Ethnoveterinary remedies used in avian complementary medicine in selected communal areas in Zimbabwe

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Abstract

Plant remedies used in avian ethno-medicine are potential candidates for the development of phytogenic feed additives. An ethno-veterinary survey was carried out in three districts in Zimbabwe in order to document plants used in poultry ethnomedicine and identify plants which have potential to be used for the development of poultry phytogenic feed additives. The survey employed questionnaire-guided oral interviews with 146 smallholder farmers. Key areas of investigation and discussion were poultry production and traditional knowledge in bird health care (ethno-treatments and poultry disease control).The survey documented a total of 36 plant species cited as being useful interventions for the treatment and management of various poultry ailments/health constraints. These medicinal plants belonged to 22 families, with the Fabaceae family the dominant family. The plant species were used to treat 11 disease/health constraint categories, with the highest number of species being used for coccidiosis. Trees (44.44%) were the main reservoir of medicinal plants followed by herbs (36.11%), shrubs (8.33%), climbers (8.33%) and flowers (2.78%).Based on the results of the survey, *Bobgunnia madagascariensis, Aloe chabaudii, Adenia gummifera., Erythrina abyssinica, Agave sisalana, Capsicum frutescens, Strychnos cocculoides, Aloe greatheadii, Tridactyle bicaudata, Senna singueana, Sarcostemma viminale., Morus alba* and *Moringa oleifera* are potential candidates for the development of phytogenic feed additives.

Keywords

Poultry, Ethnoveterinary medicine, Phytogenic feed additives, Therapeutic, Antimicrobial resistance

Abbreviations

ATCC - American Type Culture Collection

F_{ic} - informant consensus factor

IC_{50} - half maximal inhibitory concentration

MIC -minimum inhibitory concentration

PFAs - phytogenic feed additives

PRU – HGWJ Schweickerdt Herbarium, University of Pretoria

REC –Research Ethics Committee

sp. –species

Introduction

The poultry industry is the most rapidly growing agricultural subsector globally [1]. Intensive poultry production is one of the dominant sectors in the ongoing global transformation of livestock production. In sub-Saharan Africa, and indeed in most developing countries, poultry demand is high as the predominant source of protein [2]. Poultry rearing is a vital source of protein for people in rural areas in Zimbabwe, hence they are mainly kept for own consumption. However, in comparison with rural areas, poultry farming is more prevalent in urban and peri-urban areas in Zimbabwe [3]. Peri-urban poultry farmers carry out commercial poultry production at a small scale in order to supplement their income.

Commercial poultry production requires drugs to reduce mortality, thereby ensuring profitability of the sector. The drugs are used for therapy, prophylaxis, metaphylaxis and growth promotion, whereas in communal subsistence production, ethno-veterinary interventions are mainly used for therapeutic purposes. The use of antibiotic growth promoters in poultry production has substantial benefits which include prevention of subclinical disease, reduction of human pathogens, improved animal welfare, improved production efficiency and lowering of prices for the consumer [4]. Commercial production uses conventional drugs which are standardized, whilst most communal farmers in Zimbabwe use unstandardised traditional plant remedies and other ethno-veterinary practices to treat poultry diseases [5-7]. Some small scale commercial producers also incorporate ethnoveterinary remedies in the management of poultry diseases [3].

Antibiotic growth promoters are employed for disease preventative purposes and to improve growth rate and feed conversion rates in poultry production. However, although they are useful in preventing subclinical infections and promoting growth as in-feed antibiotics, they are also responsible in part for the worldwide scourge of antimicrobial resistance. The European Union and South Korea have banned the use of antibiotic feed additives in response to the threat posed by antimicrobial resistance [8, 9]. Although the banning of antibiotic feed additives is a noble initiative, the adverse effects on poultry production performance due to

disease outbreaks and economic inefficiency are inevitable. Antibiotic feed additives have important prophylactic activity and their removal has been reported to be detrimental to animal health, including causing increased prevalence of weight loss, diarrhoea and mortality due to infections in broilers [10].

The ban on antibiotic growth promoters may actually exacerbate the problem of antimicrobial resistance as therapeutic use of antibiotics increased after the ban on in-feed antibiotics. Though the overall use of antimicrobials has declined in some European countries, several studies have reported increased therapeutic usage of drugs following the withdrawal of antibiotic growth promoters [11-13]. The effect of banning antibiotic growth promoters has stimulated research on alternatives to antibiotic feed additives. Plant products known as phytogenic feed additives (PFAs) have emerged as feasible alternatives to antibiotic feed additives, hence the surge in interest in the use of plants and their extracts for growth promotion in poultry production.

In Africa communal farmers use traditional plant remedies to treat poultry diseases because they cannot afford conventional drugs. These farmers do not use plant remedies for growth promotion. The plant species used by the communal farmers are ideal candidates for research into the development of phytogenic feed additives since they potentially have therapeutic value. Research and reviews that have been published to date have highlighted that suitable phytogenic feed additives should have the following attributes: 1) therapeutic value (e.g. anticoccidial, antibacterial, immunostimulatory, antifungal, anti-inflammatory and antiulcer), 2) be rich in compounds that have beneficial effects on palatability and intestinal function, 3) be effective in promoting animal growth [14-16]. Plants used for the unorthodox treatment of poultry diseases have some of these attributes. Therefore, there is a need to identify and document other plants used in complementary medicine for the treatment of poultry so that some of these plants can be investigated and used in the development of feed additives. This is particularly so in the case of growth promoters, given the restrictions that have been placed on the use of conventional drugs for growth promotion. Documentation of the plant species will also ensure that vital knowledge about these plant remedies is not lost since it is mainly the older generation who are able to identify the plants and know how to prepare and administer the phytomedicines.

Numerous ethno-veterinary surveys have been carried out in Africa on plants that are used for the treatment of animals but only a few of these studies have focused on phytomedicines used for traditional treatment of poultry. In Zimbabwe a study on the use of application of ethno-remedies in dealing with livestock diseases and other health constraints was carried out in Nhema in the Midlands province [17]. This study identified plants used in livestock ethno-medicine in general but did not stratify the medicinal plants according to the animal species. Ethno-surveys focusing solely on plants used in the treatment of poultry ailments have also been carried out in Zimbabwe [6, 7]. These surveys were limited to people from a particular tribe. Traditional knowledge systems depend on tribe and culture.

The current survey included participants from communities from three of the ten provinces in Zimbabwe. The incorporation of participants from different provinces was done in order to increase the diversity of people providing information on the plant remedies. The surveys were conducted to document plants used in non-conventional medicine for the management of poultry diseases. The second objective was to identify plants that have the potential to be used as phytogenic feed additives given the massive global interest in these products. The study also sought to compare the plant species used by the three different communities in the alternative treatment of poultry diseases.

Results

There were more male informants (74%) than female informants (26%) in the study. Of the respondents, 89% were above 40 years of age with 41.8% belonging to the 41-60 age category whilst 47.9% were above 60 years of age (**Table 1**). A paltry 10.3% of the respondents were aged from 20 to 40. Over 80% of the respondents were Christians whilst the rest of the respondents said they practised the African traditional religion. More than half of the participants (51.4%) had attained Ordinary General Certificate Level secondary education whilst less than eight per cent (6.8%) had not received any formal education. A meagre 3.4% had undergone tertiary education.

Table 1 Demographic data of the informants

Category		Frequency	%
Gender	Males	108	74
	Females	38	26
Religion	Christianity	121	82.9
	Traditional African	25	17.1
Education	Primary Level	54	37
	O level	75	51.4
	A level	2	1.4
	Tertiary	5	3.4
	No formal education	10	6.8
Residence	Chipinge	49	33.6
	Murehwa	51	34.9
	Bindura	46	31.5
Age	20-40	15	10.3
	40-60	61	41.8
	>60	70	47.9

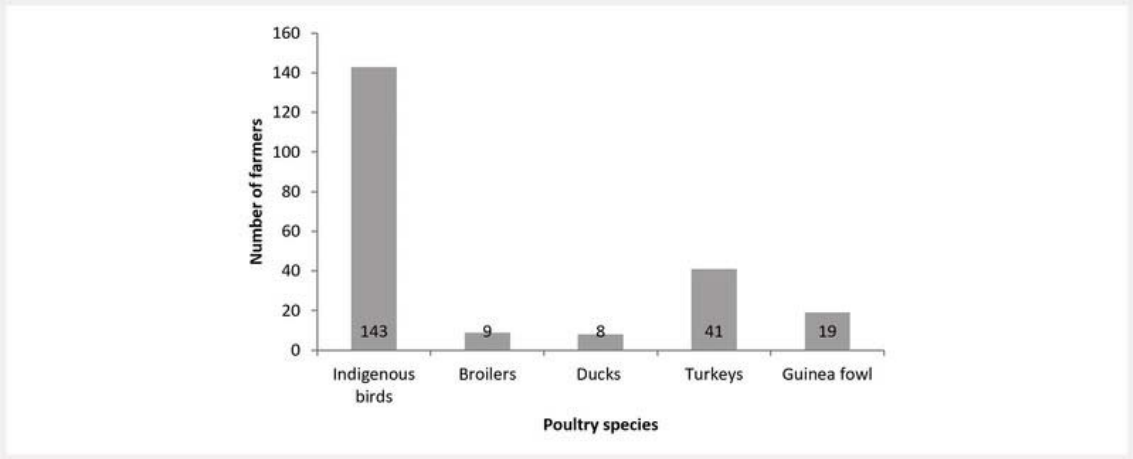

Figure 1. Poultry species data of the informants

Approximately 98% of the informants kept indigenous village chickens (**Figure 1**). The second most commonly kept avian species were turkeys with 28% of the farmers rearing them. The least cited poultry species were ducks which were reared by 5.6% of the respondents. A few farmers (6.2%) also kept broilers. Most of the farmers were small scale poultry producers with 25% having 1-10 birds and 52% owning 11-50 birds whilst a mere 4.11% of the respondents had more than 100 birds (**Table 2**). A substantial number (70.55%) of the farmers kept their

birds as free ranging backyard birds whilst few farmers (2.74%) kept them in an enclosure (**Table 3**). Twenty-six per cent of the farmers kept some of the birds as free rangers whilst keeping some in an enclosure.

Table 2 Poultry populations across study sites

Number of birds	Chipinge (N=49)	Bindura (N=44)	Murehwa (N=53)	Total
1-10	1 (2.04%)	15 (34.09%)	21 (39.62%)	37 (25.34%)
11 – 50	34 (69.39%)	22 (50%)	20 (37.74%)	76 (52.05%)
51 – 100	14 (28.57%)	4 (9.09%)	9 (16.98%)	27 (18.49%)
>100	0 (0%)	3 (6.82%)	3 (5.66%)	6 (4.11%)

Table 3 Poultry rearing systems

Way of rearing birds	Chipinge (N=49)	Bindura (N=44)	Murehwa (N=53)	Total
Free ranging backyard birds	30 (61.22%)	35 (75.55%)	38 (71.72%)	103 (70.55%)
Kept in an enclosure	1 (2.04%)	2 (4.55%)	1 (1.89%)	4 (2.74%)
Some free ranging and some kept in an enclosure	18 (36.73%)	7 (15.91%)	14 (26.42%)	39 (26.71%)

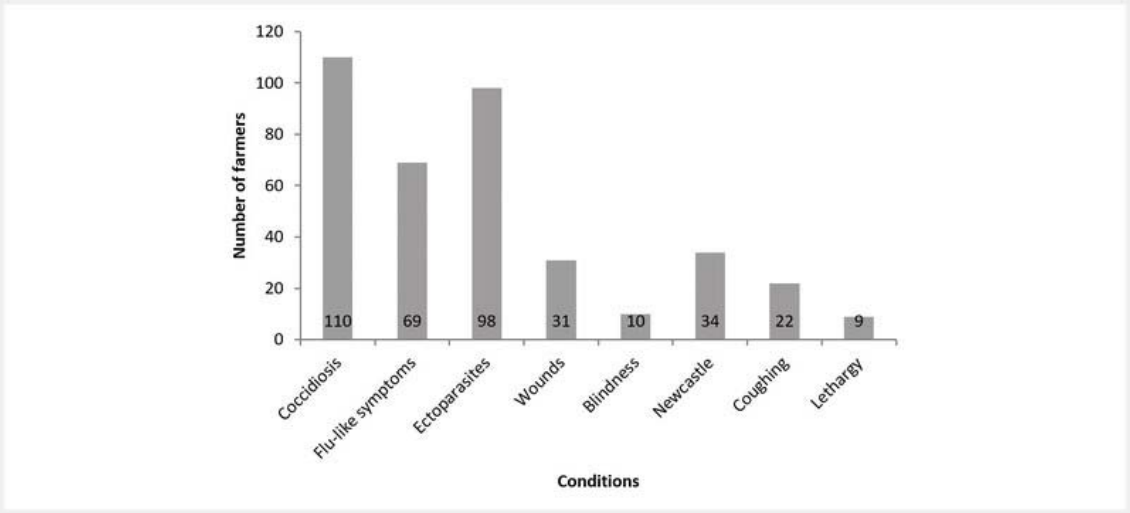

Figure 2. Common avian health constraints in Bindura, Chipinge and Murehwa districts

Coccidiosis was the most cited health constraint by the farmers (**Figure 2**). Most of the respondents were able to describe its symptoms and it is known as “chitosi” in the vernacular Shona language. Ectoparasites and flu-like symptoms were also frequently cited health challenges by the informants. Blindness and lethargy were the least cited health problems.

A total of 36 plant species were cited as being useful in the management and treatment of various poultry ailments and health problems. These medicinal plants belonged to 22 different families with the Fabaceae family being the predominant family with 7 plant species. It was followed by the Asteraceae and Solanaceae families which had 4 plant species each.

The highest number of plant species was used in the treatment of coccidiosis in affected birds. This disease condition had an informant consensus factor of 0.94 (**Table 4**) which is close to 1. A similar situation was found for wounds, coughing, Newcastle disease, flu-like symptoms, lethargy and ectoparasites, which had informant consensus factors of 0.8 and above. The species *Bobgunnia madagascariensis, Aloe chabaudii, Adenia gummifera, Erythina abyssinica* and *Agave sisalana* were the most frequently used plants in poultry complementary medicine by the informants (**Table 5**). These plant species were used to treat a broad spectrum of avian ailments including coccidiosis, Newcastle disease, flu-like symptoms and coughing. *Lippia javanica* was the most frequently used plant species for the control of ectoparasites. Blindness, fowl pox and helminthiasis had informant consensus factors of ≤ 0.5 and very few plant species were used for managing these afflictions. In addition, these conditions had a low number of citations.

Table 4 Informant consensus factor of the health constraints computed using the total number of citations of all the plant species used for the specific health constraint

Health problem/ Symptom/Disease Category	**Plant species**	**Citations**	**F_{ic}**
Coccidiosis	18	290	0.94
Wounds	13	77	0.84
Coughing	12	73	0.85
Newcastle disease	9	87	0.91
Flu-like symptoms	10	149	0.94
Lethargy	13	32	0.61
Fowl pox	6	6	0
Weight loss	2	8	0.85
Blindness	2	3	0.5
Ectoparasites	2	32	0.96
Helminthiasis	1	1	0

Table 5 Plant remedies used in avian ethno-medicine

Family	Family Botanical name Voucher number	Vernacular and English names	Frequency	Parts used and Traditional method of preparation	Ethno-medicinal use: Poultry diseases/ Symptoms
Agavaceae	*Agave sisalana* Perrine (PRU 0125424)	Mukonje/ Chikwengu (Shona) Sisal (English)	59	**Leaves:** Pound the plant and dissolve in drinking water	Coccidiosis, Coughing, Flu-like symptoms, Newcastle disease
Amaranthaceae	*Chenopodium ambrosioides* L. (PRU 0125442)	Munhuwenhuwe (Shona) Wormseed (English)	4	**Whole plant**: Crush the plant material and place in fowl runs	Ectoparasite control
Amaryllidaceae	*Crinum macowanii* Baker (PRU 0125446)	Dururu (Shona) Common vlei-lily (English)	1	**Tuber**: Fresh tuber dissolved in drinking water	Helminthiasis
Apocynaceae	*Catharanthus roseus* (L.) G. Don (PRU0125449)	Tsuramatongo (Shona) Madagascar periwinkle/ Rose periwinkle (English)	1	**Roots:** Pound the roots and mix with drinking water	Coccidiosis
	Sarcostemma viminale (L.) R.Br. (PRU 0125439)	Rusungwe/ Runyakadombo (Shona) Imvubu/Ingotsha (Ndebele) Caustic vine (English)	4	**Whole plant**: Crush the fresh plant and mix paste with poultry feed	Coccidiosis
Asphodelaceae	*Aloe chabaudii* Schönland (PRU 0125445)	Gavakava (Shona) Dwala aloe (English)	124	**Leaves:** Crush the fresh plant material and prepare infusion with water	Coccidiosis, Flu-like symptoms, Weight loss, Coughing, Lethargic birds, Newcastle disease, Fowl pox
	Aloe greatheadii Schönland (PRU 0125443)	Gavakava (Shona) Greathead's spotted leaf aloe (English)	16	**Leaves:** Crush the fresh plant material and prepare infusion with water	Coccicidiosis, Flu-like symptoms, Weight loss, Coughing Lethargic birds, Newcastle disease
Asteraceae	*Aspilia pluriseta* Schweinf. ex Schweinf. (PRU 0125448)	Mukushamvura/ Mumharadzi/ Ruhwati (Shona) Dwarf aspilia (English)	2	**Whole plant:** Char the plant and apply the ashes on wounds	Wounds

				or Dissolve the charred material in water and apply on wounds	
	Bidens pilosa L. (PRU 0125438)	Guku/Tsine (Shona) Black-jack (English)	7	**Leaves:** Crush the leaves and apply extracts on wounds	Wounds
	Vernonia adoensis var. *kotschyana* (Sch. ex Walp.) G.V. Pope (PRU 0125426)	Musikavakadzi (Shona) Tree vernonia (English)	2	**Leaves**: Crush the leaves and apply extracts on wounds	Wounds
Capparaceae	*Ximenia caffra* Sond. (PRU 0125453)	Munhengeni/ Mutsvanzva/ Mutunguru (Shona)	4	**Leaves:** Pound fresh leaves and extract sap	Wounds
Euphorbiaceae	*Euphorbia tirucalli* L. (PRU 125871)	Rusungwe/ Hejiyemukaka (Shona) Ingotsha(Ndebele) Rubber euphorbia/ Rubber hedge plant (English)	1	**Whole plant:** Crush and dissolve in drinking water	Lethargic birds
Fabaceae	*Bobgunnia madagascariensis* (Desv.) J.H.Kirkbr. & Wiersema (PRU0125425)	Mucherekese (Shona) Snake bean (English)	172	**Pods**: Grind the dried pods into a powder and dissolve in drinking water	Coccidiosis, Flu-like symptoms, Weight loss, Coughing, Newcastle disease
	Cassia abbreviata Oliv. (PRU 0125430)	Murembererembe/ Muvheneka (Shona) Isihaqa (Ndebele) Long-tail cassia (English)	1	**Bark**: Grind the dried bark and dissolve in drinking water	Lethargic birds
	Dalbergia nitidula Baker (PRU 0125427)	Mudima/Murima (Shona) Glossy flat-bean/ Purple-wood Dalbergia (English)	4	**Bark**: Dry the bark and grind into a powder and apply on wounds	Wounds
	Erythrina abyssinica DC. (PRU 0125441)	Mutiti/Munhimbiti/ Mutete/Mutsiti/ (Shona) Umgqogqogqo (Ndebele)	97	**Bark:** Grind the bark into a powder and dissolve in drinking water	Coccidiosis, Wounds, Coughing, Flu-like symptoms, Newcastle disease, Blindness

		Lucky-bean tree/Red hot poker tree (English)			
	Pterocarpus angolensis DC. (PRU 0125444)	Mubvamaropa/ Mubvamakovo/ Mubvinziropa (Shona) Umvagazi (Ndebele) Bloodwood (English)	1	**Bark:** Pound the bark and apply extract on wounds	Wounds
	Senna singueana (Delile) Lock (PRU 0125450)	Munzungunzungu Mudyanungu/ Mukundanyoka/ (Shona) Scrambled egg/Sticky pod/Winter cassia/Winter-flowering senna (English)	11	**Leaves:** Pound fresh leaves and dissolve in water	Coccidiosis, New castle disease, Coughing, Flu-like symptoms
	Xeroderris stuhlmanni (Taub.) Mendonca & Sousa (PRU0125440)	Muchemavanhu/ Mumwambizi/ Murumanyama Wing pod (English)	2	**Bark**: Crush fresh bark and dissolve in drinking water	Coccidiosis, Lethargic birds
Loganiaceae	*Strychnos cocculoides* Baker (PRU 0125437)	Mutamba/Muzhumwi (Shona) Corky monkey orange (English)	23	**Fruit:** Crush the unripe fruit and mix the contents with water and give the birds to drink	Coccidiosis, Coughing, Newcastle, Fowl pox
Meliaceae	*Khaya anthotheca* (Welw.) C.DC. (PRU 0125429)	Muvava (Shona) Red Mahogany (English)	2	**Bark:** Pound the bark and mix with drinking water	Lethargic birds, Fowl pox
Moraceae	*Morus alba* L. (PRU 0125423)	Muabhurosi/Muhingi (Shona) White mulberry (English)	5	**Leaves:** Crush the leaves and dissolve in drinking water	Coccidiosis, Coughing, Flu-like symptoms
Moringaceae	*Moringa oleifera* Lam. (PRU 0125430)	Muringa (Shona) Horseradish tree (English)	3	**Leaves**: Crush the leaves and dissolve in drinking water	Coccidiosis, Coughing,
Musaceae	*Musa x sapientum* L. (PRU 125872)	Mubhanana (Shona)	2	**Roots:** Crush the roots and mix with saline	Coccidiosis
Olacaceae	*Ximenia americana* L. (PRU 0125436)	Munhengeni/ Mutsvanzva/ Mutunguru (Shona)	5	**Leaves:** Pound fresh leaves and extract sap	Wounds, Fowl pox

		Umswanja (Ndebele) Blue sourplum (English)			
Orchidaceae	*Tridactyle bicaudata* (Lindl.) Schltr. (PRU 0125422)	Paka (Shona)	12	**Leaves:** Pound the plant and dissolve material in drinking water	Coccidiosis, Lethargy, Flu-like symptoms, Newcastle disease
Passifloraceae	*Adenia gummifera* (Harv.) Harms (PRU 0125433)	Muhore (Shona) Snake climber (English)	108	**Whole plant:** Pound the plant and dissolve in drinking water	Lethargic birds, Coccidiosis, Coughing, Flu-like symptoms, Newcastle disease, Blindness
	Passiflora edulis Sims (PRU 0125451)	Mugrandera (Shona) Granadilla/ Passion fruit (English)	3	**Leaves:** Poundfresh leaves and dissolve in water. Crush fresh leaves and extract sap for wounds	Coccidiosis, Coughing, Head wounds
Rubiaceae	*Vangueria infausta* Burch. (PRU 0125435)	Munzviru (Shona) Umviyo (Ndebele) Velvet wild medlar (English)	1	**Leaves:** Pound fresh leaves and prepare an infusion in water	Coccidiosis
Rutaceae	*Citrus limon* (L.) Osbeck (PRU 0125447)	Muremani/Mundimu (Shona) Lemon (English)	1	**Fruit**	Fowl pox
Solanaceae	*Capsicum frutescens* L. (PRU 125874)	Mumhiripiri/Toronga (Shona) Chilli pepper (English)	27	**Seeds**: Crush the seeds and mix with sugar solution for the birds to drink	Coccidiosis, Coughing, Flu-like symptoms, Newcastle disease
	Datura stramonium L. (PRU 1258710)	Zavazava (Shona) Jimson weed/Thorn apple (English)	10	**Leaves:** Crush the leaves and apply extracts on wounds	Head wounds
	Solanum incanum L. (PRU 0125431)	Nhundurwa (Shona) Intume/Umudulukwa (Ndebele) Sodom pple (English)	2	**Roots:** Grind dried roots and dissolve in drinking water	Wounds

	Solanum lycopersicum L. (PRU 0125452)	Mudomasi (Shona) Tomato (English)	12	**Leaves:** Pound fresh leaves and extract sap	Wounds, Fowl pox
Verbenaceae	*Lippia javanica* (Burm.f.) Spreng. (PRU 0125432)	Zumbani/Mumara/ Mushanimukuru (Shona) Umsuzwane (Ndebele) Fever tea/ Lemon bush (English)	28	**Leaves**: Collect fresh leaves and place in the fowl run	Ectoparasite control

Leaves were the most frequently used plant part with 47.22 per cent of the preparations being made from leaves followed by bark (16.67%), whole plant (13.89%), roots (8.33%) and fruit (5.56%). Pods, seeds and tubers were the least used plant parts with 2.78% of ethno-interventions being made from each of one them. Trees and herbs were the predominant growth forms of the plant species used in poultry complementary medicine in the three districts. These were followed by climbers and shrubs which had an equal percentage contribution whilst flowers contributed the least percentage (**Figure 3**).

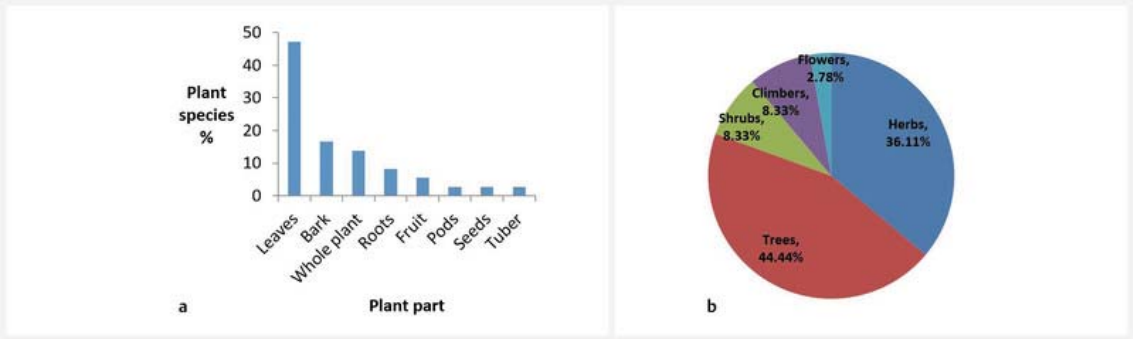

Figure 3. Characteristics of plants used in avian complementary medicine in Bindura, Murehwa and Chipinge districts A –plant part used and B – growth habit

Discussion

The low number of participants between the age of 20 and 40 may be attributed to the fact that most people in this category migrate to towns and cities in search of employment opportunities. Other ethno-surveys carried out in Zimbabwe have also reported similar age distributions with most of the respondents being over 40 [17, 18]. The high number of male participants compared to female has also been reported in previous surveys in Zimbabwe [6,

17, 19, 20]. This can be attributed to the fact that most families in Zimbabwe are male-headed families.

The findings on the types of poultry species reared by the respondents were similar to a previous survey which was done in Gutu district. Villagers in Gutu also kept chickens, turkeys, guinea fowls and ducks with chickens being the main avian species reared and also turkeys being the second most popular [6].The current study recorded that most of the farmers are small scale farmers with the highest percentage of farmers having 11-50 birds. Previous studies have also shown that most villagers are small scale producers of poultry with a mean number of chickens of approximately 22.7 and 21.8 [6, 7]. The free-range production system has also been reported to be the predominant production system [21]. Masimba et al. [6] also reported coccidiosis as the most frequently cited health constraint by communal farmers in Gutu district with all the respondents indicating that it was a problematic disease. In the current study 75% of the informants mentioned coccidiosis as a constraint. However, another survey which included different types of livestock reported fleas as the major health problem in chicken production in the Nhema communal area [17].

The fact that there was no significant difference between the number of plant species cited by the different age groups and between males and females shows that information on avian ethno-medicine is being passed from one generation to another and amongst different sexes (**Table 1S,** Supporting information). Respondents from Chipinge cited significantly more plants than villagers from the other districts (**Table 1S**). This is not surprising as people from this area have long been regarded as being rich in ethno-medicinal knowledge. *B. madagascariensis, A. chabaudii, A. gummifera* and *E. abyssinica* all had a high frequency of citation. This indicates that these species are very important in the management of poultry diseases in the communities under study. Of these four plant species, only *A. chabaudii* was used in all three communities. *A. gummifera* was used by the villagers in Manicaland only whilst *B. madagascariensis* and *E. abyssinica* were used by farmers in the two Mashonaland districts.

The high informant consensus factors of above 0.8 for coccidiosis, wounds, coughing, Newcastle disease, flu, lethargy and ectoparasites show that most of the respondents agreed on medicinal plants used in the management of these conditions. These findings showed that

farmers shared ethno-veterinary knowledge when treating these conditions. Previous surveys carried out in Zimbabwe have also reported the use of *A. chabaudii*, *A greatheadii* and *E. abyssinica* in poultry ethno-medicine [6, 17]. Maroyi [17] reported that farmers in the Midlands Province in Zimbabwe use *A. chabaudii and Aloe greatheadii* to manage a number of poultry health problems such as diarrhoea, general weakness, respiratory symptoms and septic wounds. The use reports were similar to findings of the present study (**Table 5**). The use of Aloe species to combat Newcastle, diarrhoea and other poultry ailments has also been documented in neighbouring countries such as South Africa and Botswana and other African countries including Kenya, Tanzania and Gambia [22-24]. The reported use of *E. abysinicca* in the treatment of coccidiosis is consistent with findings by Masimba et al. [6]. *E. abyssinica* is also used for the treatment of animal bloody diarrhoea in Uganda[25].

The use of *B. madagascariensis*, *A. gummifera*, *A. sisalana, S. singeana and T. bicaudata* in avian ethnomedicine has never been reported in Zimbabwe to the best of our knowledge. This shows the importance of documenting plants used in ethno-medicine by all tribes. The use of *A. sisalana* to control internal parasites in chickens has however been reported in South Africa[26]. It is also used in combination with *Microglossa pyriflora* and *Aloe* sp. leaves to treat fowl pox in Kenya [27]. The application of *B. madascariensis* for the treatment of diarrhoea in cattle and humans has been reported in Ivory Coast and the use of *A. gummifera* to treat a number of diseases in both human and veterinary ethnomedicine has also been well documented [28, 29]. *L. javanica* was the most notable plant species used for controlling ectoparasites. Similar observations on the use of *Lippia javanica* in controlling ectoparasites have been made both locally and in the region [18, 26].

The application of *S. viminale*, *X. stuhlmannii*, *S. lycopersicum* and *P. angolensis* to alleviate similar or close related animal health problems to those that were cited in this study have been reported in Masvingo and Midlands provinces in Zimbabwe [6, 7, 17, 19]. The respondents also cited the use of *C. frutescens* for the management of a wide spectrum of poultry ailments including Newcastle disease. This plant species has also been used in combination with *Lagenaria breviflora* to treat Newcastle disease in chickens in Nigeria [27]. *C. abbreviata*, *M. sapientum*, *M. oleifera* and *Solanum incanum* have also been documented as useful plant remedies in poultry ethnoveterinary medicine in other African countries

although they were not frequently cited in the present study [23, 27, 30]. The low informant consensus factors for blindness, fowl pox and helminthiasis showed that farmers had limited ethnoveterinary knowledge on remedies for the management of these conditions and plants were chosen at random when managing them.

The communal farmers also use non-herbal interventions to deal with poultry health challenges (**Table 2S**– Supporting information). Brown sugar solution was cited as an intervention for several ailments. An ethno-botanical study in India also reported the use of sugar to improve the medical properties of certain remedies [31]. The efficacy of the sugar solution might be linked to provision of energy for the birds when fighting infection. Soot was also reported to be useful in treating flu-like symptoms, coccidiosis and in stimulating appetite of birds. Previous surveys carried out in Zimbabwe have also cited the use of soot for the treatment of coccidiosis, respiratory problems and diarrhoea [6, 7]. Interestingly some of the farmers cited the use of donkey dung to treat coccidiosis.

The most frequently cited plant species in the three districts have reported pharmacological activities. The fact that these medicinal plants have proven pharmacological activity supports therapeutic claims made on the plant species. Root ethanol extracts of *B. madagascariensis* exhibited significant antibacterial activity against ATCC and methicillin resistant *S. aureus* strains with a minimum inhibitory concentration of 0.094 mg/ml for the ATCC strain and for the methicillin resistant strains MIC values ranging from 0.023 – 0.047 mg/ml were reported [32]. However, farmers in the Mashonaland districts use pods of *B. madagascariensis* instead of roots. A study carried out in Zimbabwe also showed that *A. chabaudii* had antibacterial activities against poultry bacterial pathogens [33]. The study revealed that methanol and aqueous extracts of *A. chabaudii* had antibacterial efficacy against poultry pathogens (*Salmonella gallinarum*, *Escherichia coli* and *Staphylococcus aureus*). The zones of inhibition of the extracts were comparable with those of conventional antibiotics. *S. gallinarum* is an etiological agent of Fowl Typhoid whilst Avian Pathogenic *Escherichia coli* (APEC) causes avian colibacillosis. The bioactivity of aloe extracts against these two Gram-negative bacterial species which cause several poultry ailments explains the widespread and successful use of aloe species in avian ethno-medicine by farmers in the three districts.

E. abyssinica also showed good antimicrobial properties [34]. Aqueous and ethanol leaf extracts of *E. abyssinica* both had significant antibacterial activity with an MIC of 0.098 mg/ml against *E. coli* whilst the dichloromethane leaf extract also had good antibacterial activity against *S. aureus* with an MIC of 0.098 mg/ml being reported [34]. The study by Marume et al. [34] also showed that *E. abyssinica* has anti-inflammatory activity. Extracts of the plant inhibited the enzyme phospholipase A2 in vitro. The plant exhibited anti-phospholipase activity with the bark extract of *E. abyssinica* having an IC_{50} of 0.059 mg/ml. The antibacterial and anti-inflammatory activities of *E. abyssinica* support the use of this plant in the traditional treatment of poultry. The other frequently used medicinal plants, *A. gummifera* and *A. sisalana,* have proven antioxidant and antimicrobial activity respectively [35, 36].

The proposed modes of action of antibiotic growth promoters include inhibition of pathogens that cause sub-clinical infections, reduction of microbial metabolites which might have growth-depressing effects, reduction in nutrient use by intestinal microbes and enhanced nutrient absorption and utilisation as a result of a thinner intestinal wall associated with animals on feeds containing antibiotic growth promoters [37]. Therefore, effective phytogenic supplements which can be useful as alternatives to antibiotic growth promoters should have antimicrobial and anticoccidial activities. All the plant species that were cited by the farmers as being useful for the treatment of coccidiosis have potential to be used for the development of PFAs. These include *B. madagascariensis*, *A. chabaudii, A. gummifera, E. abyssinica, A. sisalana, C. frutescens, S. cocculoides, A. greatheadii, T. bicaudata, S. singueana, S. viminale, M. alba* and *M. oleifera* as they have perceived anti-coccidial properties.

Communal farmers in Murehwa, Bindura and Chipinge districts in Zimbabwe rely on non-conventional practices to treat and manage poultry diseases and health constraints. The farmers also share ethno-veterinary knowledge when dealing with prevalent diseases such as coccidiosis. The plants identified as potential candidates for the development of phytobiotics for poultry feed should be evaluated to ascertain whether they have desirable properties to be used as alternatives to antibiotic feed additives. According to previous reviews on phytogenic feed additives, in vitro studies should evaluate whether the identified plants have therapeutic value. Future research should investigate the anticoccidial, antibacterial, immuno-stimulatory, antifungal, anti-inflammatory, antiulcer activities and toxicity of plants

cited in this survey as being useful for the treatment of enteric conditions. Although some studies have already reported the antimicrobial properties of some of these plants, it is pertinent that they be tested against *Clostridium perfringens, S. aureus, E. coli, Salmonella* spp.*, Streptococcus* spp. and *Aspergillus fumigatus* since they are the major poultry pathogens causing a plethora of diseases in poultry. Herbal and botanical growth promoters work by inhibiting the growth of these pathogenic species and also through modifying intestinal microflora thereby helping to improve bird's health status and performance [38]. After extensive in vitro investigation of the plant species, in vivo studies should be carried out to evaluate whether the plant extracts improve bird weight and the feed conversion ratio using chicken models when added to feed. In vivo studies have already been carried out on *Aloe vera* and *M. oleifera* and several other plants which were not documented in this survey with promising results [39-42].

The development of PFAs is gaining momentum as the world continues its fight against antimicrobial resistance. Phytogenic feed additives are also considered to be safer compared to synthetic antibiotic growth promoters since they are natural products and typically residue free although this does need to be verified in each case [38]. There is therefore a need to harness plants used in avian ethno-medicine so that they can be used in intensive poultry production to enable farmers to meet the demand for poultry products, given the restrictions on the use of antibiotic growth promoters. Additionally, low-cost plant-based remedies for the treatment of backyard chickens in rural areas may be developed and recommended for use to enhance food security for local people.

Materials and Methods

Study area

The study was conducted in Zimbabwe in Murehwa, a district in the Mashonaland East province, 75 km northeast from the capital of Harare (17.7456˚ S, 31. 7195˚ E); Chipinge,a district in the Manicaland province, 450 km southeast from the capital of Harare (20.1938˚ S, 32.6206˚E) and Bindura in Mashonaland Central province(17.1379˚S,31.3542˚ E) (**Figure 4**).The study sites belonged to the following agroecological regions: region 1 (Chipinge), characterised by low temperatures, high attitude, steep slopes and receiving average annual rainfall of greater than 1000 mm and deemed to be suitable for specialised diversified

farming, and region 2 (Murehwa and Bindura), characterised as suitable for intensive farming and receiving on average 750-1000 mm of annual rainfall per annum.

Figure 4. Map of Zimbabwe showing the study sites. Blue represents Bindura district, Green depicts Murehwa district whilst Red represents Chipinge district.

Data collection

A total of 146 communal farmers (49 from Chipinge district, 44 from Bindura district and 53 from Murehwa district) were orally interviewed using a semi-structured questionnaire. One district was randomly selected in the three provinces and three villages were conveniently selected in each district. Farmers were purposively chosen depending on whether they reared poultry. The interviews were conducted using the local vernacular language. Meetings were conducted with the traditional leaders and government veterinary officers of the respective areas to explain the purposes of the research prior to the interviews. Detailed information on plants used were recorded including local name, plant part used, type of plant, time of plant collection, method of preparation, poultry disease/condition treated by the plant and mode of administration. The data captured also included demographic information of the

participant, poultry species reared, poultry populations, prevalent poultry diseases and poultry keeping (whether the birds were kept in an enclosure or were free ranging). Ethical approval to conduct the study was obtained from the Faculty of Health Sciences, University of Pretoria (approval number 334/2018) and the Research Ethics Committee of the Faculty of Veterinary Sciences, University of Pretoria (approval number REC 122-19).

Plant collection and identification

Plants used for the non-conventional treatment of poultry were pointed out by the respondents and the plant specimens were collected and processed. The plant species were identified by botanists Mr. Chapano and Mr.Mapaura from the National Herbarium and Botanical Gardens of Zimbabwe. They were authenticated by a botanist, Ms MagdaNel, at the Department of Plant and Soil Sciences at the University of Pretoria. Voucher specimens were deposited in the H.G.W.J. Schweickerdt Herbarium (PRU), University of Pretoria.

Data Analysis

Descriptive and inferential statistics were generated using BM SPSS Statistics 21 and Epi Info. The number of citations (frequency) of each plant species was obtained and the Chi-square test was used to compare the number of plant species cited by the demographic group.

Informant consensus factor (F_{ic})

The informant consensus factor was calculated in order to ascertain whether farmers shared information on which plants to use to treat specific ailments. The information consensus factor (F_{ic}) was calculated using the following formula:

$$F_{ic} = \frac{n_{ur} - n_t}{n_{ur} - 1}$$

Where n_{ur} is the number of use reports in each category and n_t is the number of taxa.The informant consensus factor ranges between 0 and 1. A high value (close to 1) shows that afew plant species are used by a high proportion of people whilst a low value shows that participants do not agree on the plant species used to treat a particular disease[43].

Supporting information

Details of the mean number of plant species cited by the demographic groups together with results of the Chi-square test (**Table 1S**), and details of the non-herbal/botanical remedies used for the traditional treatment of poultry in the three districts (**Table 2S**) are provided.

Author contributions

PJ conducted the survey under the supervision and co-supervision of LJM and GM.
SK carried out statistical analysis.

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Conflict of interest

The authors declare that there are no conflicts of interest.

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