Eurasian Journal of agricultural research

Volume 3, Issue 2, November 2019

ISSN 2636 – 8226

http://dergipark.gov.tr/ejar

EDITORIAL BOARD

INTERNATIONAL INDEXING

SIS WorldCat ROOTINDEXING JOURNAL ABSTRACTING AND INDEXING SERVICE DRJI AcademicKeys UNLOCKING ACADEMIC CAREERS INDEX COPERNICUS INTERNATIONAL ESJI www.ESJIndex.org Eurasian Scientific Journal Index

CONTENTS

Feed Evaluation Methods: Performance, Economy and Environment

Oyinkansola Olubunmi OLOWU, Sema YAMAN FIRINCIOĞLU*

Niğde Ömer Halisdemir University, Faculty of Agricultural Sciences and Technologies, Animal Production and Technologies Department, 51240 Niğde, TURKEY

**Corresponding author: semayaman@ohu.edu.tr*

Abstract

Feed evaluation methods aim to give information on the feeds to meet the nutritional needs of the animal. Therefore feed evaluation is needed to assess the nutritional value between feeds. The methods to express the feed value incline to measure mainly digestibility of the feedstuff. Many feed evaluation methods have been developed and modified over the years to predict the nutritional component of the feed. The nutritive value of ruminant feeds is assessed by the chemical composition, concentration and rate and extent of digestion of feed in the rumen. Chemical, digestibility and enzymatic methods are the main methods that have been used for feed evaluation. The Weende and detergent analysis systems are the commonly used chemical methods of feed evaluation. For many years, feed digestibility has been measured by in-vivo, in situ and in-vitro digestibility techniques. This paper aims to review the feed evaluation methods of chemical, digestibility and enzymatic with emphasis on performance/outcomes, economic consideration and environmental effects/ footprints.

Keywords: Feed evaluation methods, in-vitro, in-situ, and environmental effects.

Review article

Accepted: 25 November 2019

INTRODUCTION

Feed evaluation is aimed at giving information on the capacity of individual feeds to meet the nutritional requirement of the animal (Beever et al., 2000). Several feed evaluation methods have been developed and modified over the years to predict the nutritional component of feed (Dijkstra et al., 2005). Monogastric animals have less complex feed compositions which do not require extensive feed evaluations as it is in ruminants. The nutritive value of ruminant feeds is assessed by the chemical composition, concentration, rate and extent of digestion of feed in the rumen (Chumpawadee et al., 2007). Feed evaluation is important in predicting animal performance with a degree of accuracy (Cooke, 1988). Volden (2011) emphasized the importance of feed evaluation in ration optimization and the major economic contribution of feeds in modern cattle production. Proximate feed evaluation system by Weende's analysis was developed by Henneberg and Stohman divides carbohydrates into two; the initially assumed to be indigestible crude fibre and the soluble Nitrogen free extract (Henneberg and Stohman, 1860). This method however, does not give the true situation of crude fibre digestibility by rumen microbes. Van Soest and Wine (1967) used the Detergent analysis procedure to better characterize carbohydrates into the poorly digested cell wall and completely digested cell component. The most accurate way to evaluate the nutritional value of any feedstuff is the standard measure of digestibility. It involves post ruminal collections through duodenal or abomasal cannulation of the animal (Nocek, 1988). But it has many limitations; such as laborious, time-consuming, distress the animal and will not be suitable in terms of animal rights. The Nylon-bag (in-sacco) method was first used by Orskov and McDonald (1979) to measure protein degradability in ruminants. This method has become widely used but it has inherent factors that influence digestion. The in-vitro technique does not require the use of animal and as such is less time consuming and quite cost effective (Susmel et al., 1989). It has better reproducibility and repeatability because of there is better control over factors that causes variations. This paper aims to review the chemical, digestibility and enzymatic methods of feed evaluation with emphasis on performance/outcomes, economic consideration and environmental effects / footprints.

FEED EVALUATION METHODS

Chemical, digestibility and enzymatic methods are the main methods that have been used for feed evaluation. The Weende and detergent analysis system are the commonly used chemical methods of feed evaluation. For many years, feed digestibility has been measured by in-vivo, in-situ and in-vitro digestibility techniques.

1. Chemical Method

Since the nineteenth century, the evaluation of feed has been based on its proximate composition (crude fibre, crude fat, minerals, ash, Nitrogen free extract and moisture (Wood and Badve, 2001). Chemical analysis of ruminant feeds includes the determination of dry matter content (DM), organic matter (OM), structural carbohydrate (Fibre and Non-Starch Polysaccharide NSP), soluble carbohydrate, crude fat, crude protein and inorganic matter of the feed (France et al., 2000).

The proximate feed evaluation system (Weende) developed by Henneberg and Stohman divides carbohydrates into two; the initially assumed to be indigestible crude fibre and the soluble nitrogen free extract (Henneberg and Stohman, 1860). This method however, does not give the true situation of crude fibre digestibility by rumen microbes. Van Soest and

Wine (1967) used the Detergent analysis procedure to better characterize carbohydrates into the poorly digested cell wall and completely digested cell component using Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) respectively. This process was able to show that the digestion of feeds using NDF divides the feed into 2 components which differ nutritionally (cell content and cell wall). The cell contents are available nutritionally to the animal while the cell wall part of the feed is not completely digested (Lucas, 1964). The major digestible constituent of the feed's cell wall is largely dependent on the degree of lignification (Van Soest and Marcus, 1964; Osbourn and Terry, 1977). Van Soest detergent analysis has become the most widely used method for evaluating structural carbohydrate (France et al., 2000). Cellulose, hemicellulose and lignin are the major components of the NDF, while cellulose and hemicellulose are the main components found in ADF. Studies have shown good correlation between ADF and dry matter digestibility while NDF revealed a good indication of dry matter intake (DMI) (Wood and Badve, 2001). The use of chemical composition alone is not sufficient to estimate animal intake and in-vivo digestibility. Also, non–structural carbohydrates have been difficult to analyse with this method because of their complex starch and sugar constituent.

Crude protein (CP) is calculated from the nitrogen content using the Kjedahl procedure. This involves acid digestion and distillation. The most widely used method in recent times is the Dumas method which involves combustion and determination of released gaseous Nitrogen (France et al., 2000). These methods measure Nitrogen rather than protein. The measured Nitrogen is multiplied by 6.25 to determine the approximate protein content of the feed.

The Near Infra-red Spectroscopy (NIRS) is used to measure the light absorption of different chemical bond at a range of spectrum between 1100-2500nm. This is a more recent non-traditional chemical method used to more accurately measure the CP (Landau et al., 2006). The two critical aspects of the NIRS calibration are linearity and accuracy. The coefficient of determination (R2), i.e., the proportion of variability in the reference data accounted for by the regression equation is the indicator for linearity. The standard error of calibration (SEC) represents the variability in the difference between predicted values and reference values when the equation was developed from the calibration data set. After a calibration has been set up that features high R2 and SEC, a validation method is needed, in which predictive accuracy is evaluated.

2. Digestibility Methods

In feed evaluation techniques besides the chemical methods, other methods have been developed to characterize feeds with respect to their digestibility. These techniques include the in-vivo, in-situ, and in-vitro methods.

2.1 In-vivo Method

The most accurate way to evaluate the nutritional value of any feed stuff is to feed it to the appropriate class of animal using feeding trials which is the standard measure of digestibility. It involves post ruminal collections through duodenal or abomasal cannulation of the animal. Two types of cannulas have been used; re-entrant duoedenal and simple 'T' cannulas. T cannulas require spot sampling and indigestible solid and liquid phase markers. Digestive phase markers are not required with re-entrant cannula because they conduct total digesta collection. The Cannulas are fixed in such a way as to prevent intestinal blockage and injuries to the nervous system (Nocek, 1988). The most common nutrient measured by in-vivo technique is protein. There is great variability in the estimate of in-vivo digestibility, as many methods have been employed through the years in many research trials. These include total faecal collection, use of chromic oxide as a marker, indigestible ADF/NDF as a marker, and rare earths that have been sprayed on fibre or indigestible fibre (Church, 1993). The recovery of these markers is measured to estimate digestibility. Two commonly used methods are incremental and differential techniques. Studies have shown that the in-vivo method is the most physiological although it has its own inherent limitations (Nocek, 1988). Studies have shown that contamination of digesta flow with endogenous protein, variations in digesta flow, microbial markers and animal differences are major sources of variation in this process (Solaiman et al., 1982; Ellis et al., 1982; Whitelaw et al., 1984). In-vivo digestibility methods are the standards by which other feed evaluation techniques are compared although they tend to have variation associated with inherent factor (Nocek, 1988).

2.2 In-situ (In Sacco) Method

The Nylon bag (in Sacco) method was first used by Orskov and McDonald (1979) to measure protein degradability in Ruminants. It involves the suspension of test feed in the rumen of fistulated animals. It allows for adequate interaction of feed in the ruminal environment (Nocek, 1988). It is used as reference method for feed analysis, because it is a dynamic method. Rumen environment (pH, Temperature, enzymes etc.) is better simulated using in-situ technique which has been used for many years to predict feed digestion (Chalupa, 1975; NRC, 1985). The end point degradability of the feed component is determined after incubation of feeds in nylon-dacron bags in the rumen. Rate of feed degradability have also been measured when the nylon bags are incubated for different lengths of incubation time.

The nylon bag method has become widely used but it has inherent factors that influence digestion. Digestion is affected by the formulation of the diet, bag pore size, feed sample size, feed particle size and animal differences (species, sex, age and physiological state) (Weakley et al., 1983; Susmel et al., 1989; Nocek, 1988). Microbial contamination, differences in sample preparation, processing and bag type also have their impact on digestion (Madsen and Hvelplund, 1994). Several recommendations to reduce these variations were made. Post ruminal washing, reduction in bag pore size, sample size to bag surface area and microbial correction were recommended (Lindberg, 1981; Nocek, 1988). Therefore standardization of in-vivo technique using the best parameters and conditions is of high importance in estimating true feed digestibility.

2.3 In-vitro Methods

In-vitro dry matter digestibility (IVDMD), in-vitro gas production (IVGPT) and enzymatic methods are used for estimating in-vitro digestibility.

2.3.1 In-vitro dry matter digestibility method (IVDMD)

In-vitro dry matter digestibility method (IVDMD) is used widely to determine feed digestibility. Holden (1999) in his study affirms the high correlation of in-vitro to in-vivo digestibility method. In-vitro digestibility is generally lower than in-vivo digestibility in non-forages (Wood and Badve, 2001). Over the years various methods to determine in-vitro digestibility has been developed and modified (Holden, 1999).

According to Tilley and Terry's two-stage in-vitro digestibility method (TT), the feeds are incubated for 48 hrs in rumen liquor then they are digested in pepsin. As reported by Wood and Badve (2001) the relative simplicity and usefulness of data obtained from the Tilley and Terry (TT) method had made it a widely used although it was not able to predict accurately the digestibility of tropical forages. Although it was designed to measure endpoint digestibility, it could also be used to assess the intermediate point of slowly-digested forages.

Over the years, the reagents used in the Tilley and Terry (TT) method have been modified to improve precision. The methodologies however, did not bring about modifications that improve the labour efficiency of assays or the running of multiple samples simultaneously in a single vessel (Holden, 1999).

2.3.2 In-vitro gas production technique (IVGPT)

In-vitro gas production technique (IVGPT) has been used for decades to simulate ruminal fermentation of feed and feedstuffs (Rymer et al., 2005). The basic principle of IVGPTs is to ferment feed under controlled laboratory conditions with the use of natural rumen microbes subjected to different treatments. They are incubated at 39 °C with a mixture of rumen fluid, buffer and minerals for a certain time period, typically 24, 48, 72, 96 or 144 h. The amount of total gas produced during incubation per gram of dry matter (DM) of feed samples degraded is measured (Storm et al., 2012; Wood and Badve, 2001).

In recent years, the increasing interest in greenhouse gas (GHG) emissions from agriculture has resulted in further studies and modification of the traditional IVGPTs to include measurement of methane production (Pellikaan et al., 2011). Analysis of the gas composition is done to measure the in-vitro production of methane (Storm et al., 2012).

Daisy II Apparatus; a new development by (ANKOM Technology corp, Fairport NY), allows multiple feed samples to be analysed simultaneously. This comes with great improvement in labour efficiency and the potential to improve the accuracy of assay. Holden (1999) compared the TT and Daisy II methods for predicting dry matter digestibility (DMD) with the buffer recommended by ANKOM for both systems. The results of his experiment showed good correlation between the two systems, proving that Daisy II could be used to predict the in-vitro dry matter digestibility of forages and grains.

2.3.3 Enzymatic in-vitro digestibility technique

Enzymatic in-vitro digestibility technique is used to measure protein and carbohydrate digestibility. Aufrere and Cartailler (1988) measured in-vitro degradability of feed proteins by incubating feed for 1h and 24 h using a phosphosborate buffer containing proteolytic enzyme extracted from Streptomyces griseus. Susmel et al. (1989) measured the in-vitro degradability of 16 ruminant feeds using this technique. His study revealed significant differences in the protease degradability values for many of the feeds at 1h and 24 h compared to those of the in-situ. The 1h values showed high correlation with the in-situ values while the 24h values were poorly correlated (Yu et al., 2000). Poos- Floyd et al. (1985) showed that increase in enzyme incubation time of feed decreases the correlation between the in-situ and in-vitro degradability. The influence of incubation time was attributed to the possible enzymatic inhibition caused by products of degradation due to the closed system used in in-vitro protein degradation (Krishnamoorthy et al., 1983; Crawford et al., 1978).

There was good correlation between the effective degradability in-situ and the obtained using proteolytic enzymes (Yu et al., 2000). The assessment of protein solubility using only buffers did not show similar high correlation with the in-situ values. (Krishnamoorthy et al., 1983; Poos-Floyd et al., 1985; Sauvant et al., 1987; Broderick et al., 1988). Similarly, it was found that protein solubility with only buffer cannot be used to predict protein degradation of concentrated feeds with good precision (Madsen and Hvelpund 1985). Single enzyme and broad spectra fungal and bacterial enzyme sources have also been used (Nocek, 1988) however, in-vitro degradability of protein using Aufrère method by enzymatic hydrolysis for 1h or an intermediate time of >1h and <24h has proved to be a promising laboratory procedure that can be used to predict the rate and extent of in-situ degradation with high accuracy (Yu et al., 2000).

Energy feed digestibility can also be predicted using enzymes. It is a two-step process. It involves first the pre or post treatment of feed using chemicals (HCl or detergent) and/or enzymes (amylase, pepsin, pronase) while the second step is the enzymatic action with the use of cellulase alone or a mixture with other enzymes (amylase and hemicellulose) (Aufrère and Michalet- Doreau, 1988). There are infinite variations for enzymatic degradability with different but little residual variation in standard deviation results obtained (De Boever et al., 1984). It is a simple method and its repeatability is satisfactory (Aufrère and Michalet-Doreau, 1988). The study carried out through the European Economic Community by Van Der Meer (1982, 1983) to evaluate repeatability of the enzymatic method showed little variations within the same laboratory but recorded large laboratory to laboratory variations amongst the 34 laboratories.

Enzymatic techniques give great precision in the measurement of protein and carbohydrate digestibility than is obtained from chemical or biological methods (Nocek, 1988). De Boever et al. (1984) in his study comparing 18 methods of enzymatic degradability on 31 concentrates with known digestibility showed that pepsin-cellulase gave the best predictions for enzymatic degradability.

ECONOMIC CONSIDERATION

Near Infra-red Spectroscopy (NIRS) in recent years, has been found to be preferable to traditional chemical methods as long as it is calibrated correctly. This is because it is more accurate, fast, with high precision and quite cost effective, although it has to be calibrated against already existing traditional methods. (France et al., 2000)

Amongst the digestibility methods, the in-vivo method (total collection technique) is the most reliable method of measuring digestibility of feed. Unfortunately, however, it has proved to be time consuming, laborious and expensive. It is not practical for all possible feeding situations in practice and is not possible to carry out as routine laboratory work (Zewdie, 2019; France et al., 2001).

The in-situ digestibility method is expensive, time consuming and requires the use of rumen fistulated animals (Wood and Badve 2001; Susmel et al., 1989). Its laboratory to laboratory repeatability and reproducibility is poor.

Few samples can be run at one time compared to the TT method. The in-situ technique is however, useful for evaluating kinetic rates of digestion in ruminants using multiple incubation times and computer models (Nocek, 1988). There is need for standardization of the process to obtain better digestibility predictions.

The in-vitro technique does not require the use of animal and as such is less time consuming and quite cost effective (Susmel et al., 1989). It has better reproducibility and repeatability because of there is better control over factors that causes variations. It also has high precision in predicting in vivo dry matter digestibility (Majbeesh et al., 2000). Majbeesh et al., (2000) studied to determine the reliability of the Daisy II method proved that the Daisy II method is easier and less time consuming to determine in-vitro dry matter digestibility than the TT method. He affirmed that it was useful to predict in vivo digestibility with relatively small variations.

The in-vitro gas production method is useful for feed ranking and has the potential to replace in-sacco and other existing in-vitro digestibility methods (Wood and Badve, 2001). Its high precision in assessing the daily production of methane (CH_4) also makes it one of the methods employed to determine the enteric emission of methane (a greenhouse gas) in ruminants

Digestion methods using enzymes have several advantages over those with ruminal microbes. They are low cost, less time consuming and do not require the use of cannulated animals. Comparative studies of several methods for estimating feed digestibility has revealed that enzymatic degradability gives more accurate results compared to in-vitro digestibility. (Van Der Meer, 1982; Mathiesien and Moller, 1983; De Boever et al.,1984).

ENVIRONMENTAL EFFECTS/ FOOTPRINT

Studies on the environmental foot prints of both chemical and digestibility methods are limited. Over the years, the in-vitro gas production method has been used to measure the emission of CH_4 (Methane); a Green House Gas from analysed feed sample with the aim of investigating mitigation strategies for methane emissions in ruminants. This makes the study of data on methane emission combined with rumen metabolism and digestibility possible (Johannes et al., 2011). This helps understand the correlation between Methane production and metabolism. There are similarly good methods such as the chamber method, CO_2, the Intergovernmental Panel on Climate Change (IPCC) and SF6 tracer techniques that are already been used for measuring and estimating methane emissions from ruminants (Storm et al., 2012).

CONCLUSIONS

Feed evaluation is of high importance in assessing the nutritive value of feed with the intent of optimizing animal performance. Several methods have been developed, evaluated and modified over the years to achieve this. Efficient utilization of feed and animal performance largely influences the total cost of feed. The economic impacts (advantages and disadvantages) of the individual methods and the potential of some evaluation techniques in assessing and possibly mitigating environmental foot prints is of additional value in the study of animal nutrition specifically and in agriculture as a whole.

REFERENCES

Aufrere J. & Cartailler D. 1988. Mise au point d'une méthode de laboratoire de prevision de la dégradabilité des protéines alimentaires des aliments concentree dans le rumen. *Ann. Zootech*., 37, 255-270.

Aufrere J. & Michalet-Doreau B. 1988. Comparison of methods for predicting digestibility of feeds. *Anim. Feed Sci. Technol.,* 20, 203-218.

Beever D. E. & Mould F. L. 2000. Forage evaluation for efficient ruminant livestock production. In: D.I. Givens, E. Owen, R.F.E. Axford and H.M. Omed (Editors), Forage Evaluation in Ruminant Nutrition. CABI Publishing, Wallingford, UK, pp. 15-42.

Broderick G. A., Wallace R. J., Orskov E. R. & Hansen L. 1988. Comparison of estimates of ruminal protein degradation by in-vitro and insitu methods. *J. Anim. Sci*., 66, 1739-1745.

Chumpawadee S., Chantiratikul A. & Chantiratikul P. 2007. Chemical composition and Nutritional evaluation of energy feeds for ruminant using in-vitro gas production technique. *Pakistan Journal of Nutrition*, 6(6), 607-612.

Church D. C. 1993. Ruminant Animal: Digestive Physiology and Nutrition. Oregon State University Press.

Cooke B.C. 1988. Evaluations of feed for Ration Formulation. *Proc. Nutr. Soc.,* 47(2), 135-41.

Crawford R. J. Jr., Hoover W. H., Sniffen C. J. & Crooker B. A. 1978. Degradation of feedstuff nitrogenin the rumen versus nitrogen solubility in three solvents. *J. Anim. Sci.,* 46, 1768-1775.

Chalupa W. 1975. Rumen Bypass and Protection of Proteins and Amino Acids. Journal of Dairy Science 58(8),1198-218 DOI: 10.3168/jds.S0022-0302(75)84697-2

De Boever J. L., Cottyn B. G., Vanacker J. M. & Buysse F. X. 1984. Test of different enzymatic methods on compound feeds. CEC Workshop on Methodology of Feedingstuffs for Ruminants.

Dijkstra J., Kebreab E., Bannink A., France J. & Lopez S. 2005. Application of the gas production technique to feed evaluation systems for ruminants. *Anim. Feed Sci. Technol.,*, 123-124(1), 561-578.

Ellis W. C., Lascano C. Teeter R. & Owens F. N. 1982. Solute and particle flow markers. pp 37 in protein requirements for cattle. F.N. Owens, ed. Syrup. at Oklahoma State Univ.,S tillwater.

France J., Theodorou M. K., Lowman L. S. & Beever D. E. 2000. Feeding systems and feed evaluation models: Feed evaluation for animal Production. Wallingford, Oxon, UK ; New York : CABI Pub. pp:3 -11

Henneberg, W. & Stohman, F. 1860. Begründung einer rationellen Ftterung der Wiederkäuer. Vol. 1. Schwetschtke u. Sohn, Braunschweig, Germany. P. 4

Holden L. A. 1999. Comparison of methods of in-vitro dry matter digestibility for ten feeds. *J. Dairy Sci.,* 82, 1791-1794.

Johannes M., Lund P., Weisbjerg M. R., Hellwing A. L. F. & Hvelplund T. 2011. The effect of different physical forms of rapeseed as fat supplement on rumen NDF digestion and methane emission in dairy cows. *Adv. Anim. Biosci.,* (2), 516.

Krishnamoorthy U., Sniffen C. J., Stern M. D. & Van Soest P. J. 1983. Evaluation of a mathematical model of rumen digestion and an in-vitro simulation of rumen proteolysis to estimate the rumen undegraded nitrogen content of feedstuffs. *Br. J. Nutr*., 50, 555-568.

Landau S., Glasser T. & Dvash L. 2006. Monitoring nutrition in small ruminants with the aid of near infrared reflectance spectroscopy (NIRS) technology: A review. *Small Ruminant Research*, 61, 1-11.

Lindberg J. E. 1981. The effect of basal diet on the mminal degradation of dry matter, nitrogenous compounds and cell walls in nylon bags. *Swed. J. Agric. Res*., 11, 159.

Lucas H. L. 1964. Stochastic elements in biological models; their sources and significances, in: Gurland, J. (Ed.), Stochastic models in medicine and biology. University of Wisconsin Press, Madison, pp. 355-383.

Mabjeesh S. J., Cohen M. & Arieli A. 2000. Nutrition, feeding and calves (In-vitro methods of measuring the dry matter digestibility of ruminant feedstuffs: Comparison of methods and inoculum source. *J. Dairy Sci.*, 83(10), 2289-2294.

Madsen J. & Hvelplund T. 1994. Prediction of in situ protein degradability in the rumen. Results of a European ring test. *Livestock Production Science*, 39, 201-212.

Madsen J. & Hvelplund T. 1985. Protein degradation in rumen. A comparison between in vivo, nylon bag, in-vitro and buffer measurements. *Acta Agric. Scand.*, 25 (suppl.), 103-124.

Mathiesen H. P. & Moiler J. 1983. Enzymatisk in-vitro oploseligһed. *Beretning*, 108: 1-17.

Nocek J. E. 1988. In Situ and Other Methods to Estimate Ruminal Protein and Energy Digestibility: A Review. *J. Dairy Sci*., 71, 2051-2069.

NRC, 1985. National Research Council. Ruminant Nitrogen Usage. National Academy Press, Washington DC. ISBN: 0-309-03597-X Osbourn D.F. & Terry R.A. 1977. In-vitro techniques for the evaluation of ruminant feeds. *Proc. Nutr. Soc.*, 36(2), 219-225.

Ørskov E. R. & McDonald I. 1979 The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. Journal of Agricultural Science, 92: 499-503.

Pellikaan W. F., Hendriks W. H., Uwimana G., Bongers L. J. G. M., Becker P. M. & Cone J. W. 2011. A novel method to determine simultaneously methane production during in-vitro gas production using fully automated equipment. *Anim. Feed Sci. Technol.*, 168(3-4), 196-205.

Poos-Floyd M., Klopfenstein T. & Britton R.A. 1985. Evaluation of laboratory techniques for predicting ruminal protein degradation. *J. Dairy Sci.*, 68, 829-839.

Orskov E. R., and McDonald, P. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. *Journal of Agricultural Science (Cambridge)*, 92, 499-503. doi:10.1017/S0021859600063048

Rymer C., Huntington J. A., Williams B. A. & Givens D. I. 2005. In-vitro cumulative gas production techniques: History, methodological considerations and challenges. *Anim. Feed Sci. Technol.*, 123-124(1), 9-30.

Sauvant P., Aufrere J., Michalet-Doreau B., Giger S. & Chapoutot P. 1987. Valeur nutritive des aliments concentres simple: tables et prevision. *Bull. Tech.* CRVZ Theix 70, 75

Solaiman S. G., Marty F. A. Belyea R. L. & Weiss M. F. 1982. Effect of diet composition and forage particle size on cell wall digestion rates of alfalfa and orchard grass in situ. *J. Dairy Sci.*, 65(Suppl. 1), 144. (Abstr.)

Storm I. M., Hellwing A. L., Nielsen N. I. & Madsen J. 2012. Methods for Measuring and Estimating Methane Emission from Ruminants. *Animals*, 2(2), 160-183.

Susmel P., Stefanon B., Mills C. R. & Colitti M. 1989. The evaluation of PDI concentrations in some ruminant feedstuffs: a comparison of in situ and in-vitro protein degradability. *Ann. Zootech.*, 38, 269-283.

Van Der Meer J. M. 1982. European "in-vitro" ring test. Manuel, CEC Workshop on Methodology of Feeding stuffs for Ruminants.

Van Der Meet J. M. 1983. European "in-vitro" ring test. Statistical report, CEC Workshop on Methodology of Feeding stuffs for Ruminants.

Van Soest P. J. & Marcus W. C. 1964. Method for the determination of cell-wall constituents in forage using detergent and the relationship between this fraction and voluntary intake and digestibility. Abstr. *J. Dairy Sci.,* 17, 704.

Van Soest, P. J. & Wine, R. H. 1967. Use of Detergents in the Analysis of Fibrous Feeds. IV. Determination of Plant Cell-Wall Constituents. *Journal of the Association of Official Analytical Chemists,* 50, 50-55.

Volden H. 2011. NorFor - The Nordic feed evaluation system. EAAP Publications No 130, Wageningen Academic Publishers, The Netherlands, 180p.

Weakley D. C., Stern M. D. & Satter L. D. 1983. Factors affecting disappearance of feedstuffs from bags suspended in the rumen. *J. Anim. Sci.* 56, 493-507.

Whitelaw F. G., Eadie J., Bruce L. A. & Sand W. J. 1984. Microbial protein synthesis in cattle given roughage concentrate and all concentrate diets: the use of 2, 6-diaminopimelic acid, 2-aminothylphosphonic acid and 3SS markers. *Br. J. Nutr.*, 52, 249.

Wood C. D. & Badve V. C. 2001. Recent developments in laboratory methods for the assessment of ruminant feeds, science booklet. BAIF Development Research Foundation and Natural Resources Institute UK, Pune, India. 14pp.

Yu P., Egan A. R. & Leury B. J. 2000. Predicting in sacco rumen degradation kinetics of raw and dry roasted faba beans (Vicia faba) and Lupin seeds (Lupinus albus)by laboratory techniques. *Asian-Aus. J. Anim. Sci.,* 13(10), 1377-1387.

Zewdie A. K. 2019. The Different Methods of Measuring Feed Digestibility: A Review. *E C Nutrition*, 14 (1), 68-74.

Eurasian Journal of Agricultural Research 2019; Vol: 3, Issue: 2, pp: 58-66

The Use of Agricultural Crop Residues as Alternatives to Conventional Feedstuffs for Ruminants: A Review

Muhammad Zeeshan AKRAM, Sema YAMAN FIRINCIOĞLU*

Niğde Ömer Halisdemir University, Faculty of Agricultural Sciences and Technologies, Animal Production and Technologies Department, 51240 Niğde, TURKEY

**Corresponding author: semayaman@ohu.edu.tr*

Abstract

The development and application of modern technology for upgrading crop residues has stimulated great interest in developing countries. Researchers are working on the development of crop residues particularly vegetable discarded leaves in agriculture fields as feed, with emphasis on improving their intake and digestibility in ruminants. Despite much research at universities and research stations, farmer uptake and utilization of the residues is still minimal. Reasons for this include the difficulty of transporting and storing crop residues, insufficient trials at farmer level, inappropriate technology and absence of agriculture extension services. Literature showed that crop residues have good nutritive values of crude protein (CP), metabolizable energy (ME), total digestible nutrients (TDN) and mineral contents. Results of various studies demonstrated that cereal straws and vegetable leaves from field crops and non-conventional feed resources had a significant influence on the growth performance of ruminants. The literature further revealed that vegetable leaves could be stored in the form of silage and hay and they have the potential to be used as alternative forage in the ruminant ration. This review summarizes the data of Turkey and Pakistan related to animal feed resources and availability of forage, problems associated with utilization of crop residues and recommendations about the offering of agriculture field crop residues and wastes to animals as alternatives to conventional feedstuffs.

Keywords: livestock, ruminants, crop residues; agriculture

Review article

Accepted: 25 November 2019

INTRODUCTION

There are two types of crop residues which include agriculture field crop residues and agro-industrial process residues. Agriculture field crop residues are materials left in an agricultural field or orchard after the crop has been harvested. These residues include leaves, tuber and bulbs, stems, stover, straws and sea pods (Mottet et al., 2017; Owen and Jayasuriya, 1989). The utilization of crop residues as roughages has been the subject of intense research worldwide since the 1970s. Despite this, there appears little evidence that large research has resulted in great utilization of crop residues in developing countries (Owen and Jayasuriya, 1989). When the field crops are harvested, crop residues become available. For instance, when cabbage is harvested, discarded leaves comprise up to 6 tons of edible dry matter (DM) per hectares. In the Niğde province of Turkey, approximately 109000 tons of cabbage is produced annually. Out of this only 11% is being used for livestock feed (Personal Communication). Often markets collapse (e.g. potatoes) and it is too expensive to send products to market and this "waste" (crop residue) becomes available for animal feeding. Carrots damaged at harvesting or discarded because of poor quality, comprise a good ruminant feed when fed with carrot tops. After getting grains, wheat and rice straws and maize stover become available in the field for animal feeding (Sarnklong et al., 2010; Gertenbach and Dugmore, 2004). Plowing or burning of crop residues is the first approach of farmers after harvesting. Composting the residues is another alternative. The decision to plow the residues into the soil or composting them should be changed. These crop residues can be stored for the time of drought and feed shortage periods. Low nutritional value is more important than unavailability and relatively higher costs of feeds could make crop residues a viable option (Gertenbach and Dugmore, 2004). The human population explosion is a source of worry throughout the world. Food shortages and famine are becoming endemic in many places. The population explosion is associated with a reduction in farmable land. Future population pressure in developing countries will require greater utilization of crop residues as animal feed. Feeding grains to ruminants is questioned because human and monogastric animals can utilize them better than roughages. On the other hand, the value of ruminants lies in their ability to change low-quality feed into high-quality products. This happens due to the symbiotic relationship between ruminant animals and rumen microflora. Rumen microbes can degrade the cell wall which is fibrous in nature. The second reason behind the utilization of crop wastes and residues is that most of the countries do not have enough fodder availability to meet the demand of animals. Round a year, in some months a fodder shortage is unavoidable therefore crop residues can be the best alternatives of fodders. This review enhances the importance of using agriculture field crop residues as animal feed to cope with the requirement of animals, particularly in draught and feed shortage periods. It also describes the present status, ongoing advances and future perspectives about the utilization of crop residues as an alternative to conventional feedstuffs. Problems and recommendations are discussed for sustainable animal production in these countries.

Status of Crop Residues in Turkey and Pakistan

Turkey is located between Europe and Asia has a total area is 78.35 million hectares (MH) of which 76.96 MH is a land area. The total agriculture land is decreasing gradually for the last two decades. Total utilized agricultural land is 37.80 MH of which 18.93 MH for cereals and other crop products, 0.784 MH for vegetable gardens, 0.005 MH for ornamental plants, 3.462 MH for fruits, beverages and spice crops and 14.62 MH land under permanent meadows and pastures (TUIK, 2018). The share of animal husbandry in Turkey’s agriculture sector is about 30%. Most of the livestock depend on rangelands and harvest residues for feeding during grazing seasons. Rangelands are very important particularly during crop growing seasons due to the unavailability of artificial pastures or feed resources for extensive animal husbandry during these periods. Turkey’s ruminant population consists of 17,042,506 cattle, 46,117,399 small ruminants (TUIK, 2018). Cattle number has not changed significantly, but the small ruminant number decreased seriously from 1985 to 2010. After 2010, the small ruminant number is gaining boost and increasing gradually. Due to advance agricultural techniques and mechanization, equids number decreased in the country. Turkey has more than 10 million animal units and round a year roughage demand is about 37 million tons (Holechek et al., 2004). The average altitude of Turkey is about 1000 meter and the grazing season for animals is merely 180 days (Altin et al., 2011). Out of 10 million animal units (AU), about 7.5 million AU are getting their feed from rangelands and approximately their demand is 13.5 million tons (MT) of roughages. The contribution of rangelands in Turkey is about 7.6 MT of roughages but that amount is far away to cover demands of animal (Koc et al., 2012). There is a huge gap in the supply and demand of roughages during the grazing season in Turkey. This demand is accomplished with the help of poor quality feed stubble, fallow fields and understory vegetation. Roughly, 2.65 million AU ruminants especially cattle are reared in the intensive system and their roughages demand during the summer season reached 4.75 MT. On the other side, in winter, 18.75 MT of roughages are required and the total roughage need for intensive rearing system is about to 25.5 MT. The total production from hay lands (meadow plus forage crop cultivation) is about 13.3 MT in the country. Accumulatively, there is a 12 MT roughage gap in Turkey in summer and winter. There are some alternative roughage sources, such as vegetable residues, sugar beet leaf and pulp and fruit garden understory, which account for an amount of about 5.0 million tonnes. Finally, 7.2 MT of the roughage gap is compensated by cereal straw (Koc et al., 2012).

The total area of Pakistan is 79.61 MH and only 21.86 MH are available for cultivation. Out of 21.86 MH, only 14% area has been used for fodder production. Another area is being used for rice (12%), sugarcane (3%), oilseeds (3%), pulse (3%), maize (5%) and other (8%). Feed resources for animals in Pakistan are rangelands (38%), fodder/crop residues (51%), oil cakes (2%), cereal by-products (6%), and post-harvest grazing (3%) (Sarwar et al., 2002). Livestock having share of 58.92 % in agriculture and 11.11 % in Gross Domestic Product (GDP), recorded a growth of 3.76 % compared to 2.99 % during the corresponding period last year. Pakistan has two cropping seasons, ″Kharif″ being the first sowing season starting from April-June and is harvested during October-December. Rice, sugarcane, cotton, maize, moong, mash, bajra (millet) and jowar (sorghum) are “Kharif" crops. ″Rabi″, the second sowing season, begins in October-December and is harvested in April- May. Wheat, gram, lentil (masoor), tobacco, rapeseed, barley, and mustard are "Rabi" crops. Pakistan's agricultural productivity is dependent upon the timely availability of water (Pakistan Economy Survey, 2018). Currently, 196.1 million heads of animals in Pakistan are deficient of 38.10 and 24.02% of CP and TDN respectively (Sarwar et al., 2002). Pakistan is producing 52 MT fodder and 43 MT of crop residues annually. Pakistan is producing fodder like 22 MT of berseem, 6.3 MT of sorghum, 5.3 MT of lucern, 3.05 MT of guar, 1.4 MT of sadabahar, 0.9 MT of maize, 0.7 MT of millet, 03 MT of mustards and 11 MT of others. On the other side, crop residues production is 16 MT of wheat straws, 4 MT of rice straw and husk, 1.5 MT of maize stover and 21.5 MT of others (Sarwar et al., 2002). Feed resources in Pakistan are green fodder, crop residues, grazing lands, cereal by-products, cakes, and meals. Fig-1 shows the average fodder availability per animal per day is 6-7 kg but it becomes less in extreme summer and winter (Hanjra et al., 1995). To meet with the requirement of animals for their maintenance and production levels, crops residues, forages and their conservations (silage and hay) would be the best options (Sarwar et al., 2002).

Problems associated with crop residues

Crop residues have less nutritive values as compared to fresh green fodders. For example, straws have only 4-5% average crude protein and 1.5-1.6 Mcal/kg ME. If we talk about fresh leaves of vegetables especially cabbage, cauliflower, potatoes, and carrot, we can find an average of 16-17% crude protein (as % of their DM) and 1.8-1.9 Mcal/kg ME, which is sufficient for maintenance requirement of animals. It will be a good idea to use vegetable fresh leaves as alternatives to fodder in feed shortage times. In the matter of crop residues, farmers confront many problems. The use of residues is still minimal due to some reasons including storage issues, transportation problems, lack of awareness and knowledge about the nutrient value and potential use of crop residues, absence of agriculture extension services, lack of advanced technology and insufficient trials at farmer levels (Lukuyu et al., 2011; Devendra and Leng, 2011; Anandan and Sampath, 2012; Loehr, 2012). Farmers do not have proper guidance to handle and store the residues. When they harvest, either they plow the residues with soil or burn them.

Animals face problems when we offer feed to them without calculation. Same in the case of crop residues, leaves of some leguminous plants may cause metabolic disorders like bloat (Wadhwa and Bakshi, 2013; Njidda, 2010; Soetan and Oyewole, 2009). Most of the residues possess anti-nutritional factors. Some crops have mineral deficiencies, i.e. Brassica family is deficient from Iodine. It is a goitrogenic crop, if we will not offer iodine supplements with them. Sometimes, ruminants graze on turnip, tuber, bulbs and maize cobs (Wadhwa et al., 2006; Cassida et al., 1994). These large pieces of food stuck into the esophagus and block the digestive pathway. In Table 1, we have summarized some anti-nutritional factors in various crops and their effects on animals.

Experimental reviews about the usage of crop residues as feed

The effects of feeding brassica vegetable leave on feed intake, body weight changes in goats were evaluated. Goats were fed four diets from cabbage, cauliflower, Chinese cabbage with Para grass. Due to low DM content, feed intakes of cabbage and Chinese cabbage groups were lower. The highest feed intake and body weight gain were obtained in the cauliflower group (Ngu and Ledin, 2005).

El-Shinnawy et al. (2011) designed a study to examine the possibility of utilizing cabbage wastes as an unconventional feed source for ruminant feeds and tried to improve its nutritive values by hay and silage making. The effect of urea solution either sprayed or ensiled of cabbage hay and silage making with or without urea adding as a processing technique were also investigated. The experiment was conducted on Rahmani rams using simple technologies for improving the nutritive value of cabbage. The results indicated that all cabbage wastes silages were excellent, had a normal value of pH (3.82 to 4.12) with the superiority of silage untreated with urea. The overall means of total volatile fatty acids (TVFA's) concentration for the two silages ranged from 2.15% for urea un-treated silage to 2.45% for urea treated silage. The urea un-treated silage recorded the least concentration of NH3-N (1.65%). Ensiling either with or without urea resulted in higher ($P<0.05$) digestion coefficients of organic matter (OM), CP, crude fiber (CF), nitrogen-free extracts (NFE), neutral detergent fiber (NDF), acid detergent fiber (ADF) and cellulose. These results indicated that feed intake and utilization of cabbage wastes hay could be improved by 1% urea treatment with the superiority of the ensiling process than the spraying method.

The nutritional worth of crop residues and wastes such as cauliflower leaves, cabbage leaves, pea pods, and pea vines was evaluated in comparison to conventional green oats fodder in bucks. The leaves of cauliflower and cabbage had low *($P<0.05$)* concentration of cell wall constituents, but high *(P<0.05)* concentration of CP, except that CP of pea pods was comparable with cabbage leaves. Cabbage leaves had the highest (20.6%) and pea pods had the lowest (4.8%) concentration of water-soluble sugars. Cauliflower leaves had the highest concentration of phenolic (5.9%), comparable with cabbage leaves, but the lowest concentration was observed in pea pods (0.3%). Digestibility of nutrients except that of NDF was comparable in cabbage and cauliflower leaves, but higher *(P<0.05)* than in other vegetable wastes and conventional green oats fodder. Microbial protein synthesis was high *(P<0.05)* in animals fed cauliflower leaves followed by those fed pea pods and low in bucks fed pea vines. The ME value of both cabbage and cauliflower leaves was significantly higher than that of pea vines (Wadhwa et al., 2006).

Similarly, in another study, tyfon (turnip x Chinese cabbage hybrid) was increased in the diet; there was a linear increase in ad libitum dry matter intake (DMI), total water intake, digestible DMI, and apparent digestibility of DM, CP, and neutral detergent soluble. Plasma thyroxine and triiodothyronine, packed cell volume, red blood count, and haemoglobin concentration were not affected by diet. Tyfon influenced DMI and the apparent digestibility of diets like that of a concentrate (Cassida et al., 1994).

In another study, broccoli was used as a substitute for concentrates in dairy cattle. It had no significant influence on milk protein, lactose, total solids or solids-not-fat. However, a significant increase was found in milk fat content. These results indicated that broccoli could be included in dairy cattle diets at a suitable level to replace concentrate mixture without any adverse effects on dairy performance (Yi et al., 2015).

A study was also conducted to determine the effect of dietary inclusion of discarded cabbage leaves on the intake and growth performance of lambs. Results revealed that lamb growth performance and the feed conversion rate was reduced as the level of cabbage in the diet increased. Nitrogen intake and retention were lower in lambs fed diets containing cabbage. As a result of this experiment discarded cabbage can be included in finishing diets for lambs but reduced animal performance can be expected (Nkosi et al., 2016).

Leaves of Brassica family particularly cabbage leaves can be used as roughage in the form of silage and hay. In a study, Rezende et al. (2015) made cabbage silage treated with 600 g kg^{-1} and 400 g kg^{-1} of ground corn. They recommended that the application of 400 g kg^{-1} ground corn was enough to improve the silage quality, whereas the use of the inoculant is unnecessary.

Similarly, Megersa et al. (2013) investigated the effects of substituting sweet potato leaves for concentrate on growth performance, digestibility, and carcass characteristics of bucks. Results revealed that DMI, CP intake, DM digestibility, and weight gain increased due to supplementation of sweet potato leaves in the diet. The slaughter weight, empty body weight, hot carcass weight, dressing percentage, rib-eye muscle area, and total edible offal were higher in supplemented goats compared to the un-supplemented. It could be concluded that sweet potato vine can replace the conventional concentrate and could be fed with poor quality hay to prevent body weight loss of an animal in the absence of other feed supplements.

Likewise, another study was carried out on Kurdish mature rams to determine the chemical composition, mineral content, nutrient digestibility and metabolizable energy (ME) of potato vine compared with alfalfa hay as reference forage in ruminants. Results indicated that DM, ash, minerals and NDF digestibility of potato leaves were significantly higher than alfalfa hay. NDF, ADF organic digestibility, and ME of potato leaves were lower than the alfalfa hay. It can be concluded that potato leave has high nutritive value and therefore they can be used as alternative forage in ruminant nutrition (Salehi et al., 2014).

CONCLUSION AND RECOMMENDATIONS

Crop residues are a valuable source of animal feed and utilizing the residues by grazing is very effective in returning plant nutrients to the soil. In the USA, pigs are often used with cattle to utilize crop residues, whereas, in South Africa, beef cattle alone or cattle with sheep are more commonly used. Sweet potato vine and broccoli by-products can replace the conventional concentrate and could be fed with poor quality hay to prevent body weight loss of an animal in the absence of other feed supplements. Literature also demonstrates that vegetable leaves especially cabbage, cauliflower and potatoes can be used as alternative forage in ruminant nutrition. Crop residues are low quality feeds and should be retained for non-lactating cows, beef cattle and sheep. Supplementations must be used to enhance the nutritional value of residues. Efforts should be made to help the farmers to solve their feed problems mainly focus on improving methods of harvesting, handling, processing and incorporating crop residues into a year-round feed budget. Do not destroy burn and plow the vegetable leaves in agriculture fields. Crop residues have less nutritive values as compared to green fodders. Animals should be provided with supplementations while offering crop wastes and residues particularly with those nutrients/minerals which are deficient in crops. Crop residues can be offered with highly nutritive fodder and concentrate to cope up the deficiencies. These could be used as alternatives to roughages in lean and feed shortage periods. Previous data demonstrate that animals showed good results when they fed cabbage and other vegetable leaves as fresh fodder or in the form of silage/hay. It is concluded that agriculture field crop waste and residues like cabbage leaves, cauliflower leaves, and pea pods could serve as an excellent source of nutrients for ruminants and can economize the production of animals. These results introduce several applicable techniques towards making the best use of crop residues as good unconventional feedstuffs for ruminant equivalent to any conventional feed like clover hay, maize silage or fresh fodder.

REFERENCES

Altin M., Gokkus A. & Koc A. 2011. Meadow and Range Management. I. General Principles. Ministry of Agriculture and Rural Affairs Publ., p. 376 (in Turkish).

Anandan S. & Sampath K. T. 2012. The Indian feed inventory. National Feed Assessments, p.75.

Cassida, K. A., Barton, B. A., Hough, R. L., Wiedenhoeft, M. H. & Guillard K. 1994. Feed intake and apparent digestibility of hay-supplemented brassica diets for lambs. *Journal of Animal Science*, 72(6), 1623-1629.

Devendra C. & Leng R. A. 2011. Feed resources for animals in Asia: issues, strategies for use, intensification and integration for increased productivity. *Asian-Australasian Journal of Animal Science*s, 24(3), 303-321.

El-Shinnawy A. M., El-Afifi T. M., Fatma M. S. & El-Shinnawy M. M. 2011. Using simple technologies for improving the nutritive value and proper utilization of cabbage wastes as ruminant feed. In Proceedings of the 4th Scientific Conference of Animal Wealth Research in the Middle East and North Africa, Foreign Agricultural Relations (FAR), Egypt, 3-5 October 2011, pp. 475-490. Massive Conferences and Trade Fairs, 2011.

Gertenbach W. D. & Dugmore T. J. 2004. Crop residues for animal feeding. *South African Journal of Animal Science*, 5, 49-51.

Hanjra S. H., David J.B. & Akhtar M. J. A. 1995. Fodder Production. FAO, PAK / 88 /072. Smallholder dairy development in Punjab.

Holechek J. L., Pieper R. D. & Herbel C. H. 2004. Range Management Principles and Practices. Pearson Education Inc., NJ, 607 p.

Koc A., Tan M. & Erkovan, H. I. 2012. An overview of fodder resources and animal production in Turkey. Options Mediterranean, SerieA/102, New approaches for grassland research in a context of climate and socio-economic changes. Zaragoza, CIHEAM, pp.15-22.

Loehr R. 2012. Agricultural waste management: problems, processes, and approaches. C Loehr (ed), 1st edition, Elsevier.

Lukuyu B., Franzel S., Ongadi P.M. & Duncan A.J. 2011. Livestock feed resources: Current production and management practices in central and northern rift valley provinces of Kenya. *Livestock Research for Rural Development*, 23(5), 112.

Megersa T., Urge M. & Nurfeta, A. 2013. Effects of feeding sweet potato (Ipomoea batatas) leaves as a supplement on feed intake, growth performance, digestibility and carcass characteristics of Sidama goats fed a basal diet of natural grass hay. *Tropical Animal Health and Production*, 45(2), 593-601.

Mottet A., de Haan C., Falcucci A., Tempio G., Opio C. & Gerber, P. 2017. Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. *Global Food Security*, 14, 1-8.

Ngu N. T. & Ledin, I. 2005. Effects of feeding wastes from Brassica species on the growth of goats and pesticide/insecticide residues in goat meat. *Asian-Australasian Journal of Animal Sciences*, 18(2), 197-202.

Njidda A. A. 2010. Chemical composition, fibre fraction and anti-nutritional substances of semi-arid browse forages of North-Eastern Nigeria. *Nigerian Journal of Basic and Applied Sciences*, 18(2), 181-188.

Nkosi B. D., Meeske R., Ratsaka M. M., Langa T., Motiang M. D. & Groenewald, I. B. 2016. Effects of dietary inclusion of discarded cabbage (Brassica oleracea var. capitata) on the growth performance of South African Dorper lambs. *South African Journal of Animal Science*, 46(1), 35-41.

Owen E., & Jayasuriya M.C.N. 1989. Use of crop residues as animal feeds in developing countries. *Research and Development in Agriculture*, 6 (3), 129-138.

Pakistan Economy Survey 2018. http://www.finance.gov.pk/survey/chapters_18/02-Agriculture.pdf

Rezende A. V. D., Rabelo C. H. S., Silva M. R. M. D., Härter C. J. & Veiga, R. M. 2015. Wasted cabbage (*Brassica oleracea*) silages treated with different levels of ground corn and silage inoculant. *Revista Brasileira de Zootecnia*, 44(8), 296-302.

Salehi S., Lashkari S., Abbasi R. E. & Kamangar, H., 2014. Nutrient digestibility and chemical composition of potato (Solanum tuberosum L.) vine as alternative forage in ruminant diets. *Agricultural Communications*, 2(1), 63-66.

Sarnklong C., Cone J. W., Pellikaan W. & Hendriks W. H. 2010. Utilization of rice straw and different treatments to improve its feed value for ruminants: A review. *Asian-Australasian Journal of Animal Sciences*, 23(5), 680-692.

Sarwar M., Khan, M. A. & Iqbal Z. 2002. Status paper feed resources for livestock in Pakistan. *International Journal of Agriculture and Biology*, 4(1), 186-192.

Soetan K. O. & Oyewole, O. E. 2009. The need for adequate processing to reduce the anti-nutritional factors in plants used as human foods and animal feeds: A review. *African Journal of Food Science*, 3(9), 223-232.

TUIK, 2018. Annuals of Turkey Statistics.

Wadhwa M., & Bakshi, M. P. S. 2013. Utilization of fruit and vegetable wastes as livestock feed and as substrates for generation of other value-added products. FAO, Rome. Rap Publication, 4.

Wadhwa M., Kaushal S. & Bakshi M. P. S. 2006. Nutritive evaluation of vegetable wastes as complete feed for goat bucks. *Small Ruminant Research*, 64(3), 279-284.

Yi X. W., Yang F., Liu J. X. & Wang J. K. 2015. Effects of replacement of concentrate mixture by broccoli byproducts on lactating performance in dairy cows. *Asian-Australasian Journal of Animal Sciences*, 28(10), 1449-1453.

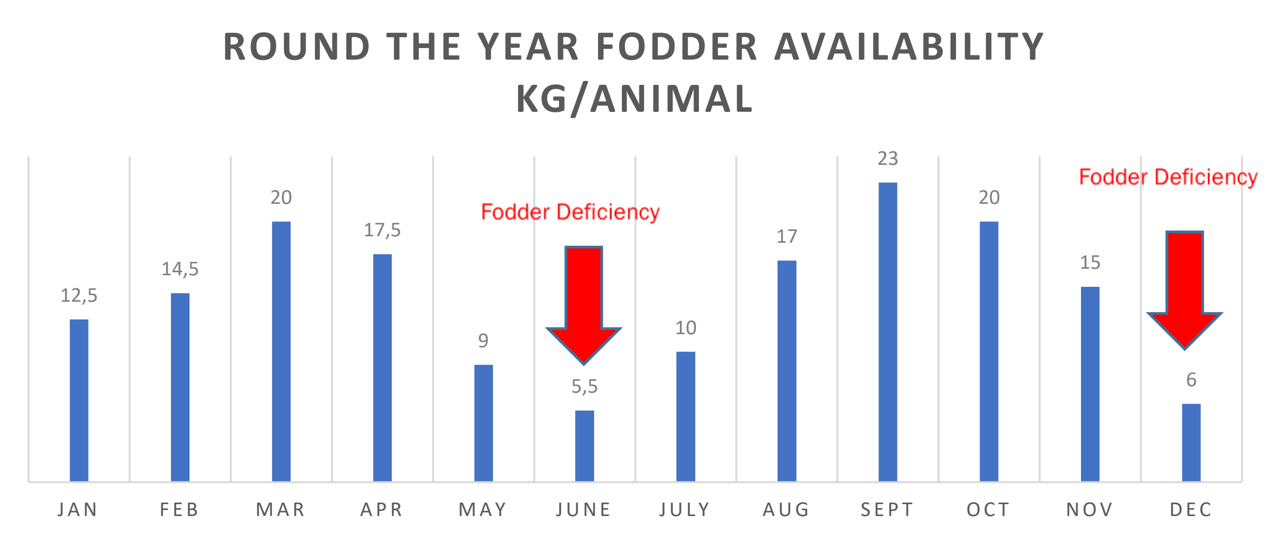

Fig 1. Round the year fodder availability per kg per animals in Pakistan

Table 1. Anti-Nutritional Factors (ANF) in various crop residues

Item	ANF	Effects
Sorghum	Prussic acid, Tannin, Glycosides	Respiratory dysfunction, Bind with protein and stop the digestion
Soybean	Trypsin inhibitor, Lectins	Protein digestion impairment, Haemagglutinins
Potatoes leaves	Trypsin inhibitor, Cyanogen, Glycoalkaloids, Nitrates	Protein digestion impairment, Respiratory dysfunction, gastrointestinal and neurological disorders and disturbance in hemoglobin function
Brassicas	Phenolics, Glucosinolates, Isothiocyanate	Fatty liver disease, Taint milk, Thyrotoxic, Goitrogenic, Poor growth
Vegetable leaves	Nitrates, phytate, Glucosinolates, Phenolic content, Mineral deficiency	Disturbance in hemoglobin function, Chelate formation with minerals,
Rice and rice straw	Phytate, Lectins	Chelate formation with minerals, Haemagglutinins

Eurasian Journal of Agricultural Research 2019; Vol: 3, Issue: 2, pp: 67-74

Use of Herbal Food Additives in Fisheries

Mustafa ÖZ

Department of Fisheries and Diseases, Faculty of Veterinary Medicine, Aksaray University, Aksaray, Turkey,

Corresponding author: ozmustafa@aksaray.edu.tr

Abstract

The use of vegetable products to prolong the shelf life of fish in addition to as a functional feed additive in aquaculture is expected to increase significantly in the near future. In parallel with the increasing world population, the inability to increase fisheries has made it inevitable to meet the aquaculture needs from aquaculture and this has led to the continuous increase of aquaculture and to reach a great market potential. Synthetic feed additives and antibiotics used unconsciously have become a major problem with the increase in aquaculture and in many countries restrictions on antibiotic use have been imposed. As a result of these restrictions, interest in functional feed additives has increased. It has been shown in many studies that it may be appropriate to use herbal products as an alternative to antibiotics and synthetic substances used as growth enhancers in aquaculture. Natural products, such as medicinal plants, can be widely used as feed additives to improve the efficiency of feed use and increase animal production performance. This study aims to promote the use of medicinal plants as an alternative to chemical products in the aquaculture sector.

Keywords: Aquaculture, medicinal plants, feed additives

Review article

Accepted: 25 November 2019

INTRODUCTION

The aquaculture sector is among the fastest growing sectors in many world countries. This growth in the sector stems from aquaculture rather than hunting. The amount of fisheries hunting remains the same or decreases from year to year. However, there is a continuous increase in aquaculture. When the aquaculture areas are examined in detail, it is seen that the largest production areas that contribute positively to the growth of the sector are marine areas or reservoir.

One of the most important elements in aquaculture has been the principle of obtaining the highest yield from the unit area and unit feed since the aquaculture areas began to shrink and feed costs increased. In addition, the quality of the obtained seafood as well as the preservation of freshness is very important.

The use of many chemicals and antibiotics is quite common in fish farming with the fight against diseases. The use of antibiotics is highly criticized for causing the development of antibiotic-resistant bacterial strains, suppression of the immune system of fish, environmental pollution and the accumulation of chemical residues in fish tissues that may harm public health. For these reasons, the interest of the aquaculture industry in plant resources is increasing day by day (Dikel, 2015).

In recent years, the use of feed additives in fish feeds to increase production has become widespread. The additives added to feeds increase the digestibility of the feed while reducing the effects of anti-nutritional factors. In addition, it plays a role in fish gaining resistance to diseases. It is desirable that probiotics to be used as feed additives should be non-pathogenic, should not produce toxic substances, should maintain their viability during storage and have high interaction with nutrients in the structure of the feed (Yıldırım et al., 2013).

Herbal additives in aquaculture are used for many purposes to increase the growth parameters of fish, to develop resistance to diseases, to improve meat quality, to increase fatty acid profile and to prolong shelf life.

When analyzing plant bioactivity according to the purpose of use in fish farming, studies with plant sources, 36% for antibacterial activity, 17% antiparasitic activity, 16% immunostimulatory activity, 14% antiviral activity, 13% growth promoter and only 4% were used for antifungal activity (Reverter et al., 2017).

In a study on this subject, it has been reported that the herbal additives used in aquaculture can be used for purposes such as Antibiotic, phytotherapy, immunostimulant effect, growth enhancer, tranquilizer in aquaculture, anesthetic agent, improving meat quality, gaining taste and odor and prolonging shelf life (Dikel, 2019). In this study, the purpose and manner of the use of herbal products, which have recently gained importance in terms of aquaculture, are summarized.

Antibiotic Use of Plant Resources in Aquaculture

Antibiotics produced from natural sources or synthetically produced can be defined as substances capable of inhibiting or killing the growth of microorganisms (Romero et al., 2012). In aquaculture, antibiotics at the therapeutic level are often administered orally to fish, often for a short time to groups of fish that share ponds, tanks or cages (Defoirdt et al., 2011).

All medicines used legally in aquaculture must be approved by the governmental authority for veterinary medicine (e.g the US Food and Drug Administration). For example, in the United

States, the following antimicrobials are authorized for use in aquatic culture: oxytetracycline, florfenicol, and sulfadimetoxine / ormetoprim. These regulatory agencies may establish rules for the use of antibiotics, including permissible delivery routes, dosage forms, withdrawal times, tolerances, and dose rates and limitations, the use of species. The most common way to deliver antibiotics to fish is by mixing the antibiotic with a specially formulated feed (Dawood et al., 2018). Recently, with the effect of some restrictive and limiting factors, the aquaculture sector has been focusing on herbal solutions that serve the same purposes instead of medicaments (medicines and chemicals with therapeutic protective and growth-enhancing effects) they have to use in production (Dikel, 2015). The use of medicinal plants in aquaculture has attracted worldwide attention and has become an active scientific research topic (Galina et al., 2009; Chakraborty and Hancz, 2011; Harikrishnan et al., 2011a). Bulfon et al. (2013) examined the use of phytomedicins on fish species in 105 scientific publications published in the literature from 1998 to 2011. In particular, 83% of these surveys were conducted between 2006 and 2011, while 15% were conducted between 2001 and 2005. Relatively few studies were conducted before 2001.

An important alternative to antibiotics is the use of functional feed additives to improve growth performance and increase immune resistance in fish. A variety of feed additives with direct and indirect modes of action may replace the effects of in-feed antibiotics used to promote growth in aquatic animals. Recently, a great number of research has been conducted on the development of alternatives to antibiotics to preserve the health and performance of aquatic animals. The most widely investigated alternatives include probiotics, prebiotics, synbiotics, acidifiers, plant extracts, nucleotides and immunostimulants such as β-glucan and lactoferrin (LF). (Dawood et al., 2018).

Most of the studies with herbal products is done in countries such as China, India, Thailand and Korea. In these countries, many plants such as garlic (*Allium sativum*), garlic grass (*Allium tuberosum*), green tea (*Camellia sinensis*), cinnamon (*Cinnamomum verum* or *C. zeylanicum*), turmeric (*Curcuma longa*), lupine (*Lupinus perennis*), mango (*Mangifera indica*), mint (*Mentha piperita*), nutmeg (*Myristica fragrans*), basil (*Ocimum basilicum* and *O. sanctum*), coral pavilion (*Origanum vulgare*), radiant (*Rheum officinale*), rosemary (*Rosmarinus officinalis*) and ginger (*Zingiber officinale*) are generally used (Dikel, 2015).

Many scientific documents indicate that garlic is used effectively in the fight against bacterial pathogens from freshwater fish, *Pseudomonas fluorescens, Myxococcus piscicola, Vibrio anguillarum*, *Edwardsiella tarda*, *Aeromonas punctata f intestinalis*, and *Yersinia ruckeri* (Lee and Gao, 2012). Rosemary plant has been found to resist Streptococcus iniae and Streptococcus agalactiae bacteria in Tilapia (*Oreochromis sp*) (Zilberg et al., 2010).

Use of Plant Resources as Growth Enhancers

Medicinal plants have been shown to have growth-promoting effects. Substances used as plant supplements essentially improve digestive enzymes and thus increase the survival and growth rates of aquatic animals (Dikel, 2019). Büyükdeveci et al. (2018) in their study of garlic found that feeds increased the density of bacterial colonies that increase the activity of proteinase enzyme in the intestinal microbiota of trout, therefore, these fish grow better. Another study showed that three plants (*Eclipta alba*, *Alteranthera sessilis* and *Cissus quadrangularis*) showed an appetizing effect and increased the activity of digestive enzymes (protease, amylase and lipase) of freshwater shrimps (Radhakrishnan et al., 2014).

There are many scientific studies showing that plant supports are used as growth enhancers in aquaculture. Garlic-enriched diets have been reported to improve the growth parameters of Nile tilapy and increase survival (Aly and Mohamed, 2010; Shalaby et al., 2006; Aly et al., 2008; Özgüven and Dikel, 2018).

Diets containing *Oregano vulgare* essential oil have been reported to improve the growth performance and survival rates of catfish (Zheng et al., 2009). In another study, the growth parameters improved as a result of oral administration of Achyranthes aspera to *Labeo rohita* (Rao et al. 2006). Xie et al. (2008) reported that the growth performance of *C. carpio* feeding on diets enriched with *Rheum officinale* increased. Uzunağaç and Dikel (2010) reported that spirulina increased the survival rate in the study of wintering Nile tilapia puppies with spirulina supplemented feed in greenhouse conditions in winter.

Similarly, when 1% fenugreek was added to the feed of *Oreochomis niloticus* fish, an increase in growth performance and a decrease in feed evaluation rate were found (Mostafa et al., 2009). In another study on the effect of black cumin oil (*Nigella sativa*) on the growth performance, body composition and fatty acid profile of rainbow trout (*Oncorhynchus mykiss*), it was reported that black cumin oil positively affected the growth of trout while reducing feed evaluation rate (Öz et al., 2018).

In another study, the use of 100 mg/kg supplemented meadow triangle in *Oreochromis aereus* fish feeds has been reported to improve the growth performance and feed evaluation rate (Turan, 2006).

Use of Herbal Additives to Improve Meat Quality and Prolong Shelf Life in Aquaculture

The use of antibiotics can cause the death of beneficial microorganisms as well as harmful microorganisms in the digestive system (Sarıca, 1999). Therefore, the additives used today to increase production and fight against diseases are being replaced by organic products or chemicals that do not leave residues in fish. Many substances such as seaweed, probiotics, bacterial compounds, enzymes and plant extracts have been used in the studies as an alternative to chemical use in the aquaculture sector (Bagni et al., 2005; Bonaldo et al., 2007).

Benkeblia (2003) investigated the antimicrobial effect of different onion species (green, yellow and red) and garlic essential oil extracts on two bacterial species (Staphylococcus aureus, Salmomella enteritidis) and three fungus species (*Aspergillus niger, Penicillium cyclopium Fusarium oxysporum).* The strongest antibacterial effect was observed in garlic and the lowest effect was observed in green onion. All of the garlic extracts showed inhibitory activity at any concentration used. Among the onion species, red onion was the strongest inhibitor.

It is obligatory to keep the aquaculture cold after harvest until it is put on the market. The microbiological activities must be stopped or slowed down whether they are stored as a whole or a product. Otherwise, the product is at risk of rapid deterioration and staling. For this purpose, there are many studies on the storage and processing of seafood. In some of these studies, herbal additives are supplemented to fish feed (Öz et al., 2017; Öz, 2016; Öz, 2017; Öz, 2018a; Öz, 2018b) and some of them are supplemented to fish meat after harvesting (Topuz et al., 2014; Aircraft, 2019; Yerlikaya, 2015; Ucak et al., 2018).

In a case study on this subject (Öz, 2018), fish harvested after 90 days feeding period by supplementing garlic (*Allium sativum*) to rainbow trout feeds were stored in deep freezer at −18 ° C and periodically changes in chemical, microbiological and sensory parameters were examined. In this research, garlic supplemented fish feed has improved sensory, chemical and microbiological levels of the rainbow trout. The effects of black cumin oil (*Nigella sativa*) on the shelf life of rainbow trout (*Oncorhynchus mykiss*) were investigated. Similarly, positive results were found in this study (Öz et al., 2017).

CONCLUSION

The aquaculture sector in our country is growing rapidly and its share in the total aquaculture production has increased above 50%. In order to make this growth sustainable and increase the yield and quality and thus the income, feed additives should be used. Herbal feed additives used in animal breeding are alternative to antibiotics and many synthetic feed additives because they are both natural and do not threaten animal and human health. With these herbal feed additives, more researches should be done to increase the productivity of the fish in different seasons, different length groups, different aquaculture environments and in different seasons, and appropriate feed rations should be established for the fish according to the positive results.

REFERENCES

Aly S. A. & Mohamed M. F. 2010. Echinacea purpurea and Allium sativum as immunostimulants in fish culture using Nile tilapia (*Oreochromis niloticus*). *Journal of Animal Physiology and Animal Nutrition,* 94(5), e31-e39.

Aly S. M., Atti N. M. A. & Mohamed M. F. 2008. Effect of garlic on the survival, growth, resistance and quality of *Oreochromis niloticus*. In *International Symposium on Tilapia in Aquaculture* (Vol. 2008, pp. 277-296).

Büyükdeveci M. E., Balcázar J. L., Demirkale İ., Dikel S. 2018. Effects of garlic-supplemented diet on growth performance and intestinal microbiota of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, 486, 170-174.

Dawood M. A., Koshio S. & Esteban, M. Á. 2018. Beneficial roles of feed additives as immunostimulants in aquaculture: a review. *Reviews in Aquaculture,* 10(4), 950-974.

Defoirdt T, Sorgeloos P, Bossier P. 2011. Alternatives to antibi-otics for the control of bacterial disease in aquaculture.*Cur-rent Opinion in Microbiology,* 14, 251–258.

Dikel S. 2015. The use of garlic (*Allium sativum*) as a growth promoter in aquaculture. *Turkish Journal of Agriculture-FoodScience and Technology*, 3(7), 529–536.

Dikel S. 2019. Su Ürünleri Yetiştiriciliğinde Bitkisel Katki Maddeleri. Veterinerlik ve Su Ürünleri Araştırmaları I. Akademisyen Kitabevi, ISBN: 9786052583111, Sayfa: 81-93.

Mostafa A. A. Z. M., Ahmad M. H., Mousallamy A. & Samir A. 2009. Effect of Using Dried Fenugreek Seeds as Natural Feed Additives on Growth Performance, Feed Utilization, Whole-body Composition and Entropathogenic *Aeromonas hydrophilachallinge* of Monosex Nile Tilapia *O. niloticus* (L) Fingerlings, *Australian Journal of Basic and Applied Sciences*, 3(2), 1234-1245.

Öz M. 2017. Çörek Otu (*Nigella sativa*) Yağının Gökkuşağı Alabalığının (*Oncorhynchus mykiss*) Karaciğer Yağ Asidi Profiline Etkisi. *Etlik Veteriner Mikrobiyoloji Dergisi*, 28(1), 55-59.

Öz, M. (2018a). Effects of garlic (*Allium sativum*) supplemented fish diet on sensory, chemical and microbiological properties of rainbow trout during storage at -18 ^{o}C. *LWT*, 92, 155-160.

Öz M. 2018b. Effects of black cumin (*Nigella sativa*) oil on ammonia and biogenic amine production in rainbow trout. *Indian Journal of Animal Research*, 52(2), 265-269.

Öz M., Dikel S. & Durmus M. 2018. Effect of black cumin oil (*Nigella sativa*) on the growth performance, body composition and fatty acid profile of rainbow trout (*Oncorhynchus mykiss*). *Iranian Journal of Fisheries Sciences*, 17(4), 713-724.

Öz M., Dikel S., Durmuş M. & Özoğul Y. 2017. Effects of Black Cumin Oil (*Nigella sativa*) on Sensory, Chemical and Microbiological Properties of Rainbow Trout during 23 Days of Storage at 2±1 C. *Journal of Aquatic Food Product Technology,* 26(6), 665-674.

Öz M., Dikel S., Durmuş M., Özşahinoğlu I. & Mumoğullarinda P. 2016. Çörek otu (Nigella sativa, L) Yağının Gökkuşağı Alabalığı (*Oncorhynchus mykiss*)'nın Depolanması

Esnasında Yağ Asidi Değişimine Etkisi. *Nevşehir Bilim ve Teknoloji Dergisi*, 4(1), 57-68.

Özgüven A., Dikel S. 2018. Sera Koşullarında Melez Tilapiaların Sarımsak (*Allium sativum*) destekli yemlerle beslenmesinin büyüme performansına ve vücut besin bileşenleri üzerine etkileri. *Journal of Advances in VetBio Science and Techniques*, 3(3), 35-44.

Radhakrishnan S., Saravana Bhavan P., Seenivasan C., Muralisankar T. & Shanthi R. 2015. Effects of native medicinal herbs (*Alternanthera sessilis*, *E clipta alba* and *C issus quadrangularis*) on growth performance, digestive enzymes and biochemical constituents of the monsoon river prawn *Macrobrachium malcolmsonii*. *Aquaculture nutrition*, *21*(4), 496-506.

Rao Y. Vasudeva B. K., Jyotyrmayee D. P. & Chakrabarti R. 2006. Effect of Achyranthes aspera on the immunity and survival of *Labeo rohita* infected with *Aeromonas hydrophila*. *Fish and Shellfish Immunology,* 20(3), 263-273.

Romero J., Feijoó C. G. & Navarrete P. 2012. Antibiotics in aquaculture–use, abuse and alternatives. *Health and environment in aquaculture*, 159.

Shalaby Shalaby A. M., Khattab Y. A. & Abdel Rahman A. M. 2006. Effects of Garlic (*Allium sativum*) and chloramphenicol on growth performance, physiological parameters and survival of Nile tilapia (*Oreochromis niloticus*). *Journal of Venomous Animals and Toxins including Tropical Diseases*, 12(2), 172-201.

Topuz O. K., Yerlikaya P., Ucak I., Gumus B. & Büyükbenli H. A. 2014. Effects of olive oil and olive oil–pomegranate juice sauces on chemical, oxidative and sensorial quality of marinated anchovy. *Food chemistry*, 154, 63-70.

Turan F. 2006. Improvement of Growth Performance in Tilapia (*Oreochromıs aureus* Linnaeus) By Supplementatıon of Red Clover (*Trifolium pratense*) in Diets, *The Israeli Journal of Aquaculture- Bamidgeh*, 58(1), 34-38.

Uçak I. 2019. Taze karideslerin raf ömrünün uzatilmasinda soğan kabuğu ekstraktının etkisi. *Gıda*, 44(2), 226-237.

Uçak I., Khalily R., Abuibaid A. K. & Ogunkalu O. A. 2018. Maintaining the quality of rainbow trout (*Oncorhynchus mykiss*) fillets by treatment of red onion peel extract during refrigerated storage. *Progress in Nutrition*, 20(4), 672-678.

Uzunağaç C., Dikel S. 2010. Kişlatma Koşullarinda Nil Tilapia Yavrularina Saf Spirulina (*Spirulina Platensis*) ve Alabalik Yeminin 4 Farkli Rejimle Verilmesinin Canli Kalma Oranina Etkilerinin Karşilaştirilmasi. *ÇÜ Fen Bilimleri Enstitüsü Dergisi*, *23*, 1.

Xie J., Liu B., Zhou Q., Su Y., He Y., Pan L., Ge X. & Xu P. 2008. Effects of anthraquinone extract from rhubarb Rheum officinale Bail on the crowding stress response and growth of common carp *Cyprinus carpio* var. Jian. *Aquaculture*, 281(1-4), 5-11.

Yerlikaya P., Ucak I., Gumus B. & Gokoglu N. 2015. Citrus peel extract incorporated ice cubes to protect the quality of common pandora. *Journal of food science and technology*, *52*(12), 8350-8356.

Yildirim Ö., Acar Ü. & Çantas I. B. 2014. Balik yemlerinde kullanilan yem katki maddeleri/Feed Additives in Aquafeeds. *Journal of Fisheries Sciences*, 8(4), 278.

Zheng Z. L., Tan, J. Y. W. & Liu, H. Y. 2009. Evaluation of oregano essential oil *(Origanum heracleoticum* L.) on growth, antioxidant effect and resistance against *Aeromonas hydrophila* in channel catfish (*Ictalurus punctatus*). *Aquaculture*, 292, 214–218.

Zilberg D., Tal A., Froyman N., Abutbul S., Dudai N., Golan-Goldhirsh A. 2010. Dried leaves of Rosmarinus officinalis as a treatment for Streptococcosis in tilapia. *Journal of Fish Diseases*, 33(4), 361-369.

Eurasian Journal of Agricultural Research 2019; Vol: 3, Issue: 2, pp: 75-79

Use of Treatment Water for Irrigation

Esra CAN

Nevşehir Hacı Bektaş Veli University,
Graduate School of Natural and Applied Sciences, Department of Environmental Engineering, Nevşehir/ Turkey

**Corresponding author: esracan.57@gmail.com*

Abstract

In this research, the use of waste water produced after treatment for irrigation purposes was investigated. Clean water resources in our world are gradually decreasing and water scarcity is experienced in some countries. For this reason, people turned to domestic water obtained after treatment. In order to meet the water needs of plants, clean water resources are needed. The use of potable water instead of drinking water for this purpose provides a large amount of savings. In this sense, the quality of the water used is very important. Treatment waters must have certain criteria for use in agricultural irrigation. Criteria for wastewater from conventional activated sludge; AKM (suspended solid), BOD (Biological oxygen demand) and total nitrogen value less than 1 mg/L, the COD (chemical oxygen demand) value should be less than 2. Ammonium value should be maximum 0.1 mg/L, total phosphorus value should be 0.5 mg/L (Anonymous, 2019). It is desirable to infect plants with any harmful substances from outside. for this reason, continuous analysis of the water used should be controlled.

Keywords: Environment, wastewater, treatment water, irrigation

Review article

Accepted: 26 November 2019

INTRODUCTION

Water resources are gradually decreasing with increasing population. This has led scientists to use wastewater. Although waste water cannot be used as drinking water, it can be used as irrigation water. Waste water can cause serious problems if not treated. If it is treated, it can be used in many fields. One of them is its use in irrigation. However, in order not to pose any health threat, the content of the wastewater should be at levels that do not affect human health. It should not contain toxic substances. Wastewater reduces the need for fertilizers with the organic substances they contain.

It is stated that the use of wastewater in irrigation has been applied for centuries, efficient use of water resources is required and wastewater is gaining more importance today (Filibeli and Yüksel, 1994).

The recovery and reuse of wastewater after treatment has become an important component of the sustainability of water at both national and international scale and has found wide application area especially in arid countries experiencing water scarcity (Pedrero et al., 2010).

Treated wastewaters are used in irrigation of school gardens, parks, landscaping areas, sports fields, in ornamental gardens, cooling, washing, boiler feeding in industrial sector, watering of golf courses, watering of road sides, fountains, decorative pools and waterfalls. used as; thus, both increasing water needs are met and clean water resources are saved (Özbay and Kavaklı, 2008).

Important Parameters in the Use of Waste Water in Irrigation

Heavy metals

If heavy metals are present in the treated water, it affects human health significantly. In case of irrigation with water containing heavy metal, heavy metals in water pass to plants. If these plants are consumed by human beings, they threaten life. The effect of heavy metal on humans is dangerous by prolonged exposure.

Pathogens

The quality of untreated wastewater causes great harm to human health if pathogens are present. These pathogens; cholera, hepatitis etc. can cause diseases.

Untreated, partial or secondary biologically treated wastewaters contain pathogens that threaten human health, albeit in different species and in different amounts (Luprano et al., 2016).

The presence of pathogens in water varies depending on the degree of treatment. In order to reduce pathogens to levels that do not harm human health, wastewater must be treated and disinfected using appropriate disinfection methods (Luprano et al., 2016). The most common treatment methods are chlorine, ozone, ultraviolet (UV) radiation (Hussain et al., 2002).

Salinity

If the amount of salt in the irrigation water is too high, the plant gets stress due to high salt exposure. It reduces the yield and quality of the plant.

Basic ions that cause salinity in soil are sodium, calcium, magnesium, etc. ions are. Salt accumulation in plant roots and soil is an important problem. The uptake of water by plant roots takes place by osmotic pressure. Due to the increase of salinity in soil water, the plant gives the cell water to the soil to dilute the soil water due to the osmotic pressure difference between it and the plant cells. This causes the plant to dehydrate and die (Jouyban, 2012).

pH

The H + ions in the irrigation water determine the pH of the water. The pH value is too high or too low affects the plant and soil negatively. Therefore, controls should be made before application.

Bedbabis et al. (2015) in their study; It has been observed that when treated with treated wastewater, it causes short and sudden increases in soil pH, it does not have a negative effect when appropriate doses are used, and if treated wastewater contains a high percentage of bicarbonate, it can be observed that the application of soils through irrigation can increase the soil pH (Bedbabis et al., 2015).

Nutrients

The high amount of nutrients in the water used in irrigation provides savings by minimizing the use of fertilizers in agriculture.

Excess of these nutrients has negative effects such as excessive plant growth, surface and groundwater contamination. Phosphorus is filtered through soil adsorption and precipitation, while nitrogen is oxidized with oxygen and becomes nitrate which can cause serious problems in groundwater (Pedrero et al., 2010).

Suspended solids

Due to the organic substances in the suspended solids, microbial activities are accelerated in the first layers of the soil and accordingly biomass increases. Both the increase in biomass and the accumulation of the non-degradable inorganic part in the Suspended Solids on the surface of the soil decreases the filtration of the soil in time and even causes clogging of the soil and irrigation pipes (Van Oort et al., 2017).

Evaluation of Waste Water for Irrigation

Water resources are gradually decreasing. With the increase in population, more clean water resources are needed. Alternative methods are used to ensure that water resources remain at levels sufficient to meet the needs of future generations. One of them is irrigation with waste water. Although the irrigation process with wastewater is initially considered with prejudice, it is an increasingly common practice.

Organic substances and chemicals may be present in the water. Removal of these substances is very important for plant, soil and human health.

- **Irrigation with urban wastewater**

Urban wastewater collected by sewer systems includes various inorganic materials, both domestic and industrial. They may contain toxic substances such as arsenic, cadmium, chromium, 64 copper, lead, mercury, zinc, especially if industrial wastewater is introduced into the sewage system. Even if the concentration of toxic chemicals does not affect human health, they may have toxic effects on plants. In terms of human health, the most important pollutants to be considered in the use of wastewater in agricultural irrigation are pathogenic microorganisms (Pescod, 1992).

- **Irrigation with industrial wastewater**

It is not used as a first choice because it contains a lot of heavy metals in industrial wastewater. In China, domestic and industrial wastewater from biological domestic wastewater treatment plant is used for agricultural irrigation. In order to determine the effect of these waters and irrigation on the amount of persistent organic pollutants in the soil, PAH (Poly Aromatic Hydrocarbons) analyzes were performed on samples taken from soils irrigated with clean waters and treated wastewaters. Analysis results showed that irrigation with treated wastewater increased PAH accumulation in soil and PAH values in soil exceeded the limit values given for soil quality standards (Chen et al., 2005).

REFERENCES

Aydın M. E., Aydın S., Bedük F. & Tekinay A. 2015. Use of Wastewater in Irrigation: Persistent Organic Pollutants in Soil and Product. *Journal of Uludag University Faculty of Engineering*, 20(2).

Bedbabis S., Trigui D., Ahmed C. B., Clodoveo M. L., Camposeo S., Vivaldi A. G. & Rouina B.B. 2015. Long-terms effects of irrigation with treated municipal wastewater onsoil, yield and olive oil quality, *Agricultural Water Management*, 160, 14-21.

Chen Y., Wang C. & Wang Z., 2005. Residues and Source Identification of Persistent Organic Pollutants in Farmland Soils Irrigated by Effluents from Biological Treatment Plants. *Environment International*, 31, 778-783.

Filibeli A. & Yüksel N. 1994. Assessment of wastewater potential for agricultural irrigation water needs. *Gökova Bay Environmental Problems and Environmental Management Symposium*, 139-152.

Hussain I., Raschid L., Hanjra M. A., Marikar F. & Van der Hoek W. 2002.International Water Management Institute. *Wastewater use in agriculture: Review of impacts and Methodological Issues in Valuing Impacts*, Colombo, Sri Lanka, Working Paper 37.

Jouyban Z. 2012. The effects of salt stress on plant growth. *Technical Journal of Engineering and Applied Sciences*, 2(1), 7-10.

Luprano M.L., De Sanctis M., Del Moro G., Di Iaconi C., Lopez A. & Levantesi C. 2016. Antibiotic resistance genes fate and removal by a technological treatment solution for water reuse in agriculture. *Science of the Total Environment*, 571, 809-818.

Anonymous 2019. Communique on Technical Procedures for Wastewater Treatment Plants, Leaving Water Quality for Different Treatment Systems. Ministry of Environment and Forestry. http://www.resmigazete.gov.tr/eskiler/2010/03/20100320-7.htm Date of Access: 2.07.2019

Özbay İ. & Kavaklı M. 2008. Treated Wastewater in Turkey and in other countries Recycling Practices Investigation. *Environmental Problems Symposium*, Kocaeli.

Pedrero F., Kalavrouziotis I., Alarcon J. J., Koukoulakis P. & Asano T. 2010. Use of treated municipal wastewater in irrigated agriculture. Review of some practices in Spain and Greece. *Agricultural Water Management*, 97, 1233-1241.

Pesco M. B. 1992. Wastewater Treatment and Use in Agriculture. Irrigation and Drainage Paper, No. 47, FAO, Rome. 125 p.

Van Oort F., Thiry M., Foy E., Fujisaki K., Delarue G., Dairon R. & Jongmans T. 2017. Impacts of one century of wastewater discharge on soil transformation through ferrolysis and related metal pollutant distributions. *Science of the Total Environment*, 590-591, 1-13.

An Important Cycle in Hydrological Cycle: Rainwater Harvesting

Eda Nur ARIKAN

Nevşehir Hacı Bektaş Veli University, Faculty of Engineering and Architecture, Environmental Engineering, Department, Nevşehir/Turkey

**Corresponding Author: edaarikan.eak@gmail.com*

Abstract

Water is one of the most important elements for living things. Water, which forms the biological structures of living things, is a vital life support that ensures the growth and development of living things since they came into the world. While most of the world is covered with water, the seas form salty seas. However, only 2.6% of the world's water reserves are composed of fresh water. Drops falling from the clouds in the form of water droplets are called rain. Rain makes the water cycle happen and clears the water on earth. Rain water which raises sea levels is also beneficial for forests, plants and people. Rain water can be stored and used to meet drinking and utility water and agricultural irrigation needs.

Keywords: Hydrological cycle, rainwater harvesting

Review article

Accepted: 26 November 2019

Introduction

As Turkey is not a country rich in water chest. On the contrary, it is a candidate country for water problems in the near future unless the necessary measures are taken. The main reasons for this are the inability to control the resources due to irregularities in the topography and the uneven distribution of precipitation and resources by region (Anonymous, 2001).

Increasing needs on the one hand and increasing standards of living on the other hand make it imperative that all opportunities are made available for the optimal use of water resources. In particular, the social and economic importance of water resources in Turkey are better understood with each passing day (Sağlam and Bellitürk, 2003).

In order to meet the increasing food needs in parallel with the population increase, agricultural production should be increased. The limited use of water and land resources and the increase in competition among sectors necessitate effective use of resources in agriculture. Irrigation takes place on 280 million ha area, which corresponds to 19% of the agricultural land in the world. 35% of the agricultural production in the world is obtained from irrigated areas and 70% of the water used is used for agricultural production (Çakmak, 2001).

Turkey's agriculture, balanced development and economic and demographic structure, especially the great importance of irrigated agriculture. Since the upper limit of agricultural land was reached 20 years ago, the increase in production in the unit area depends on technological development and increase of irrigated areas. Here, not only the increase of production, but also to obtain qualified products according to the demands of the market becomes more important. Therefore Turkey, about 65% of the money allocated for agricultural investment in recent years are spent on irrigated lands. Every year, irrigated areas expand. With irrigation, the product increased 7 times and added value increased 2.6 times. (Kanber, 1997). Some of the water used for irrigation of agricultural areas is provided by rain water. Rain is the precipitation that is formed by the condensation of water vapor in the atmosphere and falls to the earth in the form of drops with a diameter greater than 0.5 mm. The type of precipitation in which the diameter of the drops is smaller is called the drip. When the humidity in the air exceeds 100%, the water vapor condenses to form water particles. These particles come together by drifting with the wind and form clouds. When the cloud encounters a cold layer of air, the water in the cloud condenses into water droplets. Rainfall occurs when these droplets reach a drop size. If the temperature of the atmosphere is at a certain height, precipitation is in the form of rain (Anonymous, 2015).

Conventional rainwater collection systems used to drain rainwater in urban areas quickly remove rainwater from the environment via a separate or combined sewage system. With this situation, as a result of rain water transported to the soil without waiting; inadequate feeding of underground water resources, pollution of foreign bodies transported by rainwater from urban areas and receiving waters where rainwater is discharged and flood, flood and erosion problems are inevitable with traditional rainwater collection systems being insufficient in heavy rainfall. As a result of the excessive increase of impermeable hard surfaces in urban areas and the decrease of light-green areas inversely proportional to this increase, rainfall after rainfall does not penetrate the soil sufficiently (Müftüoğlu and Perçin, 2015). Rain water to be used for irrigating light green areas and agricultural areas are directed directly without any treatment. and shallow pit areas on which natural, foreign dormitory plants can be grown, "rain garden" or "bioretention" (Demir, 2012). The main function of the rain garden; to improve water quality for the immediate environment by improving the collected surface flow (Jaber et al. 2012).

Rainwater Collection

In the old times, rain water was collected and used with cistern systems, which are common in the regions where water shortage was felt. Today, rain water usage decreases water consumption to a great extent in garden irrigation, which has a large proportion of total water consumption in arid regions where water problems are experienced. Cistern application is a very effective method for such uses. Cistern applications are offered as an ideal solution especially for places where there is limited ground and surface water resources, but there is sufficient rainfall and settlements without central water supply infrastructure (Alparslan, 1992).

Cisterns can be used in rural areas, coastal areas, arid, semi-arid areas, islands and scattered settlements are located. A typical cistern system consists of four components. These;

• Collecting rainwater from roofs or floors of buildings

• Ensuring the transmission through the gutter system,

• Accumulation in rain water tank,

• Purification is transmitted to the building (Alpaslan et al. 2008).

According to the rain water collection method, the water flowing along the slope is collected. Rainwater from roofs or stony, rocky areas can be stored and used as domestic needs. This system is of little importance for food safety, but it can improve the quality of life to some extent. The water collection technique is advantageous because it is easy and inexpensive. It can be applied on almost any slope. Compared to large irrigation systems, water transmission losses are very low. Approximately 50% of the water required for domestic use can be provided by this method (Ferguson, 1998).

Advanced Rain Water Collection Systems

• Another possibility to increase the leakage rate is the use of some special stones in parking areas or public spaces.

• These stones are highly permeable and provide a suitable environment for rainwater to drain and mix into groundwater, even in torrential rains.

• An important prerequisite for the permeability of stones is the use of “clean” production techniques.

• Never cover the floor with concrete.

• Rain water permeability must be ensured.

• As the advantages of leakage, it reduces the load that the sewage system will carry. Therefore, the costs of the network and sewage system are reduced.

• There is no need to take any more safety measures against water that randomly seeps into the sewerage network.

• The advantages of rainwater and leakage systems are; reduction of wastewater treatment costs, easy way of building rainwater tanks, reducing the damage caused by floods and floods (Tanık, 2017).

Benefits of Rain Water

Rain makes the water cycle happen. The waters of the earth are cleaned by rain. Rain water is useful for field crops. Plant can be grown by irrigation. However, the fact that rain water is rich in minerals and that it affects all parts of the plant instead of a certain point increases the yield. Rain water is drinkable. It is useful in terms of minerals it contains. It can be applied to hair, hands and body. Leaves skin soft Rain meets the water needs of the trees in the forest. Thanks to the forests, oxygen is obtained for the survival of the vitality. Thanks to the rains in the spring, flower dust and pollen circulate through the atmosphere and positively affect inter-plant diversity and fertilization. Rain whips your nose, cheeks, your whole face and acts like a good sprayer for free. They can occur in many different forms, which are baked in moist air with dust from the air and in the sunlight. The clouds are officially reviving, because they contain reduced iron, zinc, manganese, and so on. with trace elements such as arginine, alanine, proline, valine, isine, histidine, aspartic acid, glutamic acid serine and so on. as the cornerstones of life are enriched with amino acids (Anonymous, 2015).

Damages of Rain Water

The biggest damage of rain is that it causes flood formation. Floods cause people to lose their lives and suffer financial damage. Sometimes it is seen that it interferes with transportation. Rainy weather can cause accidents due to tire slippage. In case of heavy rain, it prevents the development of some field plants and may even lead to decay. Fig rain can prevent the harvest of the plant. The icing of the water accumulated as a result of rainfall in winter also affects human life negatively. Avalanches, lightning strikes, hurricanes, storms and tornadoes are other damages of rain (Anonymous, 2015).

RESULTS

Water is an important source of life for human life as well as light green areas and agricultural areas, but is also important for the whole world. Agriculture should also be improved with increasing population. Product efficiency should be ensured. To achieve this, water is needed. Since rainwater collection is economically feasible, it is one of the preferred methods. It is recommended to use rainwater for irrigation of agricultural areas. With the collected rain water, productivity will be increased.

REFERENCES

Anonymous 2001. Su Havzaları, Kullanımı ve Yönetimi. Sekizinci Beş Yıllık Kalkınma Planı, Yayın No DPT:2255, ÖİK:571, Ankara. (in turkish)

Anonymous 2015. Yağmur Nedir. https://www.havaforum.com/yagmur-nedir-yagmur-nasil-olusur (Erişim Tarihi: 09.06.2015). (in turkish)

Alpaslan N. 1992. Turistik Yerleşimlerin Su İhtiyacı İçin Sarnıç Seçeneğinin İrdelenmesi. Datça Çevre Sorunları Sempozyumu Bildiriler Kitabı, Datça. (in turkish)

Alpaslan, N., Tanık, A. & Dölgen, D. 2008. Türkiye'de Su Yönetimi Sorunlar ve Öneriler. TÜSİAD Yayın No: T/2008-09/469. (in turkish)

Çakmak B. 2001. Konya Sulama Birliklerinde Sulama Performansının Değerlendirilmesi. Ankara Üniversitesi Ziraat Fakültesi, Tarım Bilimleri Dergisi 7 (3): 111-117, Ankara. (in turkish)

Demir D. 2012. Konvansiyonel Yağmursuyu Yönetim Sistemleri ile Sürdürülebilir Yağmur-suyu Yönetim Sistemlerinin Karşılaştırılması: İTÜ Ayazağa Yerleşkesi Örneği. Yüksek Lisans Tezi, İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, Çevre Mühendisliği Anabilim Dalı, Çevre Bilimleri ve Mühendisliği Programı, İstanbul, 191 s. (in turkish)

Ferguson B. 1998. Introduction to stormwater. John Wiley & Sons, New York.

Jaber F., Woodson D., LaChance C. & York C. 2012. Stormwater Management: Rain Gardens, The Department of Soil and Crop Sciences and Texas A&M AgriLife Communications, The Texas A&M System, USA, p. 20.

Kanber R. 1997. Sulama. Ç.Ü. Ziraat Fakültesi Genel Yayın No: 174, Ders Kitapları Yayın no: 52, Adana. (in turkish)

Müftüoğlu V. & Perçin H. 2015. Sürdürülebilir Kentsel Yağmur Suyu Yönetimi Kapsamında Yağmur Bahçesi. İnönü Üniversitesi Sanat ve Tasarım Dergisi. Design Issn: 1309-9876 E-Issn: 1309-9884 Cilt/Vol. 5 Sayı/No.11 27-371: Ankara Üniversitesi Ziraat Fakültesi Peyzaj Mimarlığı Bölümü, Ankara. (in turkish)

Sağlam M. T. & Bellitürk. K. 2003. Su kirliliği ve Toprak Üzerindeki Etkisi. Alatarım Dergisi, 2 (1): 46-49. (in turkish)

Tanık A. 2017. Yağmur Suyu Toplama, Biriktirme ve Geri Kullanımı İTÜ İnşaat Fakültesi, Çevre Mühendisliği Bölümü Su Kaynakları ve Kentler Konferansı Kahramanmaraş. (in turkish)