Comparative Characteristics of Various Cereals in Relation to Fodder Value, Antinutrients and Use for Poultry Feeding

Subjects: Agriculture, Dairy & Animal Science

Contributor: Olena V. Gaviley , Oleg O. Katerynych , Igor A. Ionov , Darren K. Griffin , Olena O. Dekhtiarova , Michael N. Romanov

The primary ingredients in poultry feed, cereals, are among the most widely used crops in worldwide agriculture, with principal staples being wheat, rice, corn (maize), sorghum, barley, oat and millet. The scope of this review is to provide a detailed comparative analysis of the nutritive values of cereal crops, and the antinutrients they contain, with reference specifically to their use for feeding poultry. These cereal crops range in biological value from 55 to 77.7%, in protein digestibility from 77 to 99.7%, and in net protein utilization from 50 to 73.8%. Most essential amino acids, including lysine, are found in cereal grains, whereas the nutritional value of cereals is impacted by antinutritional elements. These include non-starch polysaccharides (NSPs), such as pentosans (arabinoxylans) and β-glucan, as well as alkylresorcinols. Around 100 g/kg of pentosans are found in rye, 50–80 g/kg in wheat and 68–92 g/kg in triticale. There are strategies to reduce NSPs and other antinutrients and maximize the effectiveness of utilizing grains in compound feed for poultry. These include the application of enzyme preparations, along with dry and wet extrusion methods, for processing grains. By restricting our narrative to a direct comparison of all major staples for poultry feed, we conclude that further research is required specifically in the area of determining how economically viable it is to feed adult and young chickens with compound feeds containing various cereal crops. Furthermore, we speculate on the utility of employing enzyme preparations and extrudates to maximize feed efficiency.

cereal crops poultry feeding feeds nutritive value amino acids antinutrients enzymes extrudates

Cereal crops from the monocotyledon family Poaceae (also known as Gramineae) [1][2], have evolved from wild grasses to cultivated plants via roughly the same pathways. Additionally, there are many similarities between the domestication of seed crops in general and that of cereals in particular [3]. Larger countries are expected to benefit more from crop diversification, including diversity of cereals, and farmland area, which stabilize food production just as much as irrigation. In the effort to provide reliable food supply, this link can direct the creation of national-specific management plans and policies [4]. Wheat, rice, corn (maize), sorghum, barley, oat, and millet are the principal crops used to make staple cereals [1]. These plants have adapted to survive in conditions where they are frequently subjected to a variety of abiotic stressors, including lack of water, high temperatures, salt and mineral toxicity [1][5][6]. In terms of chemical composition [2], most cereal crops are predominantly starch, with the next most common ingredient amylose, followed by protein, then fat (see **Table 1**).

Table 1. Approximate chemical content of unprocessed grain [1] (adapted from ref. [7]).

Cereals	Moisture (%)	Crude Protein (%)	Crude Fat (%)	Starch (%)	Amylose (%)
Corn	13.94	6.86	0.51	63.12	26.80
Rice	14.97	7.06	0.66	81.36	21.26
Millet	10.93	11.20	2.47	69.83	18.84
Black rice	13.67	8.52	2.16	69.36	15.03
Wheat	12.14	12.09	1.55	73.40	25.42
Barley	12.75	11.04	1.75	74.94	37.19
Oat	13.02	12.80	6.14	66.11	48.27
Buckwheat	12.84	12.77	1.32	63.26	32.54
Sorghum	13.64	10.19	0.95	70.85	12.92

[1] The dry basis was used to express the quantities of protein, fat, starch and amylose.

Major energy and nutritional sources such as proteins, carbohydrates, minerals, amino acids, fiber, and micronutrients like zinc, magnesium and vitamins can all be found in cereals [1][8][9][10][11]. Cereals are one of the most commonly used crops in the world's agriculture, with over 2.5 billion tons harvested worldwide annually, with projection of 3 billion tons by 2050 [1][12]. Eighty percent of the cereal grains produced worldwide are grown in Asia, America and Europe [1]. Both industrialized and developing nations rely heavily on cereals as a source of nutrients [2], but their approaches to using these grains vary. Whereas 68–98% of the cereal produced in developing nations is used for human sustenance, over 70% of the cereal produced in developed nations is fed to animals [1][12][13][14].

Being used in livestock feeding, cereals are the main components of poultry feed [14][15][16][17][18]. Traditionally, corn and wheat are most widely implemented for this purpose, while barley is used to a lesser extent; rye and oat in smaller quantities. Among compound feed for poultry in developed nations, the proportion of traditional cereals has dropped recently, from 69–70% to 40–50% [19]. This is caused by both secondary substances from industrial processing and non-traditional feeds, have emerged to supplement the conventional ingredients in poultry feed [19][20]. These include novel grains, such as sorghum and triticale, that show promise and, when used rationally, can be valuable components of compound feed, effectively replacing some of the typical grains [21][22][23][24][25][26][27][28]. Another example of such cereals is black (or brown) rice that is a regular poultry feed ingredient sold on the India market [29] for utilizing it in this and other countries where similar poultry feeding practices are engaged. There are also the respective published researches showing that brown rice is a potential and effective feedstuff for poultry as established studies, e.g., in Malaysia [30] and Japan [31]. The increasing proportion of cereals being used to produce biofuels like ethanol, biodiesel, and solid fuel pellets is also considered crucial (e.g., [32][33][34][35]).

The purpose of this review is to elucidate comparative nutritive values of cereal crops, and antinutrients they contain, in relation to their use for feeding poultry.

References

1. Jeyasri, R.; Muthuramalingam, P.; Satish, L.; Pandian, S.K.; Chen, J.-T.; Ahmar, S.; Wang, X.; Mora-Poblete, F.; Ramesh, M. An overview of abiotic stress in cereal crops: Negative impacts, regulation, biotechnology and integrated omics. Plants 2021, 10, 1472.
2. Nayik, G.A.; Tufail, T.; Anjum, F.M.; Javed Ansari, M. (Eds.) Cereal Grains: Composition, Nutritional Attributes, and Potential Applications, 1st ed.; CRC Press: Boca Raton, FL, USA, 2023.
3. Harlan, J.R.; de Wet, J.M.; Price, E.G. Comparative evolution of cereals. Evolution 1973, 27, 311–325.
4. Jin, Z.; Tilman, D. Crop diversity benefits increase with nation size. Nat. Food 2024, 5, 463–464.
5. Giordano, M.; Petropoulos, S.; Rouphael, Y. Response and defence mechanisms of vegetable crops against drought, heat and salinity stress. Agriculture 2021, 11, 463.
6. Kumari, V.V.; Roy, A.; Vijayan, R.; Banerjee, P.; Verma, V.C.; Nalia, A.; Pramanik, M.; Mukherjee, B.; Ghosh, A.; Reja, H.; et al. Drought and heat stress in cool-season food legumes in sub-tropical regions: Consequences, adaptation, and mitigation strategies. Plants 2021, 10, 1038.
7. Zhang, C.; Zhang, H.; Wang, L.; Qian, H. Physical, functional, and sensory characteristics of cereal extrudates. Int. J. Food Prop. 2014, 17, 1921–1933.
8. O’Neil, C.E.; Nicklas, T.A.; Zanovec, M.; Cho, S. Whole-grain consumption is associated with diet quality and nutrient intake in adults: The National Health and Nutrition Examination Survey, 1999–2004. J. Am. Diet. Assoc. 2010, 110, 1461–1468.
9. Papanikolaou, Y.; Fulgoni, V.L. Certain grain foods can be meaningful contributors to nutrient density in the diets of US children and adolescents: Data from the National Health and Nutrition Examination Survey, 2009–2012. Nutrients 2017, 9, 160.
10. Rajkumar, G.; Selvakulasingam, B. Comparative study of nutrient composition of selected cereal grains available in Jaffna, Sri Lanka. Ann. Biol. Res. 2019, 10, 21–24. Available online: https://www.researchgate.net/publication/335712795 (accessed on 18 April 2025).
11. Torbica, A.; Belović, M.; Popović, L.; Čakarević, J.; Jovičić, M.; Pavličević, J. Comparative study of nutritional and technological quality aspects of minor cereals. J. Food Sci. Technol. 2021, 58, 311–322.
12. Alexandratos, N.; Bruinsma, J. World Agriculture Towards 2030/2050: The 2012 Revision. ESA Working Paper No. 12-03; FAO: Rome, Italy, 2012; Available online: https://www.fao.org/4/ap106e/ap106e.pdf (accessed on 18 April 2025).
13. Olugbire, O.O.; Olorunfemi, S.; Oke, D.O. Global utilisation of cereals: Sustainability and environmental issues. Agro-Science 2021, 20, 9–14.

14. Kchaou, R.; Benyoussef, S.; Jebari, S.; Harbaoui, K.; Berndtsson, R. Forage potential of cereal–legume mixtures as an adaptive climate change strategy under low input systems. Sustainability 2023, 15, 338.
15. Bessarabova, R.F.; Toporova, L.B.; Egorov, I.A. Feed and Feeding of Poultry; Kolos: Moscow, Russia, 1992; Available online: https://elibrary.ru/item.asp?id=21391195 (accessed on 18 April 2025). (In Russian)
16. Lemesheva, M.M. Poultry Feeding; Slobozhanshchyna: Sumy, Ukraine, 2003. (In Ukrainian)
17. Egorov, I.A.; Imangulov, S.A. Results and prospects of research on feeding highly productive cross-breed poultry. Sb. Nauch. tr. VNITIP 2005, 80, 98–103. Available online: https://www.elibrary.ru/item.asp?id=21185755 (accessed on 18 April 2025). (In Russian).
18. Svezhentsov, A.I.; Urdzik, R.M.; Egorov, I.A. Feed and Feeding of Poultry; Art Press: Dnepropetrovsk, Ukraine, 2006; Available online: https://elibrary.ru/item.asp?id=21391203 (accessed on 18 April 2025). (In Russian)
19. Gaviley, O.V. Efficiency of the Use of Triticale in Fodder for Breeding Chickens. Ph.D. Thesis, State Poultry Research Station of NAAS, Kharkov State Zooveterinary Academy, Kharkiv, Ukraine, 2018.
20. Kyrychenko, V.V.; Maklyak, K.M.; Varenyk, B.F.; Kutishcheva, N.M.; Trotsenko, V.I. The practical characteristics expressing of three-linear sunflower hybrids in different agro-climatic zones of Ukraine. Vìsn. Sumsʹkogo Nac. Agrar. Unìv. Ser. Agron. Bìol. 2016, 9, 129–133. Available online: https://web.archive.org/web/20220325181928/http://repo.snau.edu.ua/bitstream/123456789/5660/1/32.pdf (accessed on 18 April 2025). (In Ukrainian).
21. Smith, R.L.; Jensen, L.S.; Hoveland, C.S.; Hanna, W.W. Use of pearl millet, sorghum, and triticale grain in broiler diets. J. Prod. Agric. 1989, 2, 78–82.
22. Bratishko, N.; Gaviley, E.; Pritulenko, O.; Tereshchenko, A. Triticale in compound feed for chicken breeders. Pticevod. 2008, 9, 30–32. Available online: https://www.elibrary.ru/item.asp?id=11566990 (accessed on 18 April 2025). (In Russian).
23. Bratishko, N.I.; Gaviley, E.V.; Pritulenko, O.V.; Tereshchenko, A.V. Triticale in feeding meat-egg chickens. Pticevod. 2012, 4, 41–43. Available online: https://www.elibrary.ru/item.asp?id=17668326 (accessed on 18 April 2025). (In Russian).
24. Bratyshko, N.I.; Gaviley, O.V.; Tereshchenko, O.V.; Prytulenko, O.V. Effect of triticale on the vitamin content of eggs of different chicken breeds. Ptahìvnictvo 2010, 65, 93–100. Available online: http://avianua.com/archiv/ptahivnictvo/65/10.pdf (accessed on 18 April 2025). (In Ukrainian).
25. Zhukorskyi, O.; Prytulenko, O.; Tereshchenko, O.; Bratyshko, N. The presence of soybean, triticale and sorghum in compound feed for poultry is fully justified. Zerno i khlib 2012, 2, 14–16. Available online: https://www.researchgate.net/publication/342832208 (accessed on 18 April 2025). (In Ukrainian).

26. Różewicz, M. Production, use and efficiency of utilising grains of various cereal species as feed resources for poultry production. Pol. J. Agron. 2019, 38, 66–74.
27. Farahat, M.; Badawi, M.; Hussein, A.; Attia, G. Effect of replacing dietary corn by sorghum on the growth performance, shank skin pigmentation, carcass traits, caecal microflora and nutrient digestibility of broiler chickens. Int. J. Poult. Sci. 2020, 19, 424–431.
28. Gaviley, O.V.; Katerynych, O.O.; Ionov, I.A.; Dekhtiarova, O.O.; Griffin, D.K.; Romanov, M.N. Triticale: A general overview of its use in poultry production. Encyclopedia 2024, 4, 395–414.
29. IndiaMART. Poultry Feed Black Rice, Sree Karpagavinayagar Stores. 2017. Available online: https://www.indiamart.com/proddetail/poultry-feed-black-rice-22989634233.html (accessed on 18 April 2025).
30. Asyifah, M.N.; Abd-Aziz, S.; Phang, L.Y.; Azlian, M.N. Brown rice as a potential feedstuff for poultry. J. Appl. Poult. Res. 2012, 21, 103–110.
31. Nanto-Hara, F.; Ohtsu, H.; Yamazaki, M.; Hirakawa, T.; Sato, K.; Murakami, H. Effects of dietary brown rice on the growth performance, systemic oxidative status, and splenic inflammatory responses of broiler chickens under chronic heat stress. J. Poult. Sci. 2021, 58, 154–162.
32. Gradziuk, P.; Jończyk, K.; Gradziuk, B.; Wojciechowska, A.; Trocewicz, A.; Wysokiński, M. An economic assessment of the impact on agriculture of the proposed changes in EU biofuel policy mechanisms. Energies 2021, 14, 6982.
33. Liu, X.; Unaegbunam, E.; Stuart, D.T. Co-production of isobutanol and ethanol from prairie grain starch using engineered Saccharomyces cerevisiae. Fermentation 2021, 7, 150.
34. Wilczyński, D.; Talaśka, K.; Wałęsa, K.; Wojtkowiak, D.; Bembenek, M. Experimental study on the cutting process of single triticale straws. Materials 2023, 16, 3943.
35. Obidziński, S.; Cwalina, P.; Kowczyk-Sadowy, M.; Krasowska, M.; Sienkiewicz, A.; Faszczewski, D.; Szyszlak-Bargłowicz, J. The use of bread bakery waste as a binder additive in the production of fuel pellets from straw. Energies 2023, 16, 7313.