(NSAZ-2022)

Science and Engineering Research Board (SERB) Sponsored
National Symposium
On
Applied Zoology, Profitable Animal Production, and Health: Current Status and Future Progress (NSAZ-2022) 23rd & 24th September- 2022

Recent Trends in Applied Zoology

Dr.D.S.Rathod
Editor

Associate Editors
Dr. K.S.Raut
Mr.Datta Nalle

National Edited Book

PRABHAKAR PUBLICATION

(ISBN: 978-93-92464-55-3)

Recent Trends in Applied Zoology

Edited by: Dr.D.S.Rathod

ISBN: 978-93-92464-55-3 (First printing edition, May, 2023)

Published by: **Prabhakar publication:**

Address: 304 Siddhivinayak apartments, sutmill road, Latur - 413512

Phone: +91 8600881127, +91 8149153018

Website: www.prabhakarpublication.com

Science and Engineering Research Board (SERB) Sponsored
National Symposium
On

Applied Zoology, Profitable Animal Production, and Health: Current Status and Future Progress (NSAZ-2022) 23rd & 24th September- 2022

Recent Trends in Applied Zoology

Editor
Dr.D.S.Rathod
Head
Department of Zoology and Fishery Science,
Rajarshi Shahu Mahavidyalaya (Autonomous),

Latur- 413531, Maharashtra

Associate Editors
Dr. K.S.Raut
Mr.Datta Nalle
Department of Zoology and Fishery Science, Rajarshi Shahu Mahavidyalaya (Autonomous),
Latur- 413531, Maharashtra

Index

Chapter -11

A review of the Nutritional advantages of feeding farm animals *Cichorium intybus* as a supplement

Datta A.Nalle, Abhaysinh R. Deshmukh

Department of Zoology and Fishery Science, Rajarshi Shahu Mahavidyalaya,
(Autonomous) Latur-413512 (MS)
E-mail: iprometheous007@gmail.com

Abstract:

The inclusion of various grains in animal diets is too expensive, and it competes with human nourishment. It is now important to introduce substitute feeds that could address the issues with production costs in the livestock business while also having a good influence on animal health, production output, and product quality. Chicory pieces, for example, have been successfully added to small ruminant diets as supplements without impairing animal performance. For centuries, people all throughout the world have utilised the perennial herbaceous plant Cichorium intybus, which belongs to the family Asteraceae, as feed for animals. Chicory's popularity is rapidly rising as a result of its many health, culinary, and nutritional benefits. Chicory plant components that are useful. a seeds, b a blossom, c a root, d a roasted root, and e a field of chicory

1. Initialization

The roots are used as a substitute for coffee, animal feed, and pet food, while the leaves and blossoms are typically consumed as vegetables in salads [1]. To enhance flavour, chicory extracts are occasionally added to alcoholic and nonalcoholic beverages [2], whereas alcohol can be produced from the inulin-rich tuberous roots [3]. Ailments and illnesses of the body are treated with components of the chicory plant in several nations, as well as for preventative purposes in both people and livestock [4, 5]. Due to the somewhat bitter flavour of fresh chicory roots, they are typically debittered by boiling, drying, baking or roasting, soaking in water or citric acid solution, and then being diced or milled before being utilised as a functional food ingredient, feed, or in coffee blends [1, 6–8].

Among the many phytochemicals included in chicory root are inulin, a polysaccharide that mimics starch, coumarins, flavonoids, sesquiterpene lactones (lactucin and lactucopicrin), tannins, alkaloids, vitamins, minerals, and volatile oils [9]. Chicory's secondary metabolites, including flavonoids, tannins, and coumarins, have been shown to possess biological properties like antioxidant, anticancer, anti-inflammatory, antiparasitic, and antihepatotoxic effects that are beneficial to both human and animal health [10, 11]. Inulin, a fructose polymer with -(2-1)-glycosidic linkage, makes up up to 68% of the total compounds present in fresh chicory roots [12]. As a prebiotic with low calories and dietary fibre, inulin serves as a great sugar alternative and is a healthy option for diabetics [15, 16].

Additionally, the performance of animals fed fodder chicory is superior to pastures made of grass and comparable to that of legumes [11]. Chicory is said to boost milk production when added to pasture, according to [17]. According to several reports [18–21], grazing chicory has the potential to lower the need for anthelmintics because it is known to inhibit some internal parasites in animals. Chicory is a great complementary and/or alternative animal feed

supplement because of its chemical composition and related nutritional qualities, which are reviewed and summarized in this study.

Photochemistry of *Cichorium intybus*

A recent decrease in the prevalence of chronic diseases is closely associated with high dietary consumption of a variety of fruits and vegetables [22]. These plant parts' phytochemicals, or health-promoting elements, have a variety of biological effects, such as antioxidant, anticancer, anti-inflammatory, and glucosidase inhibition. The most common phytochemicals are phenolic acids, which include chlorogenic acids, and flavonoids (anthocyanins, flavonols, flavanone, and flavan-3-ols). Plant polyphenols are frequently found as glycosides, which are less reactive and easier to store in the cell vacuole [23].

Hexose, glucose or galactose, deoxyhexose, rhamnose, pentose, xylose or arabinose, and glucuronic acid are among the sugar residues that are liberated through glycosidic-linkage cleavage and related rearrangement events [23].Condensed tannins, one of the phytocompounds that supports animal health, have been shown in numerous studies to be present in chicory. On the other hand, high dietary tannin concentrations can harm animal productivity [27]. Carazzone et al. (2013) [23] using high-performance liquid chromatography-electrospray ionization/mass spectrometry.

Process for extracting flavonoids and phenolic acids from several strains of Cichorium intybus var. silvestre. Among the 64 compounds discovered were several hydroxycinnamic acid derivatives made of eight mono- and dicaffeoylquinic acids, three tartaric acid derivatives, 31 flavonols, and 2 flavones.concentrated on the ethnomedicinal, botanical, and phytopharmacological features of Cichorium intybus and the identification of a few phytoconstituents of chicory, including eight anthocyanins, six caffeic acid derivative isomers, and glycosides. the results of a recent review [11]

Massoud et al. (2009) [1] investigated the chemical composition of the leaves and roots of *Cichorium Intybu*s and the representative phytoconstituents presented as macronutrients, micronutrients (essential minerals), and phenolic compounds in Tables Tables1,1, ,2,2, and and3,3, respectively.

Numerous studies have shown that fresh chicory roots contain 68% inulin, which is a polysaccharide related to starch, 14% sucrose, 5% cellulose, 6% protein, 4% ash, and 3% other substances by dry weight [13, 30-32]. These researchers also noted that, by weight, dry chicory root extract has 98% inulin and 2% other components. According to a Soobo study from 2005 [33], oligofructose and inulin-type fructan are both abundant in chicory root. Chemically speaking, inulin is a polydisperse-(2,1)-fructan that can be hydrolyzed to produce fructose and glucose. Fructose, a long-chain carbohydrate made up of 22–60 fructose molecules with a terminal glucose molecule, is abundantly present in chicory (up to 94%) [34].

Their bitterness is largely caused by the presence of large amounts of sesquiterpene lactones, such as lactucin, 8-deoxylactucin, lactucopicrin, and 11ß-dihydro-derivatives [35]. Researchers [36] who discovered sesquiterpene lactones, a (+)-germacrene, from chicory roots corroborated this. Roasted chicory roots contain a variety of chemicals, including 2-acetylpyrrole, furfural, phenyl acetaldehyde, phenyl acetic acid, vanillin, pyrazines, benzothiazoles, aldehydes, aromatic hydrocarbons, furans, phenols, organic acids, and trace amounts of the insole alkaloids (ß-carbolines), harmane, and norharmane. Chicory root extract is made by filtering and centrifuging the water-soluble portion of the milled dry root to remove the volatile oils, fatty acids, alkaloids, triterpenes, flavonoids, latex, tannins, and saponins [37].

Table 1: composition of chicory plant* [1].

composition%	Root	leaf
Moisture content	75.63 ± 0.39	83.06 ± 1.55
Crude protein	4.65 ± 0.25	14.70 ± 1.03
Crude ether extract	1.69 ± 0.71	3.68 ± 0.19
Ash	4.25 ± 0.11	10.91 ± 1.86
Total carbohydrates	89.41 ± 1.07	70.71 ± 3.08
Total sugars (soluble)	11.06 ± 1.00	7.80 ± 1.45
Inulin	44.69 ± 0.88	10.95 ± 2.56
Crude fiber	5.12 ± 1.55	16.78 ± 2.20
Dietary fiber (DF)		
Insoluble DF	30.73 ± 0.33	ND**
Soluble DF	0.42 ± 0.07	ND**
Total DF	31.15	ND**

*On dry weight basis; mean ± 5.0 (each value represents the average of three determinations ± standard deviation); **ND: not determined

Table 2 Mineral content (mg/100 g) of chicory plant (leaves and roots) in comparison with RDA* [1].

Chicory plant	Macroelements					Microelements			
	Ca	K	Mg	Na	Fe	Cu	Mn	Zn	Pb
Roots	181.26 ± 4.40	103.7 ± 4.62	20.14 ± 1.69	67.42 ± 2.45	1.77 ± 0.21	0.36 ± 0.02	0.31 ± 0.10	0.39 ± 0.03	0.04 ± 0.003
Leaves	292.61 ± 13.35	166.57 ± 3.43	6.944 ± 5.86	88.84 ± 2.58	9.178 ± 0.85	0.60 ± 0.06	0.90 ± 0.01	0.91 ± 0.03	0.03 ± 0.01
RDA mg/100 g	1000–1300	-	240–420	1600	8–11	0.8–1.2	1.6–2.3	12–15	-

*RDA recommended daily requirement for men and women.

Table 3: Chicory extracts (%) as identified by HPLC [1].

Chicory	Methanolic extracts (%)	Total phenolic content*	Phenolic compound (%)	
Leaves	23.16	26.4 ± 1.05	Gallic acid	1.96
Roots	10.75	20.0 ± 0.9	Protocatechuic acid	2.50
			Chlorogenic acid	17.84
			p-Hydroxybenzoic acid	11.04
			Caffeic acid	35.22
			Isovanillic acid	1.97
			p-Coumaric acid	9.65
			Unknown compound	19.46

Three brand-new benzo-isochromenes called chicorins A, B, and C were identified from chicory roots [38, 39]. According to these specialists, the roots also include fatty acids (mostly palmitic and linoleic), pectin, -lactucerol (taraxasterol), cichoriin (esculetin-7-glucoside), fixed oils, choline, and other compounds.Cichorium intybus seeds are excellent for both ruminant and monogastric diets because they contain a wide range of nutrients. The majority of chicory seed variations, according to Ying and Gui (2012) [40], have high quantities of crude protein, which makes up more than 19% of the dry weight and is 1.6–2.4 times higher than the value in the majority of conventional grains including wheat, rice, corn and barley.

These authors also mentioned that chicory seeds are a good source of the majority of important amino acids, including methionine, lysine, leucine, isoleucine, phenylalanine, and others that are suggested for a perfect dietary protein. More than 76% of the total fatty acids profile, which also includes monounsaturated oleic acid (18:1n-9), stearic acid (18:0), and palmitic acid (16:0), are made up of the essential linoleic acid (18:2n-6) found in the seeds, which are also rich in demulcent oils, a good source of both saturated and unsaturated fatty acids [41]. When compared to lucerne seeds, chicory seeds have relatively higher concentrations of vital minerals like potassium (K), calcium (Ca), magnesium (Mg), selenium (S), and zinc (Zn) [42]. Additionally, [40] Cichorium intybus seeds were used to make cichotyboside, a sesquiterpene glycoside that was shown to have considerable hepatoprotective effect in rats against carbon tetrachloride-induced liver injury. Therefore, chicory seed can be considered a nutritious alternative and/or supplement in the diets of both humans and animals.

The blue tint of the chicory flower's perianth was first attributed to anthocyanins in 2002 by Nrbaek and colleagues [44]. Subsequent studies [45, 46] revealed that chicory flowers also contain saccharides, flavonoids, cichorine, methoxycoumarin, and essential oils. These researchers [2] had previously determined that the flowers, leaves, and shoots of chicory contain inulin, fructose, choline, resin, chicoric acid (dicaffeoyl tartaric acid), esculetin, esculin (esculetin-6-glucoside), cichoriin, umbelliferone, scopoletin, 6,7-dihydrocoumarin, and sesquiterpene lactones and their glycosides. Additionally, several researchers [47, 48] extracted vitamins A, B6, and K from red chicory, which also includes certain minerals and carotenoids. Chicoric acid was shown to be the main chemical produced from the methanolic extracts of chicory in a food chemistry study by [23, 49]. Similar to this, earlier studies [45] reported that octane, [50].

Cichorium intybus's Medical Benefits for Livestock Production

The soluble dietary fibre inulin found in chicory is a prototypical prebiotic that is particularly helpful in monogastric feeding and is also employed as a functional food ingredient [14, 51, 52]. Prebiotics are believed to promote the growth of host-friendly gut bacteria including lactobacilli and bifidobacteria for general beneficial health, according to a number of studies [53, 54]. In addition, a prebiotic may boost the immune system, lower pathogenic bacterial levels in the intestine [55], relieve constipation, lower the risk of osteoporosis by increasing the absorption of crucial minerals, particularly calcium [56], and lower the risk of atherosclerosis by reducing the liver's ability to synthesise triglycerides and fatty acids as well as their serum levels [54].

Some of the plant secondary metabolites (PSM) of the chicory plant have been reported to possess some ethnomedicinal properties. These PSM serve as herbal remedies for ailments and body conditioning in both humans and animals. Saeed et al. (2017) [59] summarized previous opinions on the health benefits of chicory herb, emphasizing its role as a hepatoprotective agent. The nutritional benefits of *Cichorium intybus* in livestock mitigating peroxidation of lipids in serum and organs, as well as improving growth efficiency,

reproduction, and health, were explained. Other bioactive properties such as antioxidant, anti-inflammatory, anticancer, antiprotozoal, antidiabetic, antimicrobial, immunological, cardiovascular, hypolipidemic, gastroprotective, analgesic, anthelmintic, productive and reproductive enhancer, and wound healing properties were also described [59]. Volatile oils are found in all parts of the plant but are more concentrated in the roots which have been found to be effective at eliminating intestinal worms [20, 21, 32].

The research conducted by Hassan et al. (2014) [60] on the effects of wormwood (Artemisia absinthium) and chicory (Cichorium intybus) extracts at various doses against ovine gastrointestinal nematodes revealed high efficacy. All the worms died after 4 hours when chicory extract (50 mg/ml) and wormwood extract (25 mg/ml) were administered in vitro against adult Haemonchus contortus [60]. Another investigation into the anthelmintic properties of forage chicory against gastrointestinal nematode parasites found that feeding pasture to experimentally infected calves (70% of chicory dry matter) dramatically lowers worm burdens and faecal egg counts of Ostertagia ostertagi. The anthelmintic effects of dietary chicory have been discovered [61]. Sesquiterpene lactones have been found in both fresh and silage chicory feed.

The polyphenolic acid of chicory roots is thought to have a variety of health-promoting properties, including anticarcinogenic, anti-inflammatory, antiviral, antibacterial, antimutagenic, antifungal, anthelmintic, immune-stimulating, and antihepatotoxic activity, as well as antioxidant properties, according to research by Milala et al. (2009) [62] and other researchers. Also, according to many researchers [63, 67–69], chicory PSM can protect the digestive system, lower blood cholesterol, and act to combat the Human Immunodeficiency Virus (HIV). As a result, the addition of preparations high in prebiotic saccharides and polyphenols derived from chicory can be used to support a diet's healthful qualities while also serving as both food and a herbal remedy. Research [70], The toxicity of chicory root to internal parasites is widely established. Inulin is said to reduce parasites like Ascaris [71] and Trichuris [72] in pigs, according to later reports.

It has been proposed that one potential mechanism is the decrease of intestinal pH, which is unfavourable for the growth of the parasite embryo. It was demonstrated in two distinct studies [18, 21] that chicory consumption by farm animals decreased worm burdens, which led to its widespread usage as a feed additive with a low fibre content. In the study carried out by Marley and associates, (2003) [73], it was observed that there were significantly less helminths overall in the abomasum of lambs that grazed on chicory.

A small amount of sesquiterpene lactones [77] and condensed tannins [32, 74–76] are also present in chicory, which may impair ruminants' ability to use protein effectively as well as their intestinal parasite populations. Sesquiterpene lactones in chicory extract were also found to prevent the hatching of sheep's Haemonchus contortus eggs [78]. An earlier study [79] found that utilising a larval migration and inhibition assay, extracts rich in condensed tannins and sesquiterpenes from C. intybus were shown to suppress the larval motility of lungworm and gastrointestinal nematodes. Chicory is affordable and effective against parasites and the Lawsonia bacteria, according to a research on pigs in Denmark [80], but when taken excessively, it can have unpleasant side effects.

Livestock: *Cichorium intybus*

According to a study [81], the nutritional value of a chicory crop varies depending on the stage of growth, crop health, and environmental factors. Chicory has been shown in the literature to be an effective fodder for lamb finishing. The herb offers amazing properties including growing well at low soil pH levels and minimum annual rainfall of 600 mm. The forage has a notable

high nutritional value, with a CP of 14–24%, a leaf digestibility of 70–80%, and a ME of 13.7 MJ/kg DM [82]. Condensed tannins and other secondary metabolites found in chicory have a beneficial effect on internal parasites in lambs, reduce methane generation, and boost sheep reproduction rates. [83]. Hopkins et al. (1995) [84] also recorded that lambs that grazed chicory on their finishing phase showed no change in meat quality and were not fatter than the lambs fed lucerne forage.

In 2004, Brown and Moot's study [85] found that lucerne forage provided 30% more yearly crude protein (CP) and ME intake for sward than chicory or red clover due to its combination herbage quality and higher herbage consumptions. This suggests that lucerne has a better potential to increase the production of animals. The study also showed that red clover, lucerne, and chicory all had high ME concentrations (10.9–11.3 MJ/kg DM). Red clover and lucerne both produced high concentrations of CP (0.25 to 0.29 g/g DM), while chicory had a lower concentration (0.18 g/g DM).

In New Zealand, chicory remains leafy throughout the first summer but turns to seed during the second summer, lowering the quality of the feed [29]. Chicory herbage quality with 0–20% stem has a lower DM content than ryegrass pasture, according to a study comparing the two (Table 4). Additionally, compared to ryegrass pasture, chicory's chemical composition has less fibre, more protein, more soluble carbohydrates, and more minerals (P, K, S, Ca, Mg, Na, Zn, Cu, and B). Chicory's high digestibility and low fibre content prevent it from being a viable sole diet for cows, but because it can be eliminated from the cow more quickly than perennial ryegrass, this can enhance voluntary feed intake [29].

Table 4 Herbage value of chicory and fodder [29].

	DM (%)	Protein (% DM)	Soluble sugars + starch (% DM)	Fibre (% DM)	Digestibility (% DM)	ME (MJ/kg DM)
Chicory	7–15	16–27	10–22	20–30	72–83	11.5–13.0
Ryegrass*	10–30	12–28	8–21	40–55	65–85	9.5–12.5

Cichorium intybus's antinutritional characteristics

Once they have exceeded an appropriate intake level, some PSM may have harmful or toxic effects on the growth and performance of livestock, according to some researches [88]. Classes of active PSM include alkaloids, terpenes, saponins, lactones, glycosides, and phenolic compounds, whose excessive ingestion can have a negative impact on ruminant and non-ruminant health and, in some cases, even endanger their survival [21]. For instance, when added to the diets of ruminants at a rate more than 4-5% of dry matter, tannins and other PSM have been linked to lower feed intake, impaired dry matter digestibility, and impaired rumen metabolism [89]. Additionally described side effects include animal weight loss, toxicity, and death [90,]

Conclusion

Cichorium intybus is grown and employed for a variety of applications throughout the world. It is frequently used as a therapeutic and preventative measure or to preserve overall health. It

is a very adaptable plant that provides advantages to both animals and people because of the significant amounts of proteins, carbohydrates, minerals, and phytobioactive components it contains. Some of the phytoconstituents used in livestock production have been found to have benefits for animals, whether they are parasitized or not. As a result, chicory provides an excellent, affordable, sustainable, and natural livestock supplement or substitute feed ingredient. To avoid toxicity at high PSM concentrations, caution should be used when chicory is added to diets or let to graze by ruminants. It is highly advised to conduct more study on the multifunctional capabilities of the phytobioactive components found in chicory, their antinutritional effects, the ideal amount to include in animal diets, the underlying mechanism of action, and the biochemical makeup of the active PSM.

References

1. Massoud M. I., Amin W. A., Elgindy A. A. Chemical and technological studies on Chicory (*Cichorium Intybus L*) and its applications in some functional food. *Journal of Advanced Agricultural Research*. 2009;14(3):735–756.
2. Bais H. P., Ravishankar G. A. *Cichorium intybus* L.—cultivation, processing, utility, value addition and biotechnology, with an emphasis on current status and future prospects. *Journal of the Science of Food and Agriculture*. 2001;81(5):467–484.
3. Chandra S., Kumar M., Dwivedi P., Arti K. Studies on industrial importance and medicinal value of chicory plant (*Cichorium intybus* L.) *International Journal of Advance Research*. 2016;4(1):1060–1071.
4. Schillhorn van Veen T. W. *Ethnoveterinary Research and Development*. London, UK: Intermediate Technology Publications; 1996. Sense or nonsense? Traditional methods of animal disease prevention and control in the African savannah; pp. 25–36.
5. Van der Merwe D., Swan G. E., Botha C. J. Use of ethnoveterinary medicinal plants in cattle by Setswana-speaking people in the Madikwe area of the North West Province of South Africa. *Journal of the South African Veterinary Association*. 2001;72(4):189–196
6. Baek H. H., Cadwallader K. R. Roasted chicory aroma evaluation by gas chromatography/mass spectrometry/olfactometry. *Journal of Food Science*. 1998;63(2):234–237.
7. Desprez B. F., Delesalle L., Dhellemmes C., Desprez M. F., Rambaud C., Vasseur J. Genetics and breeding of industrial chicory, a historical review. Proceedings of the Eighth Seminar on Inulin; 1999; Lille, France.
8. Leite Toneli J. T. C., Mürr F. E. X., Martinelli P., Dal Fabbro I. M., Park K. J. Optimization of a physical concentration process for inulin. *Journal of Food Engineering*. 2007;80(3):832–838. doi: 10.1016/j.jfoodeng.2006.07.012.
9. Varotto S., Lucchin M., Parrini P. Immature embryos culture in Italian red chicory (*Cichorium intybus* C) *Plant Cell, Tissue and Organ Culture*. 2000;62(1):75–77. doi: 10.1023/A:1006468229414.
10. Hoste H., Jackson F., Athanasiadou S., Thamsborg S. M., Hoskin S. O. The effects of tannin-rich plants on parasitic nematodes in ruminants. *Trends in Parasitology*.
11. Das S., Vasudeva N., Sharma S. *Cichorium intybus*: a concise report on its ethnomedicinal, botanical, and phytopharmacological aspects. *Drug Development and Therapeutics*. 2016;7(1):1–12.

12. Hui Ru Y., Shaoh H., Yingli Y. The extraction and purification of inulin. *Natural Product Research and Development*. 2002;14:p. 65.
13. Kim M., Shin H. K. The water-soluble extract of chicory reduces glucose uptake from the perfused jejunum in rats. *Journal of Nutrition*. 1996;126:2236–2242.
14. Madrigal L., Sangronis E. Inulin and derivates as key ingredients in functional foods: a review. *Archivos Latinoamericanos de Nutrición*. 2007;57:387–396.
15. Park K. J., de Oliveira R. A., Brod F. P. R. Drying operational parameters influence on chicory roots drying and inulin extraction. *Food and Bioproducts Processing*. 2007;85(3 C):184–192. doi: 10.1205/fbp07016.
16. Li D., Kim J. M., Jin Z., Zhou J. Prebiotic effectiveness of inulin extracted from edible burdock. *Anaerobe*. 2008;14(1):29–34.
17. Waugh C. D., Clark D., Harris S. L., Thom E. R., Copemanand. P. J. A., Napper A. R. Chicory for milk production. *Proceedings of the New Zealand Grassland Association*. 1998;60:33–37.
18. Tzamaloukas O., Athanasiadou S., Kyriazakis I., Huntley J. F., Jackson F. The effect of chicory *(Cichorium intybus)* and sulla *(Hedysarum coronarium)* on larval development and mucosal cell responses of growing lambs challenged with *Teladorsagia circumcincta*. *Parasitology*. 2006;132(3):419–426.
19. Heckendorn F., Häring D. A., Maurer V., Zinsstag J., Langhans W., Hertzberg H. Effect of sainfoin *(Onobrychis viciifolia)* silage and hay on established populations of *Haemonchus contortus* and *Cooperia curticei* in lambs. *Veterinary Parasitology*. 2006;142(3-4):293–300.
20. Van Loo J. How chicory fructans contribute to zootechnical performance and well-being in livestock and companion animals. *Journal of Nutrition*. 2007;137(11):2594S–2597S.
21. Athanasiadou S., Githiori J., Kyriazakis I. Medicinal plants for helminth parasite control: Facts and fiction. *Animal*. 2007;1(9):1392–1400.
22. Margett B., Buttriss J. *Plants: Diet and health*. Oxford, UK: Blackwell Publishing; 2003. Epidemiology linking consumption of plant foods and their constituents with health; pp. 49–60.
23. Carazzone C., Mascherpa D., Gazzani G., Papetti A. Identification of phenolic constituents in red chicory salads (*Cichorium intybus*) by high-performance liquid chromatography with diode array detection and electrospray ionisation tandem mass spectrometry. *Food Chemistry*. 2013;138(2-3):1062–107
24. Tsuda T., Horio F., Uchida K., Aoki H., Osawa T. Dietary cyanidin 3-O-*β*-D-glucoside-rich purple corn color prevents obesity and ameliorates hyperglycemia in mice. *Journal of Nutrition*. 2003;133(7):2125–2130.
25. Wang J., Mazza G. Effects of anthocyanins and other phenolic compounds on the production of tumor necrosis factor α in LPS/IFN-γ-activated RAW 264.7 macrophages. *Journal of Agricultural and Food Chemistry*. 2002;50(15):4183–4189.
26. Youdim K. A., McDonald J., Kalt W., Joseph J. A. Potential role of dietary flavonoids in reducing microvascular endothelium vulnerability to oxidative and inflammatory insults. *The Journal of Nutritional Biochemistry*. 2002;13(5):282–288. doi: 10.1016/S0955-2863(01)00221-2.

27. Makkar H. P. S. Effects and fate of tannins in ruminant animals, adaptation to tannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. *Small Ruminant Research*. 2003;49(3):241–256
28. *Farmfacts, DairyNZ*. 2013. Chicory management.
29. Nadkarni A. K. *Indian Materia*. Bombay, India: Medica; 1976.
30. Varier P. S. *Indian Medicinal Plants a Compendium of 500 Species*. Chennai, India: Orient Longman; 1994. *Cichorium intybus Linn*; p. p. 74.
31. Wilson R. G., Smith J. A., Yonts C. D. Chicory root yield and carbohydrate composition is influenced by cultivar selection, planting, and harvest date. *Crop Science*. 2004;44(3):748–752. doi: 10.2135/cropsci2004.0748.
32. Soobo S. *Effects of prebiotics, probiotics andsynbiotics in the diet of young pigs [Ph.D. thesis]* Wageningen, Netherlands: Wageningen University; 2005.
33. Phelps C. F. The physical properties of inulin solutions. *Biochemical Journal*. 1965;95:41–47.
34. Peters A. M., Van Amerongen A. Relationship between levels of sesquiterpene lactones in chicory and sensory evaluation. *Journal of the American Society for Horticultural Science*. 1998;123(2):326–329.
35. De Kraker J.-W., Franssen M. C. R., De Groot A., König W. A., Bouwmeester H. J. (+)-Germacrene A biosynthesis - The committed step in the biosynthesis of bitter sesquiterpene lactones in chicory. *Plant Physiology*. 1998;117(4):1381–1392.
36. Nandagopal S., Kumari B. D. Phytochemical and antibacterial studies of chicory (CichoriumintybusL.) A multipurpose medicinal plant. *Advances in Biological Research*. 2007;1(1-2):17–21.
37. Hussain H., Hussain J., Saleem M., et al. Cichorin A: A new benzo-isochromene from Cichorium intybus. *Journal of Asian Natural Products Research*. 2011;13(6):566–569.
38. Hussain H., Hussain J., Ali S., et al. Cichorins B and C: Two new benzo-isochromenes from Cichorium intybus. *Journal of Asian Natural Products Research*. 2012;14(4):297–300.
39. Ying G. W., Gui L. J. Chicory seeds: a potential source of nutrition for food and feed. *Journal of Animal and Feed Sciences*. 2012;13(2):1736–1746.
40. Marcone M. F., Jahaniaval F., Aliee H., Kakuda Y. Chemical characterization of Achyranthes bidentata seed. *Food Chemistry*. 2003;81(1):7–12.
41. Plaza L., De Ancos B., Cano M. P. Nutritional and health-related compounds in sprouts and seeds of soybean (Glycine max), wheat (Triticum aestivum.L) and alfalfa (Medicago sativa) treated by a new drying method. *European Food Research and Technology*. 2003;216(2):138–144.
42. Ahmed B., Khan S., Masood M. H., Siddique A. H. Anti-hepatotoxic activity of cichotyboside, a sesquiterpene glycoside from the seeds of Cichorium intybus. *Journal of Asian Natural Products Research*. 2008;10(3-4):223–231.
43. Nørbæk R., Nielsen K., Kondo T. Anthocyanins from flowers of *Cichorium intybus*. *Phytochemistry*. 2002;60(4):357–359.
44. Judžentiene A., Budiene J. Volatile constituents from aerial parts and roots of Cichorium intybus L. (chicory) grown in Lithuania. *Chemija*. 2008;19(2):25–28. [Google Scholar]
45. Abbas Z. K., Saggu S., Sakeran M. I., Zidan N., Rehman H., Ansari A. A. Phytochemical, antioxidant and mineral composition of hydroalcoholic extract of

chicory (Cichorium intybus L.) leaves. *Saudi Journal of Biological Sciences*. 2014;22(3):322–326.
46. Ćustić M., Poljak M., Toth N. Effects of nitrogen nutrition upon the quality and yield of head chicory (Cichorium intybus L. var.foliosum) *Acta Horticulturae*. 2000;533:401–410.
47. Mulabagal V., Wang H., Ngouajio M., Nair M. G. Characterization and quantification of health beneficial anthocyanins in leaf chicory (Cichorium intybus) varieties. *European Food Research and Technology*. 2009;230(1):47–53.
48. Drazen J. M. Inappropriate advertising of dietary supplements. *The New England Journal of Medicine*. 2003;348(9):777–778.
49. Street R. A., Sidana J., Prinsloo G. Cichorium intybus: Traditional uses, phytochemistry, pharmacology, and toxicology. *Evidence-Based Complementary and Alternative Medicine*. 2013;2013
50. Mejer H. *Transmission, infection dynamics and alternative control of helminths in organic swine [Ph.D. thesis]* Danish Centre for Experimental Parasitology, Royal Veterinary and Agricultural University; 2006.
51. Roberfroid M. B. Inulin-type fractans: functional food ingredients. *The Journal of Nutrition*. 2007;137:2493S–2502S.
52. Roberfroid M. B. Prebiotics: preferential substrates for specific germs? *American Journal of Clinical Nutrition*. 2001;73(2):406S–409S.
53. Kaur N., Gupta A. K. Applications of inulin and oligofructose in health and nutrition. *Journal of Biosciences*. 2002;27(7):703–714.
54. Liu H., Ivarsson E., Dicksved J., Lundh T., Lindberg J. E. Inclusion of Chicory (Cichorium intybus L.) in pigs' diets affects the intestinal microenvironment and the gut microbiota. *Applied and Environmental Microbiology*. 2012;78(12):4102–4109. Roberfroid M. B., Cumps J., Devogelaer J. P. Dietary chicory inulin increases whole-body bone mineral density in growing male rats. *Journal of Nutrition*. 2002;132(12):3599–3602.
55. Jensen M. T., Hansen L. L. Feeding with chicory roots reduces the amount of odorous compounds in colon and rectal contents of pigs. *Journal of Animal Science*. 2006;82(3):369–376.
56. Rasmussen M. *Regulation of porcine hepatic cytochrome P450 by chicory root implication for boar taint [Ph.D. thesis]* Aarhus, Denmark: Department of Food Science, Faculty of Science and Technology, Aarhus University; 2012.
57. Saeed M., Abd El-Hac M. E., Alagawany M., et al. Chicory (Cichorium intybus) Herb: chemical composition, pharmacology, nutritional and healthical applications. *International Journal of Pharmacology*. 2017;13(4):351–360.
58. Hassan A. I., Osman S. A., Al-Gaabary M. H., Abo El-Soud K. M. Effects of chicory (*Cichoriumintybus*) and *Artemisiaabsenthium* extracts against ovine gastrointestinal nematodes. *International Journal of Food, Agriculture and Veterinary Sciences*. 2014;4(2):43–53
59. Peña-Espinoza M., Thamsborg S. M., Desrues O., Hansen T. V. A., Enemark H. L. Anthelmintic effects of forage chicory (Cichorium intybus) against gastrointestinal nematode parasites in experimentally infected cattle. *Parasitology*. 2016;143(10):1279–1293.

60. Milala J., Grzelak K., Król B., Juśkiewicz J., Zduńczyk Z. Composition and properties of chicory extracts rich in fructans and polyphenols. *Polish Journal of Food and Nutrition Sciences*. 2009;59(1):35–43.
61. Kim M. The water-soluble extract of chicory reduces cholesterol uptake in gut-perfused rats. *Nutrition Research*. 2000;20(7):1017–1026.
62. Ahmed B., Al-Howiriny T. A., Siddiqui A. B. Antihepatotoxic activity of seeds of Cichorium intybus. *Journal of Ethnopharmacology*. 2003;87(2-3):237–240.
63. Papetti A., Daglia M., Grisoli P., Dacarro C., Gregotti C., Gazzani G. Anti- and pro-oxidant activity of Cichorium genus vegetables and effect of thermal treatment in biological systems. *Food Chemistry*. 2006;97(1):157–165.
64. Peschel W., Sánchez-Rabaneda F., Diekmann W., et al. An industrial approach in the search of natural antioxidants from vegetable and fruit wastes. *Food Chemistry*. 2006;97(1):137–150.
65. Wang M., Simon J. E., Aviles I. F., He K., Zheng Q.-Y., Tadmor Y. Analysis of antioxidative phenolic compounds in artichoke (Cynara scolymus L.) *Journal of Agricultural and Food Chemistry*. 2003;51(3):601–608.
66. Innocenti M., Gallori S., Giaccherini C., Ieri F., Vincieri F. F., Mulinacci N. Evaluation of the phenolic content in the aerial parts of different varieties of *Cichorium intybus* L. *Journal of Agricultural and Food Chemistry*. 2005;53(16):6497–6502.
67. Mares D., Romagnoli C., Tosi B., Andreotti E., Chillemi G., Poli F. Chicory extracts from Cichorium intybus L. as potential antifungals. *Mycopathologia*. 2005;160(1):85–92.
68. Ivarsson E., Frankow-Lindberg B. E., Andersson H. K., Lindberg J. E. Growth performance, digestibility and faecal coliform bacteria in weaned piglets fed a cereal-based diet including either chicory (Cichorium intybus L) or ribwort (Plantago lanceolata L) forage. *Animal*. 2011;5(4):558–564.
69. Petkevicius S., Knudsen K., Nansen P., Roepstorff A., Skjoth F., Jensen K. The impact of diets varying in carbohydrates resistant to endogenous enzymes and lignin on populations of Ascarissuum and Oesophagostomumdentatum in pigs. *Parasitology*. 1997;114(6):555–568.
70. Thomsen L. E., Petkevičius S., Bach Knudsen K. E., Roepstorff A. The influence of dietary carbohydrates on experimental infection with Trichuris suis in pigs. *Parasitology*. 2005;131(6):857–865.
71. Marley C. L., Cook R., Keatinge R., Barrett J., Lampkin N. H. The effect of birdsfoot trefoil (Lotus corniculatus) and chicory (Cichorium intybus) on parasite intensities and performance of lambs naturally infected with helminth parasites. *Veterinary Parasitology*. 2003;112(1-2):147–155.
72. Li G., Kemp P. D. Forage Chicory (Cichorium intybus L.): a review of its agronomy and animal production. *Advances in Agronomy*. 2005;88:187–222.
73. Kidane A., Houdijk J. G. M., Athanasiadou S., Tolkamp B. J., Kyriazakis I. Effects of maternal protein nutrition and subsequent grazing on chicory (Cichorium intybus) on parasitism and performance of lambs. *Journal of Animal Science*. 2010;88(4):1513–1521.
74. Lombardi D., Vasseur E., Berthiaume R., DeVries T. J., Bergeron R. Feeding preferences and voluntary feed intake of dairy cows: effect of conservation and harvest

time of birdsfoot trefoil and chicory. *Journal of Dairy Science*. 2015;98(10):7238–7247.
75. Miller M. C., Duckett S. K., Andrae J. G. The effect of forage species on performance and gastrointestinal nematode infection in lambs. *Small Ruminant Research*. 2011;95(2-3):188–192.
76. Foster J. G., Cassida K. A., Turner K. E. In vitro analysis of the anthelmintic activity of forage chicory (Cichorium intybus L.) sesquiterpene lactones against a predominantly Haemonchus contortus egg population. *Veterinary Parasitology*. 2011;180(3-4):298–306.
77. Molan A. L., Duncan A. J., Barry T. N., McNabb W. C. Effects of condensed tannins and crude sesquiterpene lactones extracted from chicory on the motility of larvae of deer lungworm and gastrointestinal nematodes. *Parasitology International*. 2003;52(3):209–218.
78. Roepstorff A., Mejer H., Thomson L. E., Thamsborg S. M., Byrene S. M. Chicory root improves the taste and odour of organic pork. *Newsletter from Danish Research Centre for Organic Farming*. 2005;1(3):1–4.
79. Laws D., Genever L. *Using Chicory and Plantain in Beef and Sheep Systems*. Kenilworth, UK: AHDB Beef & Lamb Stoneleigh Park; 2016.
80. Burnett V., Ponnampalam E. *Specialist Forages Lamb Finishing Guidelines*. Victoria, UK: The Future Farming Systems Research; 1996.
81. Holst P. J., Kemp M., Hall D. G. Summer lamb production from puna chicory (*Cichoriumintybus*) and lucerne (*Medicago sativa*). Proceedings of the Australian Society of Animal Production; 1998; pp. 145–148.
82. Hopkins D. L., Holst P. J., Hall D. G., Atkinson W. R. Carcass and meat quality of second-cross cryptorchid lambs grazed on chicory (Cichorium intybus) or lucerne (medicago sativa) *Australian Journal of Experimental Agriculture*. 1995;35(6):693–697.
83. Brown H. E., Moot D. J. Quality and quantity of chicory, lucerne and red clover production under irrigation. *Proceedings of the New Zealand Grassland Association*. 2004;66:257–264.
84. Komolong M., Nicol A. M., Poppi D. P., Fraser T. J., Kirsopp S. Nutrient supply for lamb growth from Grasslands Puna chicory (*Cichoriumintybus*) and Wana cocksfoot (*Dactylisglomerata*) *Proceedings of the New Zealand Society of Animal Production*. 1992;52:85–87.
85. Wales W. J., Kolver E. S. Challenges of feeding dairy cows in Australia and New Zealand. *Animal Production Science*. 2017;57(7):1366–1383.
86. Githiori J. B., Athanasiadou S., Thamsborg S. M. Use of plants in novel approaches for control of gastrointestinal helminths in livestock with emphasis on small ruminants. *Veterinary Parasitology*. 2006;139(4):308–320.