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Original Article

Comparative Nutritional Analysis of Domestic and Imported Commercial Canary Egg Food and Mixed Seeds Based Diets

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ABSTRACT

In this study, the aim was to determine the nutritional content of specially formulated commercial soft/egg foods for canaries, preferred by professional breeders in Türkiye, and the nutritional and raw material content of seed mixtures, thereby providing insights into the general diet compositions and essential feeding regimens for canaries. The study examined 17 different seed types, eight mixed seed feeds, and 11 egg food formulations. Two main groups, "domestic" and "imported," were formed from these mixed seed feed and egg food products. The nutritional content ratios of each feed material were determined through chemical analyses, and the predicted metabolizable energy values were calculated and compared between group averages. According to the results, there were no significant differences (p>0.05) between the data of domestic and imported mixed seed feed groups in terms of parameters other than crude fiber (CF). However, the CF value was found to be statistically significantly lower in the imported group (p<0.05), and a decreasing trend in the crude ash (CA) value was also observed in the same group. It was determined that almost all parameters resulted in similar values between the domestic and imported egg food groups. However, when each feed product was evaluated separately, significant data differences and wide variation ranges were found within the groups, especially in terms of crude fat and starch parameters. As a result, it is understood that domestically produced commercial egg food formulations with basic nutritional content comparable to European imported products are available for use by canary breeders in Türkiye. However, it is apparent that imported products, particularly in mixed seed formulations, had raw materials with lower CF and CA contents.

INTRODUCTION

The canary (Serinus canaria) is a bird genus belonging to the finch (Fringillidae) family within the passeriformes order. With over 200 wild subspecies, canaries are distributed across Asia, Africa, and Europe. Domesticated canaries (Serinus canaria domestica) are believed to have originated from the Atlantic canaries found in the Macaronesian Islands, including Portugal's Azores and Madeira, as well as Spain's Canary archipelago (Arnaiz-Villena *et al.*, 2009). Initially admired for their melodious songs, canaries were domesticated in the 15th century. Their physical attributes, such as color and shape, were later enhanced through zootechnical and genetic studies, which garnered significant interest and expanded their breeding worldwide (Birkhead, 2014). Domestic canaries are small birds, typically weighing between 12 and 30g (average 22g), with lifespans ranging from 6 to 16 years (Kamphues & Meyer, 1991; Harper & Turner, 2000; McDonald, 2006;

Dorrestein, 2009; Pollock, 2012; Speer *et al.*, 2020). Their diet primarily consists of seeds (granivorous) and a daily feed intake of approximately 3-4g DM (Harper & Turner, 2000). However, their diet may occasionally include fruits, vegetables, soy-based products, boiled eggs, insects, and maggots, which offer significant nutritional benefits (Taylor *et al.*, 1994; Hidayat *et al.*, 2015). By diversifying their diet, canaries can obtain the essential nutrients (amino acids, fatty acids, minerals, vitamins, etc.) they require. Nonetheless, relying solely on plant seeds as their primary feed source can lead to inadequate nutrient intake during critical stages such as reproduction, egg-laying, growth, and molting, resulting in developmental disorders and various health issues. If canaries' daily diet is limited to specific seeds or seed mixtures, potential nutrient deficiencies may involve amino acids like lysine, methionine, and cysteine; minerals like calcium (Ca), phosphorus (P), sodium (Na), iron (Fe), zinc (Zn), iodine (I), selenium (Se), and manganese (Mn); and vitamins like riboflavin, pantothenic acid, niacin, B12, A, D3, E, K, and choline (McDonald, 2006; Sandmeier & Coutteel, 2006; Dorrestein, 2009).

In canary breeding, issues arise due to seed-based nutrition. Consequently, some individual keepers or breeders use homemade dietary formulations for their birds, while others opt for commercially available products that claim to provide the essential nutrients required by these birds. However, the lack of sufficient scientific data and established standards for canary nutrition makes it unclear whether these commercial products truly meet the birds' needs (Sandmeier & Coutteel, 2006). Most published sources on canary breeding and nutrition are written by hobbyists who share knowledge gained through mentor-apprentice relationships or personal observations and experiences, rather than being based on scientific research (Mevliyaogullari *et al.*, 2021).

The primary objective of this study is to gather information about the fundamental nutritional regimes of canaries by analyzing the raw and nutrient composition ratios of various domestic and imported commercial seed feed mixtures specifically formulated for canaries, as well as the basic nutrient content ratios of specially formulated canary foods.

MATERIALS AND METHODS

In this study, frequently used canary feed ingredients such as shelled and unshelled canary seed (*Phalaris canariensis*), Hemp (*Cannabis sativa* L.), Flax (*Linum usitatissimum*), Niger (*Guizotia abyssinica*), Canola (rapeseed; *Brassica napus L.*), Poppy (*Papaver somniferum Linnaeus*), hulled Oats (*Avena sativa*), Turnip (Turnip - *Brassica napobrassica*), Mung Bean (*Vigna radiata L.*), Radish (*Raphanus sativus* L.), Perilla (*Perilla Frutescens*), and hulled and peeled White Millet (White millet; *Panicum miliaceum L.*), Yellow Millet (Yellow millet; *Panicum miliaceum L.*), Red millet (Red millet; *Panicum miliaceum L.*), and Black millet (Black millet; *Panicum miliaceum L.*) were obtained as separate (pure/unmixed) seed samples. Each feed material was analyzed individually for dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), crude fiber (CF), crude ash (CA), and starch content ratios, and the "predicted metabolizable energy (PME)" values of the feeds were calculated based on the obtained data.

It should be noted that, among the seed feeds listed above, some were available as hulled/unshelled varieties. In such cases, shelled seeds were dehulled then analyzed to determine the net nutrient composition of the seed's internal structure, considering that canaries typically consume seeds after dehulling them. The separate seeds, seed mixtures and egg foods used in the study were selected from the commercial original brand products with closed packaging, which were offered for sale in the Turkish market. Study consisted of four domestic (DS) and four imported (IS) mixed seed formulations, highly preferred by canary breeders, were selected and designated as "Domestic Seed Mixture (DSmix)" and "Imported Seed Mixture (ISmix)" respectively, forming two main groups. The basic nutrients and chemical content (DM, OM, CP, EE, CF, CA, and starch) ratios of each feed formulation in these main groups were determined separately. PME values were calculated, and statistical comparisons of group averages were conducted. Additionally, to determine the raw material (seed feed) content ratios of these mixes (given the lack of sufficient information on product labels or verification of the accuracy of provided information), 50-gram samples of each feed formulation (50 g × 2 = 100 g) were weighed in two replicates. These mixed seed samples were sieved and manually separated to determine seed contents and usage rates (%). This approach aimed to provide a general assessment of raw material (seed variety) preferences and ratios used by manufacturers when formulating these types of products.

In the study, two primary groups were established, namely "Domestic egg food (DEg)" and "Imported egg food (IEg)," which consisted of four domestically produced and seven imported (from Germany, Belgium, and Italy) formulas. These formulas are generally preferred by numerous professional canary breeders. The nutrient content ratios of each formula in these main groups were determined, and statistical evaluations between the group averages were conducted. No assessment was performed regarding the raw material content information (feed materials used, formulation ratios, etc.) of these commercial egg foods. The nutrient content analyses of the seed, compound feed, and food formulations utilized in the experiment were determined according to AOAC (2005) guidelines. The energy values of the diets were calculated as predicted metabolizable energy (PME) using the equations provided below (NRC, 1994; Harper, 2000; Werquin *et al.*, 2005; Cornejo *et al.*, 2012).

* SCH (%) = 100 – (%CP + %EE + %CF + %Moisture + %Ash).

** PME (kJ/g DM) = [(18.4 × CP) + (36.4 × CF) + (16.7 × SCH)] / 100

Where, PME: Predicted metabolizable energy, SCH: Soluble carbohydrate, CP: Crude protein, CF: Crude fat, EE: Ether extract, DM: Dry matter.

The statistical analysis of the data was conducted using the SPSS v.15.0 (SPSS for Windows, Chicago, SPSS Inc.) software package. The assumptions for parametric tests were analyzed (normality and homogeneity), and Student's t test was performed to determine the differences and significance between the experimental groups by making pairwise comparisons were conducted between group means. The statistical differences were $p<0.05$.

RESULTS

In Table 1, the nutrient content's chemical analysis values for each forage seed suitable for pet birds are presented. Table 2 provides the feed material content ratios for both domestic and imported mixed seed feed groups, while Table 3 displays the chemical analysis values of their respective nutrient contents. Additionally, the nutrient content's chemical analysis values for the domestic and imported food groups can be found in Table 4. Lastly, Table 5 offers a representative list of the raw material content ratios for mixed seed feed products from a local (Türkiye) producer that specializes in producing feed formulations for pet birds.

DISCUSSION

Forage Seeds

When encountering an unfamiliar seed, seed-eating birds may acquire nutritional habits by first recognizing the material as feed and subsequently developing the capacity to efficiently process it (e.g., peeling, grinding, rendering it swallowable, digesting, etc.). It is known that forage habits are passed from adult birds to their offspring. Intriguingly, adult male canaries display greater courage and innovation when experimenting with new feeds, thereby playing a crucial role in transferring their newly acquired feeding skills to both females and chicks (Cadieu *et al.*, 2008; 2010). In this study, the analysis of forage seed results reveals that the dry matter values are 89%, while the organic matter values exceed 85% in all seed groups.

Table 1 – Chemical composition analysis values of forage seeds to be used in feeding pet birds.

Seed varieties	DM	OM	CP	EE	Starch	CF	Ash	PME (kJ/g)
Canary seed	91.92	94.35	18.27	6.73	53.21	10.37	5.65	14.9
Canary seed (Dehulled)	91.12	89.09	21.69	7.70	63.02	0.79	2.23	17.1
Oat (Dehulled)	92.58	98.29	16.55	7.06	65.75	4.26	1.71	16.5
Mung Beans	89.21	85.92	26.78	1.50	52.39	4.02	3.69	15.0
Hemp	96.18	94.76	27.12	38.63	0.00	37.08	5.24	19.1
Flax	96.27	96.48	25.79	44.24	1.98	34.33	3.52	20.9
Niger	97.51	94.48	23.03	39.52	0.00	38.26	5.52	18.6
Canola (Rape)	96.76	96.12	22.70	41.05	1.40	39.60	3.88	19.1
Blue poppy	95.54	93.29	23.62	46.73	2.28	27.12	6.71	21.4
Turnip	96.41	96.19	27.97	41.68	0.56	39.81	3.81	20.3
Radish	97.02	93.50	25.61	43.79	2.80	2.90	3.63	24.6
Perilla	95.89	92.30	26.75	45.09	2.27	12.27	3.75	23.3
White millet (Dehulled)	90.38	89.31	12.94	3.30	81.78	0.76	1.18	15.9
White millet	89.72	86.33	12.76	4.58	68.45	6.69	3.78	14.8
Yellow millet	89.77	87.63	11.12	4.07	65.08	12.70	2.38	14.0
Red millet	90.06	87.81	11.75	4.27	64.57	11.34	2.50	14.3
Black millet	90.76	87.02	14.12	4.53	57.49	13.71	4.12	13.9

DM – dry matter, OM – organic matter, CP – crude protein, EE – ether extract, CF – crude fiber, PME – predicted metabolizable energy.

Table 2 – Feed material contents and formulation of domestic and imported feed seed mixtures.

Seed varieties	Groups (*Mean ±SE*) DSmix (n=8)	ISmix (n=8)	*p*-value
Canary	64.16 ±3.83	66.92 ±1.16	0.509
Niger	10.25 ±3.63	11.01 ±1.90	0.855
Hemp	2.57 ±0.48	3.70 ±0.52	0.133
Flax	3.69 ±0.67	5.16 ±0.10	0.067
Oat	4.64 ±0.89	5.67 ±0.21	0.305
Canola (Rape)	14.52 ±4.21	8.91 ±4.55	0.387
Perilla	Detected in only 2 sample	Detected in only 2 sample	-
Millet	-	Detected in only 1 sample	-

DSmix – domestic seed feed mixtures; ISmix – imported seed feed mixtures; n – number of samples; SE – standard error.

Table 3 – Chemical composition analysis values of domestic and imported feed seed mixtures.

Analyzed Parameters	Groups (*Mean ±SE*) DSmix (n=8)	ISmix (n=8)	*p*-value
DM	94.25 ±0.39	94.54 ±0.37	0.597
OM	89.38 ±0.44	89.91 ±0.36	0.369
CP*	20.62 ±0.26	20.64 ±0.11	0.955
EE*	18.42 ±1.06	16.89 ±0.79	0.265
Starch*	35.29 ±1.53	38.77 ±1.25	0.100
CF*	13.11^{a} ±0.39	11.61^{b} ±0.36	0.014
Ash*	5.17 ±0.12	4.91 ±0.08	0.086
PME (kJ/g DM)	17.2 ±0.25	17.2 ±0.20	0.980

DSmix – domestic seed feed mixtures, ISmix – imported seed feed mixtures, n – number of samples, SE – standard error, DM – dry matter, OM – organic matter, CP – crude protein, EE – ether extract, CF – crude fiber, PME – predicted metabolizable energy, *DM% – Determined on the basis of dry matter

Table 4 – Raw material content chemical composition analysis values of domestic and imported canary soft/egg foods.

Parameters	Groups (*Mean ±SE*) DEg (n=8)	IEg (n=14)	*p*-value
DM	93.15 ±0.89	93.46 ±0.45	0.732
OM	90.39 ±1.26	89.67 ±0.41	0.602
CP*	19.41 ±1.64	18.04 ±1.14	0.490
EE*	9.56 ±2.75	12.23 ±1.69	0.391
Starch*	49.19 ±2.97	44.52 ±1.74	0.160
CF*	8.35 ±1.78	7.89 ±1.45	0.843
Ash*	2.98 ±0.62	4.04 ±0.30	0.097
PME (kJ/g DM)	16.3 ±0.42	17.0 ±0.43	0.327

DEg – domestic egg food, IEg – import egg food, SE – standard error, DM – dry matter, OM – organic matter, CP – crude protein, EE – ether extract, CF – crude fiber, PME – predicted metabolizable energy, *DM% – Determined on the basis of dry matter

This classification as "dry food/feed" suggests that their nutritional content can be adequately evaluated by the body (OM). In terms of crude ash, the majority feed group exhibits levels below 5% (average 3.5%), indicating that content without nutritional activity is at a minimum.

It is well-established that the key parameters for determining diet quality are CP, CF, starch, and CF contents. High CP, CF, and starch values reflect the diet's high digestibility and nutritional value. However, high CF values are undesirable in bird nutrition, as their fermentative digestion mechanisms are underdeveloped, preventing them from truly digesting plant structures. According to NRC (1994), feeds containing over 18% CF are categorized as "roughage." Upon examining Table 1, it can be observed that the CF value reaches up to 40% in certain seed types. Nonetheless, both psittasiform and passeriform birds consume seed feed by removing the seed's outer shell and ingesting only the inner parts. In this study, the reported values pertain to seeds—mostly ground with their shells – fed to canaries, which explains the high CF values. As these types of seed bait are commercially available, and since each seed is not sold in a peeled (shell-free) form due to their small physical structure, manual sorting (by hand under laboratory conditions) is impossible. Consequently, seeds in this study were ground and analyzed with their shells. Taking into account that birds do not consume CF at these levels in reality, the data on seed feeds in the table should be evaluated accordingly.

In Table 1, hemp, flax, niger, canola, poppy, perilla, radish, and turnip seeds were observed to have significant crude fat content (39-47%), and correspondingly, their gross energy values were also notably high. According to NRC (1994), feed materials characterized by "over 20% protein and less than 18% fiber" are classified as "protein supplements." It was understood that these oilseeds, listed here with crude protein ratios between 22-28% even in their shelled form, were also included in the protein supplement classification. In making comments and evaluations for seed feeds, it would be correct to consider the unshelled/peeled form consumed by birds, and therefore the minimized crude fiber content.

The NRC classifies feeds containing "less than 20% CP and less than 18% fiber" as "energy feed sources," with cereal grain feeds being the most important members of this group. Upon examining the seeds listed in Table 1, canary seed, oat, and millet seeds were identified as grain types and were dominant in terms of starch content (53-68% in their shelled form). Oat seed, used as a peeled product in canary nutrition, had a nutritional value nearly equal to that of canary seed (16.55% CP, 7.06% CF, 65.75% starch). Millet seeds, on the other hand, featured four different types (white,

Table 5 – Raw material compositions of mixed seed feed products obtained domestic feed producers.

	Composition of the raw materials %										
Products	Canary	Canola	Niger	Flax	Hemp	Oat	Wild seed	Biscuit	White millet	Red millet	Yellow millet
Canaray1	42	16	20	8	2	12	-	-	-	-	-
Canaray2	58	7	16	5	6	6	2	-	-	-	-
Canaray3	65	-	15	5	5	5	5	-	-	-	-
Canaray4	62	-	15	10	5	8	-	-	-	-	-
Canaray5	66	21	5	8	-	-	-	-	-	-	-
Canaray6	60	18	4	4	2	-	12	2	-	-	-
Canaray7	65	24	2	8	1	-	-	-	-	-	-
Canaray8	68	24	1	3	2	-	-	-	-	-	-
Canaray9	66	30	1	2	1	-	-	-	-	-	-
Averages Canary	61.3	20	8.8	5.9	3	7.8	6.3	2	-	-	-
Bird1	10	5	5	5	-	-	75	-	-	-	-
Bird2	50	10	3	3	4	30	-	-	-	-	-
Bird3	20	-	3	2	-	-	-	-	10	5	60
Bird4	10	-	1	2	1	-	-	2.5	10	10	63.5
Bird5	10	-	1	2	1	-	-	-	10	10	66
Average Bird	20.0	7.5	2.6	2.8	2.0	30.0	75.0	2.5	10.0	8.3	63.2

Canary 1-9 are marketed as canary seed mix, Bird 1-5 are marketed as budgerigar, goldfinch and other pet birds seed mixes.

yellow, red, and black) that could be used as feed, depending on the variety of shell color. Millet seeds exhibited higher starch (~82% in peeled millet, 57-68% in hulled) but lower oil (3-5%) content compared to canary seed and peeled oats. Regarding the use of millet seeds in canary breeding, some breeders or feed producers were found to incorporate them into their diets, albeit minimally, but canaries did not genuinely prefer consuming millet seeds. Consequently, millet seeds were used for lovebirds, parakeets, etc., rather than canary diets, and were more preferred in small-sized parrot bird diets, where they were enjoyed and consumed by this group of birds. Differently, within the energy feed group, mung bean, a legume plant, had significant starch (52%) content besides being a protein source, allowing it to be considered as a starch source or a combined product (CP + starch) in pet bird nutrition. However, probably because mung bean seed had a larger physical volume compared to other seeds and canaries were small birds, it was not possible for them to swallow this seed as is, and it was observed that the birds did not prefer to eat this seed type. In this case, some growers chose to grind mung beans into flour (seed or sprout meal) and use them in diet formulations, while others preferred to use the seeds as a green feed source by germinating them.

Predicted Metabolizable Energy of Feeds

Nutrition is an essential function for supplying chemical energy to maintain metabolic activity and vitality in all living organisms. It is important to note that songbirds have an average basal metabolic rate that is 50-60% higher than that of non-singer birds of the same body size, and their normal body temperature is approximately 2°C higher (around 42°C) (Walsberg, 1983). Special methods and equation calculations have been developed by numerous researchers, scientific academies, and institutions to determine the energy values of diets. However, due to the variety of methods and equations proposed, many different numerical results are obtained for each feed substance studied and examined. Moreover, since many individual and environmental factors affect the energy efficiency of feed/foods, these methods allow for reaching theoretical and estimated numerical values rather than providing actual energy values (Mateos *et al.*, 2019).

In canary diets, diet metabolism efficiency should be high, and for this reason, it is desirable to have high proportions of rapidly soluble and convertible nutrient content. It has been calculated that the average daily dry matter intake of a canary with an average body weight of 22-23 g ranges from 3 to 4 g, corresponding to approximately 70 kJ of gross energy and 45-75 (avg. 62) kJ of metabolizable energy per bird per day. Furthermore, it has been determined that the gross energy intake for canary chicks is almost equivalent to that of an adult canary by the 11th day after hatching. Digestibility values for protein, fat, and carbohydrates are similar to those obtained for budgerigars, but the digestibility coefficient is likely dependent on the seed type and digestive system lipase and amylase activities (Harper & Turner, 2000). In the presented study, PME values related to feeds were calculated and presented in the relevant tables. As can be seen in the tables, products with high EE content have significantly high energy values (hemp, flax, niger, canola, poppy, radish, turnip, perilla), followed by products with high starch content (canary seed, hulled oats, mung beans, millet). As mentioned earlier, when preparing diet formulations for caged birds' nutrition (especially for soft foods), it is essential to maintain the energy balance; otherwise, various problems such as fat accumulation, obesity, and developmental disorders may arise in the birds.

Seed Mixtures

Doherty & Cowie (1994) attempted to instill a forced feeding habit for a specific seed by separately providing it to groups of newly hatched canary chicks that were just starting to learn to feed on their own. Initially, each group adapted to the feeds given to them, but subsequently, when a mixed seed diet was provided to these experimental groups, their feeding habits gradually changed, resulting in a transformation similar to that observed in the control group fed with mixed feed from the beginning. This study demonstrates that birds also have tendencies to prefer certain feed materials and will gravitate towards their preferred feed when alternatives are provided.

At the same time, the relationship between seed size and beak size and anatomical shape (the processability of seeds in the beak) has been found to be the primary determinant factor in granivorous birds' preference for feed type. However, they can also determine their preferences based on the nutritional (protein, fat, carbohydrates, moisture, energy) and antinutritional content and to some extent the digestibility characteristics of feeds. In frugivorous bird groups, the color and appearance of the plant have been identified as influential factors in feed preference (Díaz, 1996; Titulaer *et al.*, 2018). In canary breeding, considering these characteristics of birds, mixed seed diets with various contents are formulated to allow them to determine their individual feed preferences.

In the presented study, it was observed that six different seeds, namely canary seed (avg. 64.2-66.9%), niger (avg. 10.3-11.0%), canola (8.9-14.5%), hulled oats (4.6-5.7%), flax (avg. 3.7-5.2%), and hemp (avg. 2.6-3.7%), were used as common main components in the compared domestic and imported seed feed mixtures, with some mixtures additionally including perilla (1.3-6.5%) and millet (0.4%) seeds (Table 2). As can be inferred from this data, the main components of mixed seed diets were composed primarily of canary seeds, constituting over 64% of the diet, followed by niger and canola seeds, each preferred at approximately 11% (forming 19-26% of the total mixture), and supplemented with hulled oats, flax, and hemp seeds at approximately 3 to 6% (comprising 11-15% of the total mixture).

Furthermore, in the presented study, when examining the data shared in Table 5, obtained from a domestic company producing ready-made seed formulations for pet birds, apart from the sample mixed seed formulations analyzed, it was observed that canary mixed seed feed formulations with similar numerical values and characteristics were prepared. This company has formulated nine separate formulations specifically for canaries, primarily using canary seeds at rates over 61%, along with (in descending order) 20% canola, 8.8% niger, 5.9% flax, 3% hemp seeds, and also incorporating approximately 7.8% hulled oats in some of their products. Sandmeier & Coutteel (2006) have also reported that in canary seed feed mixtures produced in Belgium, canary seeds (62%) were predominantly used, while canola/rapeseed (22%), hulled oats (8%), hemp (3%), flax (3%), and niger (2%) seeds were maintained at lower levels.

One of the significant findings when examining the mixed feed seed group data in the presented study is that the CF values were considerably higher (12.19-14.03% for domestic and 10.75-12.47% for imported seeds; $p<0.05$) in imported seed mixtures, which are considered of higher quality by breeders, while CA levels were kept at levels close to statistical significance (4.88-5.46% for domestic and 4.73-5.09% for imported seeds). In conclusion, it would be more logical to evaluate the nutrient consumption of these types of seed-eating birds by considering the seed's hulled state and assuming that essential nutritive chemical components, such as CP, CF, and starch, mainly originate from the seed's inner structure, and that they can only obtain minimal amounts of fibrous nutrient components (cellulose, hemicellulose, lignin, etc.) from the seed's inner structure.

Canary Seed

The preference for canary seed as the main feed material in domestic canary mixed seed diets is not coincidental. It has long been known by breeders that the seeds of the Phalaris canariensis plant are the most preferred feed for canaries, and for this reason, they are called "canary seeds". In a study conducted by Hidayat *et al.* (2015), canaries were given a mixed diet consisting of barley, canary, millet, mustard, and niger seeds, and it was determined that their feeding preferences were primarily canary seed at a rate of

48.1% (consumption of 2.75 g/day per bird), followed by mustard seed at 24.3% (1.39 g/day), niger seed at 16.9% (0.97 g/day), barley at 5.6% (0.32 g/day), and millet at 4.8% (0.27 g/day). According to Black (2007), the least preferred feed for canaries is canola/rapeseed. In the presented study, both whole and hulled (manually separated) canary seeds were ground and analyzed for their importance in canary nutrition. It was determined that the nutritional content of the hulled seeds (inner part), which the canaries particularly consume after removing the shell, contained 21.69% CP, 7.70% CF, 63.02% starch, 0.79% CA, 2.23% EE, and 17.1 kJ/g ME. The main component of canary seed is found to be starch, which is known to be an easily digestible and convertible carbohydrate structure into metabolic energy in the digestive system. Studies have shown that canary seed has a smaller, denser, and more resistant starch structure compared to other cereal grains, which can lower the glycemic index of the diet and promote probiotic activity, digestion, and satiety mechanisms, making this seed valuable in terms of nutrition. Furthermore, it has been found that canary seeds have a higher fat and protein content compared to cereal grains, resulting in a richer fatty acid and amino acid/peptide composition. The unique molecules in their structure have been shown to have significant health-promoting effects against cardiovascular diseases, especially due to their antidiabetic, antioxidant, antiamnesic (memory loss preventing), immune-stimulating, antithrombotic, antihypertensive, opioid, and neuroactive effects (Valverde *et al.*, 2017; Patterson *et al.*, 2018; Mason *et al.*, 2020). In conclusion, the reasons for canaries' preference for canary seed may include their ability to recognize the nutritional composition of the seed as meeting their own needs for growth and development, their instinctual or experiential understanding of the nutraceutical or pharmacodynamic effects mentioned above, and the seed's physical structure being ergonomically suitable for canary beak and digestive anatomy, making it easy for the bird to process and adopt as their favorite and most suitable seed.

Alternative Feed Seeds

In compound seed diets, oats, mung beans, hemp, flax, niger, poppy, canola/rapeseed, radish/turnip, perilla, and millet seeds are commonly utilized as secondary feed ingredients.

It is established that starch is either nonexistent or present at very low levels (0.0-1.98%) in the nutritional composition of hemp, canola/rapeseed, niger, and flax seeds. In contrast, their crude protein ratios are relatively elevated (22.70-27.12%), and crude fiber ratios are substantially high (38.63-44.24%) (Table 1). Nutritionally, these seeds possess a richer and more complex structure compared to starch-dominant cereal seeds, including essential or non-essential amino acids, fatty acids, vitamins, minerals, and so on. Additionally, their energy efficiency is considerably high (NRC, 1994). It is crucial to incorporate these seed types into the diets of adult birds during breeding seasons – when they need increased protein, energy, vitamins, and minerals (courtship, nest construction, mating, etc.) – and throughout the growth and developmental stages of hatchlings. However, continuing with the same seed-dominant feeding approach outside these periods may likely result in obesity, gout, reproductive issues, and other problems. Consequently, during times when canaries experience reduced metabolic activities, it would be more logical to switch to simpler and starch-heavy diets, such as those with higher proportions of canary seed, millet, and oat seeds, to minimize potential disease risks associated with nutritional imbalances (Harper & Turner, 2000; Sandmeier & Coutteel, 2006; Black, 2007; Dorrestein, 2009). Indeed, feed manufacturing companies tend to increase the proportion of high-protein and fatty seeds in some mixed feeds to cater to canaries' seasonally or periodically varying requirements (e.g., breeding, growing, singing period feeds), while opting for formulations with a greater emphasis on canary seeds in their standard products.

Egg Food

Breeding practices and subsequent scientific research have indicated that canaries may not receive adequate and balanced nutrition from single-type seed diets in cages. Consequently, both professional breeders and specialists have endeavored to develop alternative diet compositions that can fulfill the needs of canaries. Presently, numerous companies within the sector create a variety of bird-specific commercial feed formulations and provide them to breeders. Each company can select plant and/or animal feed raw materials they consider appropriate and incorporate them into their feed formulations. In the study presented here, the focus was on determining the fundamental nutritional content rather than identifying the specific feed raw materials that constitute the composition of the feeds. This study formed two primary groups: one comprised of 4 "Domestic production egg foods (DEg)" and the other of 7 "Imported egg foods (IEg)" formulations, which are generally favored by numerous professional canary breeders in Türkiye. Nutritional contents were ascertained through analyses. When examining the DM, CP, CF, EE, ash, and starch levels of the feeds, it was established that there were no statistically significant differences between the group averages regarding these parameters (p>0.05). Nevertheless, when the feed samples from both groups were assessed within the group, it became evident that there were significant variations between almost every different feed sample in terms of all parameters, indicating an absence of specific standardizations. Reviewing existing literature and studies related to this subject reveals that adult canaries are generally considered to be adequately nourished with diets containing 16-18% CP, 17-18% CF, 48-50% carbohydrates, and 1.80-2.1 MJ/100 g gross energy nutritional contents. However, it has been suggested that during the growth stage of chicks, the diet protein ratio should be raised to 22% and that a high-quality amino acid source must be utilized. Boiled egg white (in the form of a puree) has emerged as the most favored product for this purpose (Taylor *et al.*, 1994; Harper & Turner, 2000; Sandmeier & Coutteel, 2006). Moreover, in recent years, numerous alternative feed-diet products have been developed by experts based on scientific data. These products can be easily acquired and practically employed by both amateur and professional breeders, and they are believed to comprise nearly all the nutrients that canaries require periodically throughout their life cycles in sufficient and balanced quantities.

As emphasized by Sandmeier & Coutteel (2006), seed-based diets in canary nutrition had been associated with low growth and development performance and a higher propensity to cause nutritional disorders. Consequently, the development of granulated products that contained the necessary nutrients in balanced proportions had been considered a good alternative. Through carefully formulated diets composed of various feed ingredients, essential amino acids for birds, such as arginine, isoleucine, leucine, lysine, methionine, phenylalanine, valine, tryptophan, and threonine, as well as all other nutrients required by these caged birds, had been provided (McDonald, 2006). However, it had been advised that vitamin (especially fat-soluble vitamins) and mineral (especially calcium) supplements should not be added to canary diets haphazardly to avoid hypervitaminosis and mineral-related metabolic disorders (such as calcifications) (Sandmeier & Coutteel, 2006).

An important aspect that had been considered in food formulations was the balance between protein and carbohydrate content. Under normal conditions, it had been believed that these birds instinctively recognized their needs for carbohydrates, proteins, and other nutrients (Kaytee, 2021). However, when pellet formulations were composed of mixed raw materials and did not offer the birds any alternative choice regarding carbohydrate or protein intake, both adult individuals and their offspring had been forced to consume these products. Moreover, pellet formulations could have been modified by the breeder, and unprofessional changes to the content might have caused various nutritional problems in birds. For example, adding carbohydrates indiscriminately to a diet perceived to have a high protein content in an attempt to lower the protein ratio could have led to increased food consumption, especially during the first feeding periods when offspring were dependent on parental feeding to cover their protein-amino acid deficiencies. However, this would have inadvertently exposed them to excessive carbohydrates in the food content, which could have later resulted in obesity-related nutritional disorders (Black, 2007). Therefore, it had been beneficial to seek professional support when preparing or using food formulations. Indeed, in the presented study, it had been determined that the nutritional contents (especially important parameters such as CP, CF, and starch) of the analyzed food products had varied considerably.

Canary breeding includes the cultivation of color factor birds (color canaries) as a hobby. It is known that many zootechnical and genetic studies have been conducted for breeding purposes in this direction (Birkhead, 2014). In color-oriented canary breeding models, red, orange, yellow, green, and white color group canary productions are most common. To change the color of the feathers in this type of breeding, specific color factors are introduced into the animals' water or diet from the age of 3-6 weeks for canary chicks and from two weeks before the breeding season for adult birds until the end of the molting period (Moustaki, 2021). This is because feather tissue can only absorb these color pigments from circulating blood into their metabolism during the new feather formation process (Koch, 2015). In red canaries, "canthaxanthin" and "ß-carotene" supplements are specifically used as color factors, while "lutein" support is provided to enhance the color of yellow canaries (Sandmeier & Coutteel, 2006; Speer *et al.*, 2020). Some companies in the sector have prepared and offered commercial special color factor products or color-factor-formulated feeds for these purposes. Some natural products (yellow-red fruits and vegetables such as cherries, red sweet peppers, carrots, turnips, sweet potatoes, as well as green plants like Spirulina algae, broccoli, etc.) can also be utilized for this purpose. However, it is worth mentioning an important detail: avocados should be strictly avoided because they contain an antinutritional substance (Persin) with lethal effects on canaries (Speer *et al.*, 2020; Moustaki, 2021). In addition, it has been determined that dark-colored canary species, especially those with natural dark colors like black and brown, require tyrosine and phenylalanine amino acids for the formation of melanogenesis (Taylor *et al.*, 1996; McDonald, 2006).

In the presented study, two of the imported feeds were color-factored (red and yellow). The red one was supported with ß-carotene and the yellow one with lutein. According to the obtained analysis results, they were found to be quite different from each other in terms of nutritional content. In reality, it cannot be said that color-factored feeds are formulated with a distinct superiority over other feeds in terms of nutritional content. Their only difference is the addition of extra color factors to the content. Therefore, whether a homemade product or a ready-made commercial product is used for this type of canary nutrition, the nutritional quality and balance of the product must be evaluated in any case.

CONCLUSION

In conclusion, the nutritional content of domestically produced and imported commercial soft/egg foods and seed mixtures used by professional canary breeders in Türkiye was thoroughly analyzed in this study. Considerable variability within the egg food groups, particularly in crude fat and starch content, was observed, highlighting the importance of individual product evaluation. As for mixed seed formulations, it was observed that imported products used raw materials with lower crude fiber and ash content. It was concluded that domestically produced commercial soft/egg food formulations in Türkiye were comparable to imported products in terms of basic nutritional content. For future research, it is recommended that the impact of these nutritional differences on canary health, performance, and reproducibility be investigated. Additionally, exploring the potential benefits of using alternative feed ingredients or modifying feed formulations to optimize the nutritional balance for canaries can be considered. Ultimately, these findings could guide the development of improved feed products and best practice guidelines for canary husbandry, promoting the sustainability of the canary breeding.

CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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