or nutritional benefits of recreational and psychoactive substances (but see Leonti and Casu, 2014; see also Bonet and Valles, 2002 and Pardo de Santayana et al., 2006 for alcoholic beverages such as spirits and beer). This study, which includes an analysis of the Maasai psychoactive tea, contributes to this underexplored area of the food-medicine continuum.

Although we note that the use of Maasai beverages and herbal additives, including gender differences in use, only makes sense within the Maasai's broader ethnomedical system and worldview, we are primarily interested in how environmental interactions might account for differences in use. Specifically, do gender differences articulate with hypothesized sex differences in toxin avoidance and fetal protection? How might consumption of Maasai beverages and herbal additives affect the presence and distribution of disease causing agents? This exploratory research will provide the foundation for future research addressing these questions.

2. Materials and methods

Data were collected during two separate 2-month long field trips (summer of 2015; fall of 2015) in the context of a larger One Health (Quinlan and Quinlan, 2016) project of Maasai ethnobiology and health (e.g. Caudell et al., 2107). The first phase of this inquiry was to determine the frequencies of use of Maasai beverages and identify the plants that are added to them. The second study further investigated what plants are used and rationales for use.

2.1. Study population

Research was conducted among the semi-nomadic agropastoralist Maasai residing in Simanjiro District, Manyara Region, in northern Tanzania, which is part of the eastern Serengeti ecosystem (see Fig. 2). Simanjiro Maasai live along an economic continuum from subsistence-level herding and agriculture to intensive cash cropping. For recent accounts of Simanjiro Maasai see Leslie and McCabe (2013), McCabe

Fig. 2. Map of Tanzania with approximate research location (squared-box) in Simanjiro district, Manyara region, northern Tanzania. Image adapted from "Tanzania Location Map", © Sémhur/Wikimedia Commons, CC BY-SA-3.0 (https://commons.wikimedia.org/wiki/File:Tanzania_location_map.svg), and "Tanzania in Africa" by TUBS/Wikimedia Commons, CC BY-SA-4.0 (https://commons.wikimedia.org/wiki/File:Tanzania_in_Africa_(-mini_map_-rivers).svg).

et al. (2014), Miller et al. (2014), Quinlan et al. (2016), and Sachedina and Trench (2009). A total of 66 adult Maasai participated in the study.

2.2. Key informant interview

Open-ended, semi-structured interviews (Reyes-García et al., 2006) were conducted with four key informants to investigate the different types of beverages used, as well as the plants that are added to them. Key informants were adult Maasai residing in the study community and whom Maasai participants and field assistants recognized as being knowledgeable of traditional plant medicines. Maasai often use more than one term to refer to the same species of plant. Therefore, following completion of the freelist interviews (detailed below) we conducted interviews with four additional key informants to verify plant names (all local names of collected plant specimens are reported in Appendix 1).

2.3. Plant collections

Maasai key informants and local guides helped locate the plants identified in the key informant interviews. Voucher specimens of all species we could find growing during this mobile interview were collected in duplicate, pressed, and sent to the National Herbarium of Tanzania for identification and storage. The specimens were identified by Dr. Njau. All plant names were checked with www.theplantlist.org on August 9, 2017.

2.4. Structured surveys for frequency of use of beverages

Participants (n = 32) provided their gender, age and self-reports of the following: number of "cups" (i.e. the tin, coffee-cup sized, glasses used to consume tea) of *almajani* (tea) they have each day; how long since they last consumed *motorí* (soup) (converted to number of days) and how many "bowls" (i.e. the tin bowls used to consume *motorí*) they had; and how long since they last consumed *okiti* (psychoactive tea) and how many "cups" they had.

2.5. Freelist interviews indicating prominent plant additives

Participants (n = 40, 34 new participants and 6 that participated in the structured survey) provided their gender and age, and were asked to freelist (or "free-list"; Quinlan, 2017; Weller and Romney, 1988) the plants that they add to motorí. Freelisting is a well-established method for this type of medicinal ethnobotanical data (Quinlan, 2005, 2017; Nolan and Robbins, 1999; Hernández et al., 2003). Ethnographic interviews and the frequency of use survey revealed that only women prepare *almajani* and only men prepare and consume *okiti*. Therefore, only women (n = 20) were asked to freelist plants that are added to *almajani* and only men (n = 20) were asked to freelist plants that are added to *okiti*. Composite salience scores (Σ), called composite salience values (CSV) (Quinlan, 2005), were then calculated for each of the plants added to each beverage. After freelisting plants each participant was asked why (i.e. the use rationale) they add the plant to the soup or tea, which part(s) of the plant they use, and if they know of any other medicinal uses of the plant(s). The use rationales provided by participants were categorized into one or more of 35 rationales for use (excluding mentions of "I do not know").

2.6. Data analysis

All data were analyzed on Stata/IC 11.0 for Mac. Spearman rank correlations (r_s) and *t*-tests (t) were used to examine gender and age differences in self-reports of beverage consumption and CSV of herbal additives and use rationales. To compare proportions of male and female use of a beverage two-group proportions tests were used and z-scores (z) are reported. All tests are two-tailed and significance was set

Table 1
Summary statistics of self-reported use of Maasai beverages.

	Female	Male	Total
n	16	16	32
Mean age (SD)	35.3 (10.7)	42.4 (15.1)	38.8 (13.4)
Mean cups of almajani per day (SD)	2.5 (0.5)	3.1 (1.3)	2.8 (1.0)
Mean bowls of motorí[a] (SD)	3.3 (1.6)	4.8 (1.7)	4.2 (1.8)
Mean days since last used motorí[b] (SD)	70.3 (128.8)	10.9 (11.6)	47.5 (104.3)
Mean cups of okiti[c] (SD)	1.0 (1)	4.3 (3.7)	3.76 (3.6)
Mean days since last used okiti[d] (SD)	4637.5 (4637.5)	1943.1 (4584.1)	2392.2 (4685.6)
Proportion use *A. anthelmintica* as salt in porridge	0.8	0.9	0.8
Median frequency-use scores	1.0	1.0	1.0

[a] n = 27; five women were unable to answer the question.
[b] n = 26; six men were not asked this question.
[c] n = 19; thirteen women were unable to answer the question.
[d] n = 12; 14 women and six men were unable to answer the question.

Table 2
Summary statistics for freelist interviews, including total and mean number of plants listed for *almajani*, *motorí*, and *okiti*.

	Female	Male	Total
n	20	20	40
Age (SD)	42.2 (13.5)	45.5 (13.0)	43.8 (13.2)
Almajani			
Total plants mentioned	22		22
Mean number plants per participant (SD)	4.6 (1.7)		4.6 (1.7)
Motorí[a]			
Total plants mentioned	38	41	59
Mean number plants per participant (SD)	6.1 (2.2)	7.2 (2.4)	6.7 (2.3)
Okiti			
Total plants mentioned		29	29
Mean number plants per participant (SD)		3.9 (1.9)	3.9 (1.9)

[a] Female n = 16; total n = 36.

at $p < 0.05$. Samples sizes vary for some questions because not all participants were able to answer each question.

3. Results

3.1. Plant specimen collections

Twenty-four herbal additive specimens, from 14 plant families, were collected (Appendix 1).

3.2. Structured surveys for frequency of use of beverages

Participants reported a mean of 2.8 cups (SD = 1.0, min = 2, max = 6) of *almajani* (tea) consumed per day (Table 1). Number of cups of *almajani* did not vary by gender or age.

Participants reported consuming a mean of 4.2 bowls (SD = 1.8, min = 1, max = 7) of *motorí* (soup) the last time they had it, which was on average 47.5 days (SD = 104.3, min = 1, max = 510) before the interview. Men reported consuming significantly more bowls of *motorí* than women ($t = -2.17$, $p = 0.04$), but there was no significant difference in the number of days since it was last consumed. Women's self-reported amount of *motorí* consumed ($r_s = -0.60$, $p = 0.049$, $n = 11$), and men's days since last using *motorí* ($r_s = -0.75$, $p = 0.01$, $n = 10$), had significant negative rank correlations with age, indicating that older people use less. Days since last consuming *motorí* had significant negative rank correlations with the number of days since last consuming *okiti* ($r_s = -0.65$, $p = 0.02$, $n = 12$).

Participants reported consuming a mean of 3.8 cups (SD = 3.6, min = 0.5, max = 15) of *okiti* (psychoactive tea) the last time they had it, which was about 6.5 years (SD = 4685.6 days, min = 1, max = 14,600) before the interview. Significantly more men (100%) than women (18%) had ever used *okiti* ($z = -4.7$, $p = 0.000$); only two women were able to recall when they last had *okiti*, one of whom last

Table 3
Composite salience value (CSV) and the proportion of participants that mentioned each of the top *almajani*, *motorí*, and *okiti* additives.[a]

Species, Family	CSV	Proportion
Almajani additives		
Zanthoxylum chalybeum (Rutaceae)	0.66	0.80
Acacia nilotica (Leguminosae)	0.57	0.80
Lannea fulva (Anacardiaceae)	0.28	0.45
Pappea capensis (Sapindaceae)	0.22	0.35
Croton macrostachyus (Euphorbiaceae)	0.29	0.40
Motori additives		
Zanthoxylum chalybeum (Rutaceae)	0.54	0.75
Vepris uguenensis (Rutaceae)	0.40	0.47
Pappea capensis (Sapindaceae)	0.29	0.44
Dombeya rotundifolia (Malvaceae)	0.28	0.50
Albizia anthelmintica (Leguminosae)	0.27	0.42
Engosikiryanjoi (species name unknown)	0.16	0.33
Olchurai (species name unknown)	0.11	0.25
Okiti additives		
Acacia nilotica (Leguminosae)	0.74	0.85
Pappea capensis (Sapindaceae)	0.25	0.30
Albizia anthelmintica (Leguminosae)	0.24	0.40
Zanthoxylum chalybeum (Rutaceae)	0.16	0.25

[a] Numbers of *almajani*, *motorí* and *okiti* plants shown are based on the mean number of plants reported in the freelist interviews for each beverage (i.e. 4.6, 6.7, and 3.9, respectively, which were rounded up to the nearest whole number).

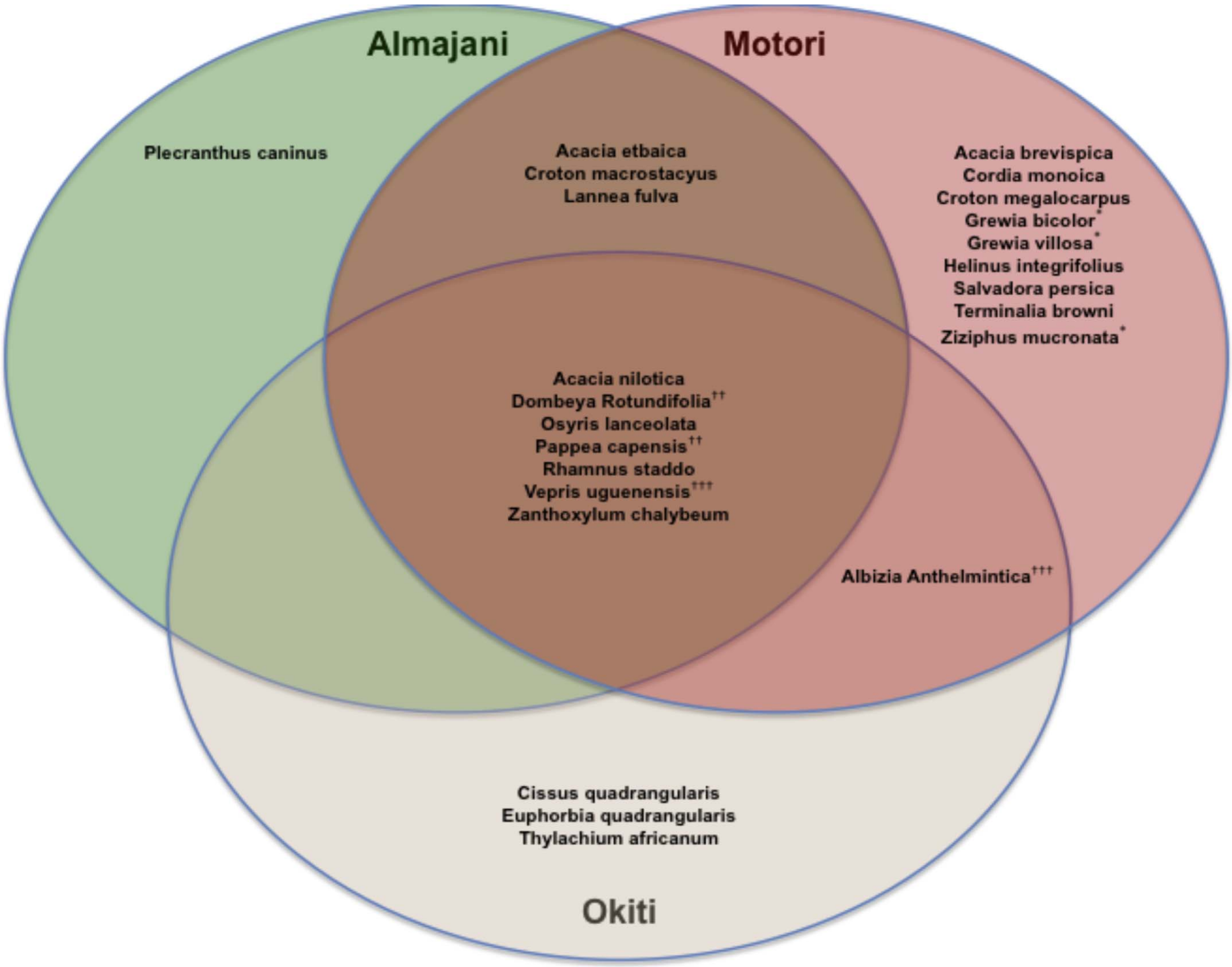

Fig. 3. Species names of the plants that are added to each of the three Maasai beverages, shown in alphabetical order. Only plants that were collected and confirmed by two or more participants are shown. *$p < 0.05$; *Motorí* additives mentioned by significantly more women than women. ††$p < 0.01$; *Motorí* additives mentioned by significantly more men than women. †††$p < 0.001$; *Motorí* additives mentioned by significantly more men than women.

consumed *okiti* over ten years before the interview. One male participant also reported last consuming *okiti* over ten years before the interview, which was nearly three standard deviations above the mean for men's number of cup's of *okiti*. After removing these outliers, the mean number of years was 1.5 (or 537 days), which did not significantly vary by age. In contrast, with the outliers removed self-reported amount of *okiti* had significant positive rank correlations with age ($r_s = 0.70$, $p = 0.04$, $n = 9$).

3.3. Freelist interviews indicating prominent plant additives

Participants freelisted a total of 71 additives, and each additive was associated with a mean of 1.5 beverages. The total number of plants reported for each beverage is shown in Table 2 and the CSV's of the most salient plants for each beverage are shown in Table 3. Thirty-eight additives (54%) were "confirmed", i.e. reported by two or more participants for a beverage, including 64% of the *almajani* additives, 52% of the *motorí* additives, and 52% of the *okiti* additives. Of the plants that were confirmed and collected (n = 24), Maasai reported using seven of them in all three beverages, three in *motorí* and *almajani* (but not *okiti*), one in *motorí* and *okiti* (but not *almajani*), nine in *motorí* only, three in *okiti* only, and one in *almajani* only (Fig. 3).

There were 26 total use rationales that were reported by two or more participants for *almajani*, *motori*, or *okiti*. Of these, ten were mentioned for all three beverages, seven were mentioned for both *motorí* and *okiti* (but not *almajani*), four for both *motorí* and *almajani* (but not *okiti*), one was unique to *almajani*, three were unique to *motorí*, and two were unique to *okiti* (Fig. 4). (See Appendix 2 for a detailed list of use rationales for each collected plant specimen, and for use rationales reported by > 15% of participants for each Maasai beverage.)

Participants reported a total of 20 rationales for adding a plant to *almajani* (M = 4.9, SD = 2.2), with 75% of rationales confirmed, i.e. reported by two or more participants. The rationale mentioned by the greatest proportion of participants was "organoleptic" (i.e. to turn the liquid red and/or for its pleasant flavor and/or smell; 75%), and participants reported a mean of 2.3 plants that they add to *almajani* for this purpose. The rationale with the greatest number of plants used was "to treat body aches and pains" (M = 2.4), although only 35% of women reported adding plants for this purpose.

There were 32 total rationales for adding a plant to *motorí* (M = 6.4, SD = 2.8), with 75% of rationales confirmed. Men (M = 7.8) reported significantly more rationales than women (M = 4.9; $t(32) = -3.43$, $p = 0.002$). The rationales mentioned by the most participants were "organoleptic" (60%), "treat body aches and pains" (57%), and "to treat

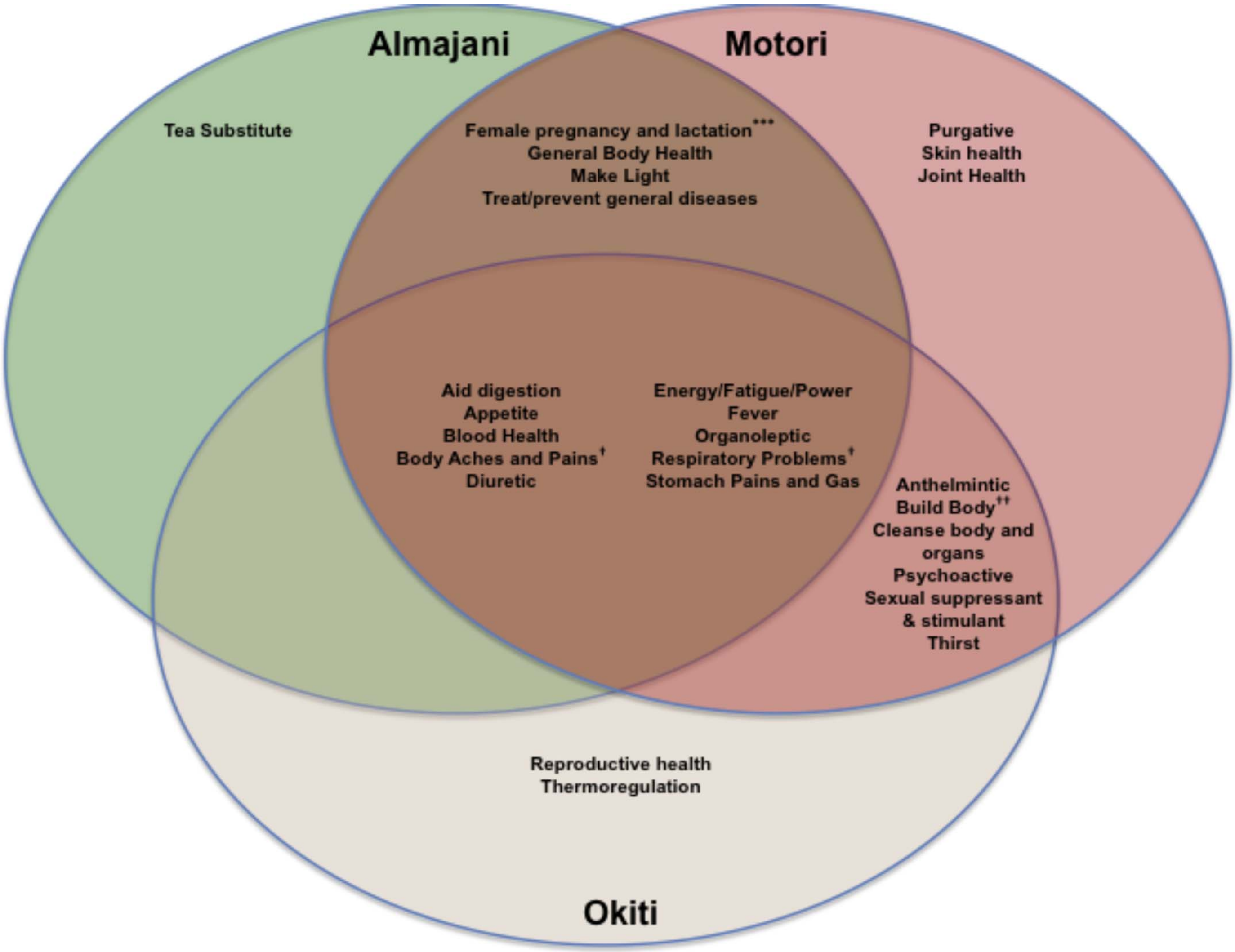

Fig. 4. Rationales reported for adding an herbal additive to each Maasai beverage. Only rationales reported by two or more participants for each beverage are shown. Rationales listed in alphabetical order. For summary statistics of these, and other rationales, see Table 2 in Appendix 2. †$p < 0.05$; Significantly more men than women mentioned rationale with respect to *motorí*. ††$p < 0.01$; Significantly more men than women mentioned rationale with respect to *motorí*. ***$p < 0.001$; Significantly more women than men mentioned rationale with respect to *motorí*.

fevers" (57%), with means of 2.2, 2.1, and 1.2 plants, respectively, used for these purposes. The rationale with the greatest number of plants reported was "to enhance female pregnancy and lactation" (M = 2.7).

Participants reported a total of 20 rationales for adding a plant to *okiti* (M = 4.2, SD = 2.0), with 95% of rationales confirmed. The most frequently reported rationale was "psychoactive effects", and participants reported a mean of 1.6 plants used for this purpose. The rationale with the greatest mean number of plants reported was "to treat stomach pains and gas" (M = 1.7), although only 16% of men reported adding plants for this reason.

Eleven of the *motorí* additives, and five of the *motorí* rationales, had significant gender differences in the proportion of participants that reported them (Table 4). Most women reported adding a plant to enhance pregnancy or lactation, with most of these (81%) saying that the plant helps increase breast milk. Age was significantly correlated with the CSV of several of the *almajani*, *motorí*, and *okiti* herbal additives (Table 5). In contrast, none of the rationales of use significantly varied by age.

Finally, we found that Simanjiro District Maasai only add medicinal plants to the food-beverages *almajani, motori* and *okiti*, and not to milk alone, as has been found with Maasai elsewhere (e.g. Parker et al., 2007). Maasai in this area did not speak of adding plants to milk alone, and one elderly participant (a laibon, or traditional healer) informed us that the Maasai in the study region do not add plants to milk as much as they used to.

4. Discussion

Maasai reported 38 confirmed, i.e. listed by two or more participants, plants that they add to beverages (*almajani*, *motorí*, and *okiti*), and 24 of these were collected and identified. Seven species (Fig. 1) are common to all three Maasai beverages, and these cluster with 10 common ailments. Moving outward from this core, Maasai beverages and their additives increasingly involve gender specific concerns. *Okiti* is primarily for men, whereas the intersection of *motorí* and *almajani* have some female-specific functions and perhaps general family health uses. As with ethnobotanical findings elsewhere (e.g. the Popoluca of Mexico (Leonti et al., 2002), Matsigenka and Yora of the Peruvian Amazon (Shepard, 2004), and the Hausa of Nigeria (Etkin, 2006), organoleptic rationales (i.e. sensory properties of the plant generally reminiscent of the condition)) were one of the most frequent rationales Maasai reported for adding a plant to teas and soups. Organoleptic motivations mentioned by Maasai include the ability of the plant to turn the color of the beverage red, a preference for pleasant tasting and/or

Table 4
Proportion of men and women that mentioned each *motorí* additive and use rationale, including z-scores. Only plants and rationales with significant gender differences in CSV are shown.

	Female	Male	Z-score	p value
n	16	20		
Male Bias				
Plants				
Albizia anthelmintica	0.00	0.75	− 4.54	0.0000
Vepris uguenensis	0.13	0.75	− 3.73	0.0002
Dombeya rotundifolia	0.25	0.70	− 2.68	0.0073
Pappea capensis	0.19	0.65	− 2.78	0.0055
Olchurai (species name unknown)	0.06	0.40	− 2.32	0.0201
Rationales				
Body aches/pains	0.38	0.74	− 2.15	0.03
Respiratory problems	0.19	0.53	− 2.07	0.04
Reproductive problems	0.00	0.32	− 2.47	0.01
Build body	0.00	0.47	− 3.19	0.001
Female Bias				
Plants				
Engosikiriyanjoi (species name unknown)	0.69	0.05	4.03	0.0001
Osilalei (species name unknown)	0.31	0.00	2.69	0.0071
Olmesera (species name unknown)	0.38	0.05	2.45	0.0144
Grewia bicolor	0.25	0.00	2.37	0.0177
Ziziphus mucronata	0.25	0.00	2.37	0.0177
Grewia villosa	0.31	0.05	2.10	0.0357
Use rationales				
Enhance pregnancy and/or lactation	0.94	0.11	4.91	0.000

Table 5
Spearman rank correlations of herbal additive CSV versus age. Only plants with significant age differences in CSV are shown.

	r_s
Almajani additives	
Rhamnus staddo	− 0.45*
Motorí additives	
Male	
Pappea capensis	0.53*
Acacia nilotica	0.49*
Vepris uguenensis	− 0.59**
Zanthoxylum chalybeum	− 0.59**
Okiti additives	
Pappea capensis	0.48*
Dombeya rotundifolia	− 0.52*

** $p < 0.01$.
* $p < 0.05$.

smelling plants especially in *almajani* and *motorí*, and use of bitter tasting plants known for their medicinal or psychoactive effects in *motorí* and *okiti*.

Maasai typically drink almajani two or three times daily, yet, this is the first discussion of *almajani* (tea, *chai*) published in the indexed ethnobiological literature. Perhaps the relatively modern introduction of *C. sinensis* in 1905 (Heiss and Heiss, 2011) leads researchers to consider it outside of Maasai indigenous, local, or traditional plant knowledge (per Bollig and Schulte, 1999; Heinrich et al., 1998), and therefore not *ethno*botanical or *ethno*pharmacological. Berkes (1993:3) uses the term "traditional" for "knowledge and beliefs, handed down through generations by cultural transmission". Tea does not grow in the arid Maasai ecosystem, but it is readily available and very inexpensive because Tanzania is a tea producer, and neighboring Kenya is the world's top exporter of tea (before China and India) (Heiss and Heiss, 2011). Even the smallest Maasai shop carries tea, and it is one of the few things that Maasai regularly purchase, as they have for about five generations. We maintain that *C. sinensis* is a widely consumed traditional plant for Maasai. It plays an important social function in that Maasai share it with one another, and offer it to guests visiting an *nkang*. Further, it plays an important role in maintaining and regulating Maasai health because it is the base or "mixer" to which Maasai add antimicrobial and health-promoting plants in general, and for maternal and infants' health in particular, as several plants are mentioned that increase breast milk production.

Our results suggest that plants used by one Maasai population might not necessarily overlap with plants used by other Maasai populations. For example, of all the plants added to teas by a group of Kenyan Maasai (Bussmann et al., 2006), only one of them (*Osyris lanceolata* Hochst. and Steud [Santalaceae]) is also added to tea by the Maasai in this study. Similarly, Maundu et al. (2001) reports a number of plants used in soups by Maasai of Loita Hills in Kenya. These Maasai generally prefer to use *A. nilotica* (L.) Delile (Leguminosae), but in our study *A. nilotica* was not frequently mentioned as a soup additive. Moreover, Sindiga (1994), data from Holford-Walker (1951) indentified eleven plants used as stimulants by Maasai, whereas we only identified (i.e. a voucher specimen was collected *and* the plant was reported by two or more participants) three—*A. nilotica*, *A. anthelmintica,* and *Cissus quadrangularis* L. (Vitaceae). Taken together, these findings suggest that either different traditions or different ecological conditions or a combination influence localized Maasai ethnomedicines.

We note too that while some Maasai groups add plants to milk (cf Parker et al., 2007), the Simanjiro District Maasai have reportedly abandoned this practice outside of milk-heavy *almajani*. Indeed, we never observed anyone add plants to milk outside of *almajani* with milk, which we discussed here. These Maasai do, however, use a number of plants to clean and sterilize milk gourds. For example, after rinsing with water or cow urine the roots of *A. anthelmintica* are used as brushes to clean the inside of the containers. The coals of *oloirien* (*Olea Africana* Mill [Oleaceae]), a sacred tree, are then used to "disinfect" and dry the containers (Ibrahim, 2001). The smoke gives the milk a characteristic "smoky" flavor.

4.1. Antimicrobial effects of maasai herbal additives

We now examine the known antimicrobial and anti-helminthic activity of three of the most frequently reported plants: *Zanthoxylum chalybeum* Engl. (Rutaceae), *A. nilotica*, and *A. anthelmintica*. Although there are no *in vivo* data on compounds extracted from these plants, there are *in vitro* studies, with the caveat that the specimens reported in the literature are not necessarily the same sub-species of plant in our study region, and subspecies could differ somewhat in their chemical composition.

Z. chalybeum, the most frequently listed plant across all beverages (and a commonly used traditional "antibiotic"), contains an alkaloid (skimmiamine, in the seeds) that might have antiviral properties against measles (Olila and Opuda-Asibo, 2002). It also contains compounds with antimalarial (Gessler et al., 1994; Bouquet et al., 2012) and antibacterial activity against *Staphylococcus aureus* bacterium (Gibbons et al., 2003), *Micrococcus luteus*, and *Bacillus subtilis* (Matu and Van Staden, 2003). *B. subtilis* in particular is associated with diets high in proteins and animal fats, such as the diets of Maasai pastoralists. *Z. chalybeum* also contains numerous aromatic compounds (Neuwinger, 1998) that might contribute to its pleasant organoleptic attributes.

A. nilotica, the most reported additive in *okiti* and the second most reported additive in *almajani*, also contains numerous compounds with antimicrobial effects. Extracts from the stem, leaves and pods contain compounds exhibiting antifungal properties against *Candida* spp., (Hamza et al., 2006) and *Aspergillus flavus* (ur Rahman et al., 2014), as well as antibacterial against *B. subtilis*, *Klebsiella pneumoniae* (ur Rahman et al., 2014)*, S. aureus, Salmonella typhi*, and *Escherichia coli* (Saini et al., 2008), including community- and nosocomial-acquired, and multi-drug resistant strains of *E. coli* (ur Rahman et al., 2014; Khan et al., 2009). *S. typhi* and *E. coli* are two well-known food-borne pathogens. A recent study by Call et al. (unpublished) found a higher prevalence of oxytetracycline (OCT) resistant *E. coli* among Maasai in our study area compared to neighboring ethnic populations. The high prevalence is related to the widespread veterinary use of OCT, that OCT is usually self-administered despite high rates of illiteracy (i.e. 59% among household heads), and that Maasai regularly consume raw (i.e. unpasteurized) milk (Caudell et al., 2007; Roulette et al., 2017). It is therefore particularly intriguing to discover that one of the most salient Maasai herbal additives, *A. nilotica*, contains antimicrobial activity against drug resistant E. coli. We speculate that the use of *A. nilotica* in Maasai teas could help modulate gastrointestinal infections. Conversely, it could contribute to the prevalence of antibiotic-resistant *E. coli* in this population.

Finally, *A. anthelmintica* was frequently reported as an anti-helminthic, and extracts have demonstrated anti-helminthic activity *in vivo* against gastrointestinal nematodes in ruminants (Gradé et al., 2008; Hussain, 2008 and references therein, but see Githiori et al., 2003). *A. anthelmintica* is also the only Maasai herbal additive that Maasai report using as an anti-helminthic *and* for its psychoactive effects (moreover, it is used as a salt-substitute in porridge). This is interesting considering that many of the world's most widely used recreational drugs contain compounds with anti-helminthic effects (Hagen et al., 2013). Tobacco and cannabis, for example, appear to protect Aka foragers of the Central African Republic from intestinal helminth infections (e.g. Roulette et al., 2014, 2015). It is thus possible that use of *A. anthelmintica* in *okiti*, *motorí*, or as a salt substitute in porridge could help modulate helminthiasis in the Maasai.

This exploratory project did not examine the exact proportions of ingredients used, which is an important component to explaining alleged psychoactive and pharmacological properties. It is, however, an important first step into elucidating the cultural uniformity and variation in plants used, and how they compare across three different Maasai medicinal beverages. An important next step will be to investigate the proportion of ingredients used, and how much and how frequently a beverage is consumed in relation to different therapeutic and/or sociocultural contexts. Moreover, it is important to note that there are likely to be effects that are not associated with the pharmacology of the plant *per se*. For example, Maasai believe that medicinal soups and teas that are “red” are more effective, more palatable, and in some cases, increase blood health. Indeed, red plant pigments may contain either anthocyanin or betalain flavonoids, which promote healing and protect against destructive oxidative damage (Stintzing and Carle, 2004), inhibit ulceration and tumor growth, regulate nitric oxide production that causes autoimmune inflammation, and decrease capillary permeability, and reduce edema (Kong et al., 2003). However, the Maasai's belief also reflects findings from Western populations showing that the color of a pharmaceutical pill can influence its perceived effectiveness (e.g. Schapira et al., 1970; de Craen et al., 1996). These are what Moerman and Jonas (2002) call “meaning effects” – medicines, including their taste, aroma, color, and other attributes, possess symbolic meanings that, themselves, can influence a plant's effect on the body (Moerman, 2002), including “psychoneuroimmune benefits” that can intensity a plants palliative value (Quinlan, 2010).

4.2. Gender differences

Outside of the “core” of Maasai medical ethnobotany, Maasai food-medicines involve gender specific patterns of use and use rationales. In addition, men reported consuming the beverages, with the exception of *almajani*, in greater amounts and potentially more frequently than women. Gender differences in use are likely due to a number of factors including differences imposed by social, political, or economic norms. For example, Maasai women usually serve *almajani* to men first. Women drink whatever remains, which might not be as much as men had. Furthermore, at least one female participant said that because women are required to work at the *nkang* it limits the number of opportunities that they have to go to *orpul*, a ritual “meat feast” or “healing retreat” (Burford et al., 2001), and drink *motorí* and *okiti. Orpul* takes place in the bush lasting several days to over a month, during which men slaughter steers and consume large quantities of meat and broth inducing an intestinal purge. Maasai slaughter small-stock (sheep and goats) for quotidian household meat consumption, while they reserve cattle for *orpul* and other special occasions (Quinlan et al., 2016). *Orpul* is primarily for men, but there is, infrequently, a women's *orpul* near the *nkang* (Ibrahim, 2001). According to our unpublished data, more men than women report ever attending *orpul*, and men had been to *orpul* more recently than women. For more depth on *orpul*, including types and foods consumed, see Ibrahim (2001).

Gender differences are also due to internal motivations such as differences in nutritional and reproductive health needs. Towns and van Andel (2016), for example, found that the use of wild plants by pregnant and lactating women from Ghana and Benin is structured by the *emic* concept of strengthening—which includes both the nutritional requirements of reproduction as well as the need to sustain physical health. The authors argue that the concept of strengthening “resonates within the food-medicine continuum, bridging the local diet and herbal pharmacopoeia of women's plant use during pregnancy” (pg 377). Plants used by Maasai women play a similar important role in pregnancy and lactation. Maasai women, for example, report using a number of plants in *motorí* to increase breast milk or “flush” the reproductive system after birth. This might also account for the unexpected negative correlation between women's self-reported amount of *motorí* consumed and age—younger women are consuming more *motorí* than older women because Maasai women believe that *motorí* plays a role in regulating pregnancy and lactation.

Additional internal factors such as bitter taste and aversive learning might influence female patterns of food-medicine use. Maasai women were less likely to report using plants with strong aversive effects such as bitter taste, that induce nausea, or that are psychoactive, which supports the fetal protection explanation for female patterns of use of food-medicines. Although women use a number of plants during pregnancy to make birth less difficult many of the same herbs are associated with post-partum anemia in women and low birth weight in children (Sindiga, 1994), and *A. anthelmintica*, which men but not women use in *motorí* (men also add it to *okiti*) contains sesquiterpenes and kosotoxins (Hussain, 2008) that are extremely aversive and can cause nausea, vomiting, looseness of stool, allergic reactions, and toxicity. The main ingredient in *okiti*, the psychoactive tea that women typically do not consume, are the fruits of *A. nilotica* which contain neurotoxins that could disrupt central nervous system development. It is therefore at least possible that women's low use of *motorí* and *okiti*, relative to men, is due in part to fetal protection. Even *Z. chalybeum*, which is widely used for its pleasant organoleptic properties by men and women, contains compounds with strong antiacetylcholinesterase effects (as does *Vepris uguenensis* Engl. [Rutaceae]) (Yang et al., 2011), cytotoxic effects on human W138 fibroblast cells (Kuete, 2014), and narcotic effects and death in rabbits (Neuwinger, 1998). It is also used as an arrow poison in Tanzania and Rwanda.

4.3. Psychoactive food-medicines

Despite the vast body of anthropological and ethnobotanical research demonstrating the medicinal uses of psychoactive substances in traditional societies (e.g. Furst, 1972; Schultes and Smith, 1976; Watson et al., 1983; Wilbert, 1987; Winter, 2000; Schultes et al., 2001; Mitchell and Hudson, 2004), psychoactive beverages are an understudied component of the food-medicine continuum. One exception is a study conducted by Leonti and Casu (2014) on Soma, an Indo-Aryan intoxicating drink that, in the Vedas, was considered food of the gods and simultaneously a plant and a god itself. Leonti and Casu propose that Soma was a beverage containing a range of plants with psychoactive compounds, including protoberberines and tryptamines.

In our study, the most salient *okiti* additive was *A. nilotica*. Maasai report that its fruits are used for their psychoactive effects. It is a widely used stimulant by Maasai throughout Kenya and Tanzania (e.g. Maundu et al., 2001; Sindiga, 1994), and it contains numerous psychoactive alkaloids, including dimethyltryptamine and N-methyltryptamine, tryptamine, β-carbolines, mesculine, bufoteinine and nicotine (Auwal et al., 2014). Another salient psychoactive additive, and one reported by Merker (1910) and Baumann (1894), is *A. anthelmintica*. Merker (1910) states that it is one of the Maasai's favorite drugs, and Baumann (1894:162) reports that it "produces vomiting and is a purgative, and when consumed heavily produces berserk rage". Participants also reported using *C. quadrangularis* for its psychoactive effects. However, we were unable to identify any literature describing psychoactive compounds from *A. anthelmintica* and *C. quadrangularis*. Without additional pharmacological research it is difficult to link the purported psychoactive effects to the chemical properties of the plants. Future research should therefore quantitatively examine the three ingredients reported here, as well as ingredients reported for other Maasai groups (e.g. Sindiga, 1994), in relation to their phytochemical profile.

Many of the descriptions of the effects of *okiti* offered by our informants (e.g. increase angriness, aggressiveness, and craziness) are similar to descriptions made by Baumann (1894), Merker (1910), Fratkin (1975) and others. It also fits well with the hypothesis that *okiti* traditionally played an important role in contributing to the *moran* warriors reputation as fierce warriors (Lehmann and Mihalyi, 1982), despite the fact that *moran* no longer engage in warfare. Use of *okiti* is, however, still an important part of the healing retreat, *orpul*. Although *orpul* was originally a tradition of the *moran* warrior age-class, based on our participant observation young and old Maasai men attend. This might explain why we found no difference in the amount of time that young and old Maasai men last consumed *okiti*. In contrast, older men reported consuming more cups of *okiti* than younger men. This might indicate that medicinal uses of *okiti* as e.g. sexual stimulants, to manage sexual health, and/or to control thermoregulation, among others, are more applicable to older, rather than younger, Maasai men. It might also indicate that patterns of use are changing among Maasai youth. Finally, based on participant observation we found that male and female children (but not adolescent or adult women) sometimes also attend *orpul* (see also Ibrahim, 2001). Our informants indicate that while at *orpul* children generally do not consume *okiti*; if they do it is only in very small concentrations and/or it is diluted.

Although the primary reason for *okiti* is psychoactive, the beverage also serves other digestive and health promoting functions. Maasai add plants to *okiti* to treat body aches and pains and to aid digestion. Moreover, *okiti* is the only beverage in which Maasai mentioned adding plants to control body temperature, and the only beverage to which men add plants to manage reproductive health (excluding sexual stimulants and suppressants).

4.4. Limitations

Although we investigated gender differences for a number of variables, we did not correct for compounding error in this exploratory project. Here, we sought to detect signals for use in future investigation, whereas correcting for pair-wise error rates can result in the loss of statistical power. Our study was also not a direct investigation of plants to manage reproductive health. Further, the Maasai are a deeply gender-divided patriarchal society, which translates to an over-representation of male perspectives in published research (Kimondo et al., 2015). Information about Maasai women's health and ethno-gynecology remains important for future researchers to collect. For now, we have uncovered that Maasai women's reproductive concerns, over e.g. pregnancy and lactation, influence women's use of beverages relative to men. Finally, the authors are not fluent in Maasai language and worked with translators during this four month long study of Maasai ecology and medicinal plant use in cultural context. We present our targeted findings here. Research expanding sociolinguistically on these findings would add further to the ethnographic record.

5. Conclusions

Like Maasai of other regions, Maasai of northern Tanzania have retained a rich body of knowledge of, and continue to use, herbal additives frequently. Although organoleptic rationales were the most salient reason for adding a plant to a beverage, Maasai herbal additives might also influence health in both positive and negative ways, and these ways, in turn, vary by gender. Whereas men's rationales for using herbal additives center on therapeutic and psychoactive effects, women's rationales center on concerns over pregnancy and lactation. Some of the herbal additives might contain antimicrobial and/or anti-helminthic compounds that could help modulate infections in this population.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jep.2018.01.022.

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