



Test Method Summary and References

The science behind soil and plant testing is well established and varied. There has been little change in the way samples are prepared and, with the exception of exchange membrane technology used in the Resin-P method, in the way that nutrients are extracted. Subsequently, determinations of various analytes of interest are based on traditional wet chemistry methods, as reflected by the large number of older references given below. More recently, with major improvements in analytical technology and computer capabilities, there has been a shift to greater use of instrumental methods to determine these analytes.

The following list gives a brief description of our tests, and a list of references pertaining to each one. Some methods have been modified from the original.

Soil

Sample Preparation

Soils are dried in a forced air convection drier at 35°C and crushed to pass through a 2mm sieve. No correction is made to an oven-dried basis (103°C). In-house experiments have determined residual moistures to be typically 5%.

Volume Weight

A fixed volume (12 mL) of dried and ground soil is weighed.

pH

Ten mL of soil is slurried with 20 mL of water, and after standing, the pH is measured (1:2 v/v slurry).

1. Blakemore, L.C., Searle, P.L., Daly, B.K. 1972. Methods for chemical analysis of soils. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 10A. p A1.1.
2. Metson, A.J. 1971. Methods of chemical analysis for soil survey samples. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 12. p 21.
3. Blakemore, L.C., Searle, P.L., Daly, B.K. 1987. Methods for chemical analysis of soils. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 80. p A1.1.
4. Brezinski, (1983). Kinetic, Static and Stirring Errors of Liquid Junction Reference Electrodes. Analyst. 108: 425.

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Phosphorus

Phosphorus is extracted using Olsen's procedure (0.5M sodium bicarbonate, pH 8.5, 1:20 v/v soil:extractant ratio, 30 minutes extraction), and the extracted phosphate is determined colorimetrically by a molybdenum blue procedure.

- 1.Watanabe, F.S. and Olsen, S.R. (1965). Test of an ascorbic acid method for determining phosphorus in water and sodium bicarbonate extracts from soil. *Soil Science Proceeding*. p 677.
- 2.Murphy, J. and Riley, J.P. (1962). A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta*. 27, p 31.
- 3.Council on Soil Testing and Plant Analysis, (1980). *Handbook on reference methods for soil testing*. p47.
- 4.Council on Soil Testing and Plant Analysis (1980). *Reference Methods for Soil Testing*.
- 5.Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA Circular 939*.

Cations

Cations (K, Ca, Mg, Na) are extracted using ammonium acetate (1.0M, pH 7, 1:20 v/v soil:extractant ratio, 30 minutes extraction), and determined by ICP-OES. Levels found are converted to concentrations in the soil on a weight basis using the Volume Weight test result.

This extraction procedure does not extract all the cations as determined by the original leaching column procedure. Typically greater than 90% of the exchangeable potassium and sodium are extracted, with 80% of the exchangeable calcium and magnesium being measured. For general diagnostic work, this discrepancy is of little concern, but for research work it may need to be considered.

- 1.Council on Soil Testing and Plant Analysis, (1980). *Handbook on reference methods for soil testing*. p58.
- 2.Methods of soil analysis used in the State Testing Laboratory at Oregon State University. *Special Report 321, Agricultural Experiment station, Oregon State University, Corvallis*.
- 3.Blakemore, L.C., Searle, P.L., Daly, B.K. 1972. *Methods for chemical analysis of soils*. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 10A. p A6.1.
- 4.Metson, A.J. 1971. *Methods of chemical analysis for soil survey samples*. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 12. p 172.

Cation Exchange Capacity

Cation Exchange Capacity (CEC) is calculated by summation of the extractable cations and the extractable acidity. The extractable acidity is determined from the decrease in pH of the buffered ammonium acetate cation extract.

This method tends to slightly under estimate the CEC compared to that found by the leaching column procedure.

The CEC values for soils with either high soluble salts or free calcium carbonate will be overestimated by this summation method. Apart from some glasshouse soils, very few New Zealand soils are in these categories.

- 1.Hesse, P.R. (1971). *A textbook of soil chemical analysis*. John Murray, p 35, 88.

Lime Requirement

Lime requirement is a calculation based on the soil's cation exchange capacity and base saturation.

- 1.In-house calculations derived theoretically from first principles.
- 2.Edmeades, D.C., Wheeler, D.M., Waller, J.E. (1984). Comparison of methods for determining lime requirements of New Zealand soils. *New Zealand Journal of Agricultural Research* 28: 93-100.



TECHNICAL NOTES

Soluble Salts

Glasshouse soil soluble salts are extracted with saturated calcium sulphate solution (1:2.5 w/v soil:extractant ratio, 1 hour shaking). A water extraction (1:5 w/v soil:extractant ratio, 30 minutes shaking) is used for field soils. In both cases, the conductivity of the extract is converted empirically to a percentage soluble salts in the soil.

1. Windsor, G.W., Davies, J.N. and Massey, D.M. (1963). Salinity studies . I: Effect of calcium sulphate on the correlation between plant growth and electrical conductivity of soil extracts. J. Sci. Fd Agric., 14:p42
2. Page, A.L. et al (1982). Methods of Soil Analysis. Part 2 - Chemical and Microbiological Properties. Second Ed. Am. Soc. Agron. p167.
3. Blakemore, L.C., Searle, P.L., Daly, B.K. 1972. Methods for chemical analysis of soils. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 10A. p A9.1.

Phosphate Retention (not routinely used – replaced by ASC test)

A standard solution containing 1000 mg/L P and buffered to pH 4.65 is used. After overnight shaking (1:5 w/v soil:extractant ratio), the P remaining in solution is determined colorimetrically. The P retained by the soil is calculated by difference and expressed as a percentage of the total.

1. Blakemore, L.C., Searle, P.L., Daly, B.K. 1972. Methods for chemical analysis of soils. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 10A. p A5.6.
2. Saunders, W.M.H. (1965). Phosphate retention in New Zealand soils and it's relation to free sesquioxides, organic matter and other soil properties. New Zealand Journal of Agricultural Research. 8:30.

Anion Storage Capacity (ASC)

Calculated from 0.02M potassium phosphate extraction for organic-S and sulphate-S. Residual P in this extract is converted to the "PR" scale, based on conversion formulae established in-house.

1. Blakemore, L.C., Searle, P.L., Daly, B.K. 1972. Methods for chemical analysis of soils. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 10A. p A5.6.

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Organic Matter

This is determined by the Dumas method of combustion. Each sample is combusted to produce varying proportions of CH₄ and CO gas. The CH₄ and CO gas is oxidised to CO₂ using the catalysts Copper Oxide and Platinum. The CO₂ is then measured using a Thermal Conductivity detector. The total C measured is converted to organic matter using the Van Bremmelen factor of 1.724.

1. D.W Nelson and L.E. Sommers. Total Carbon, Organic Carbon and Organic Matter. SSSA, Methods of Soil Analysis Part 3; Chemical Methods, p 983 (1996)

Available Nitrogen, AN (Anaerobically Mineralisable Nitrogen ,AMN)

The soil is incubated for seven days at 40°C, after which the ammonium-N is extracted with potassium chloride (2M potassium chloride, 1:5 v/v soil:extractant ratio, 15 minute shaking), and determined colorimetrically. The result is expressed as kg/ha, assuming a 15cm sampling depth, for AN (and as ug/g for AMN).

1. Keeney, D.R. and Bremner, J.M. (1966). Comparison and evaluation of laboratory methods of obtaining an index of soil nitrogen availability. *Agron. Journal*. 58:498.
2. Hinds, A.A. and Lowe, L.E. (1980). Application of the Berthelot reaction to the determination of ammonium-N in soil extracts and soil digests. *Comm. Soil Sci. and Plant Anal.* 11:469.

Mineral Nitrogen (Ammonium-N and Nitrate-N)

NO₃-N and NH₄-N in soils are extracted using 2M KCl and determined colorimetrically (NH₄-N by Berthelot colorimetry, NO₃-N by Cd reduction and NED colorimetry)

Analysis is carried out on fresh soils, to avoid losses of NH₄-N on drying. Results are reported on a dry weight basis however, by calculation using %moisture of the soil (measured as dry matter).

1. Keeney, D.R. and Nelson, D.W. (1982). *Methods of Soil Analysis, part 2: Chemical and Microbiological Properties – Agronomy Monograph no. 9* (2nd edition)

Reserve Magnesium

Magnesium is extracted using boiling hydrochloric acid (1M, 1:40 w/v soil:extractant ratio, 15 minutes boiling). After filtration, magnesium is measured in the filtrate by ICP-OES, and the magnesium from the Basic Soil test is subtracted. The difference is designated as the reserve magnesium.

1. Metson, A.J. (1975). Magnesium in New Zealand soils II. *New Zealand Journal of Agricultural Research*. 18:319.

Reserve Potassium

Readily available potassium is removed by extraction with nitric acid (1M, 1:100 w/v soil:extractant ratio, 20 minute boiling). The potassium removed by a subsequent extraction with nitric acid (1M, 1:25 w/v soil:extractant ratio, 10 minutes boiling) is designated as the reserve potassium. Potassium is measured in the filtrate by ICP-OES

1. Blakemore, L.C., Searle, P.L., Daly, B.K. 1972. *Methods for chemical analysis of soils*. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 10A. p A9.1.
2. Metson, A.J., Arbuckle, R.H., and Saunders, M.L. (1956). The potassium-supplying power of New Zealand soils as determined by a modified normal-nitric-acid method. *Trans 6th Int Cong Soil Sci B*. 619-27.
3. Metson, A.J. (1968). The long-term potassium-supplying power of New Zealand soils. *Trans 9th Int Cong. Soil Sci 2*. 621-9.

0.02M CaCl₂ Extractable Aluminium (this method adopted mid 2010)

Exchangeable Aluminium is extracted with 0.02M Calcium Chloride solution. Aluminium in the filtrate is measured by ICP-OES.

1. D.C. Edmeades, C.E. Smart and D.M. Wheeler. Aluminium toxicity in NZ soils. *NZ journal of agricultural research*. 1983, Vol. 26: 493-501

1M KCl Extractable Aluminium (this method replaced with 0.02M CaCl₂ extraction mid 2010)

Aluminium is extracted from the soil using potassium chloride (1M, 1:10 w/v soil:extractant ratio, 30 minutes shaking). Aluminium in the filtrate is measured by ICP-OES.

1. Westerman, R.L. (1990). *Soil Testing and Plant Analysis*. (Soil Science of America Book Series, 3rd Edition).
2. Blakemore, L.C., Searle, P.L., Daly, B.K. 1972. *Methods for chemical analysis of soils*. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 10A. p A9.1.



TECHNICAL NOTES

Resin P

Soluble and partially soluble sources of P are extracted using an ion exchange membrane and water extraction technique (1:30 w/v soil:extractant ratio, 16 hours shaking). Subsequent elution of P from the strip is done using sodium chloride and P is determined colorimetrically.

1. Saggarr, S., Hedley, M.J. and White, R.E. (1990). A simplified resin membrane technique for extracting phosphorus from soils. *Fertiliser Research* 24. 173-180.
2. Saggarr, S., Hedley, M.J., White, R.E., Gregg, P.E.H., Perrott, K.W. and Cornforth, I.S. (1992). Development and evaluation of an improved soil test for phosphorus. 2. Comparison of the Olsen and mixed cation-anion exchange resin tests for predicting the yield of ryegrass grown in pots. *Fertiliser Research* 33. 135-144.

Boron

Boron is extracted using 'hot water' (0.01M CaCl₂, 1:2 w/v soil:extractant ratio, 10 minute boiling) and measured by ICP-OES.

1. Gaines, T.P. and Mitchell, G.A. (1979). Boron determination in plant tissue by the azomethine-H method. *Comm Soil Sci. and Plant Anal.* 10:1099.
2. Wolf, B. (1971). The determination of boron in soil extracts, plant materials, composts, manures, waters and nutrient solutions. *Comm. Soil Sci. and Plant Anal.* 2:363.
3. Wolf, B. (1976). Improvements in the azomethine-H method for colorimetric determination of boron. *Comm. Soil Sci. and Plant Anal.* 7:331.

Sulphate-S and Extractable Organic S

Soils are extracted using 0.02M potassium dihydrogen phosphate (30 minute shaking).

SO₄-S is measured by anion-exchange chromatography (IC) and Total S is measured by ICP-OES. Extractable organic S is calculated by difference (Total S – SO₄-S = OS)

1. Searle, P.L. (1988). The determination of phosphate-extractable sulphate in soil with an anion-exchange membrane. *Comm. Soil Sci. and Pl. Anal.* 19(13), 1477-1493.
2. J.H. Watkinson & K.W. Perrott (1990). A New Soil Test for Sulphate and Mineralisable Organic Sulphur. *Proceedings of the NZFMRA Conference.*

EDTA Trace Metals

The trace metals manganese, zinc, copper and cobalt are extracted using buffered EDTA (0.02M, pH 5.5, 1:4 w/v soil:extractant ratio, 16 hour shaking). The metals in the filtrate are measured by ICP-OES.

1. Forbes, E.A. (1976). Cobalt, copper and zinc in yellow-brown pumice soils under grazed, permanent pasture. *New Zealand Journal of Agriculture Research.* 19:153-164.
2. Sherrel, C.G., Percival, N.S. and Gee, T.M. (1990). Effects of cobalt application on the cobalt status of pastures. 1. Pastures with history of regular cobalt application. *New Zealand Journal of Agriculture Research.* 33:295-304.
3. G.B.C. Scientific Equipment Pty Ltd. *Flame methods manual for atomic absorption.* Victoria, Australia.

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Mehlich3 Extractable Elements

Soil extracted with the mehlich3 extractant containing acetate, ammonium nitrate, ammonium fluoride, nitric acid and EDTA (pH 2.6, 1:10 v/v soil:extractant ratio, 5 minutes shaking) is analysed by ICP-OES for P, K,Ca,Mg,Na,Mn,Zn,Cu,Fe,Co,B and Al.

1. Soil Analysis – Handbook of Reference Methods. Soil & Plant Analysis Council, Inc.(1999)

'Total' Nutrients

Metals are extracted from soils and composts by a moderate temperature nitric/hydrochloric acid digestion. The method does not produce “true total” results, as interstitially-bound metals (e.g. K,Na,Ca,Fe,Al,Ni) are not totally released from the silica matrix. The metal fraction is called either 'Total Recoverable' or 'Acid Extractable Total'. Elements are determined either by ICP-OES or ICP-MS.

1. US EPA 200.2. Sample Preparation Procedure for Spectrochemical Determination of Total Recoverable Elements. Revision 2.8 EMMC Version.

2. A.I. Vogel. “A Textbook of Quantitative Analysis”. 3rd edition, p230 (1961)

Saturated Paste Extracts

A volume of soil is brought to saturation point with water and the filtrate analysed by ICP-OES for P, K, Ca, Na, and Mg. Soluble Salts are measured potentiometrically using a conductivity electrode (EC). NO₃-N and NH₄-N are measured colorimetrically. Results are reported as the concentration of analyte in the extract.

The Sodium Absorption ratio (SAR) is calculated as:

$$SAR = Na / \sqrt{(Ca + Mg) / 2}$$

where the total cation concentrations in the saturation extract are in meq/L

1. Handbook of Reference methods for soil analysis. Council on Soil Testing & Plant Analysis, Georgia University. 1992

2. Soil Testing and Plant Analysis 3rd ed. Soil Science Society of America Book Series. Wisconsin, USA 1990. p306-308
Plant Tissue

Sample Preparation

Plant tissue samples are oven dried at 62°C and ground to pass through a 1mm sieve. No correction is made to an oven-dried basis (103°C) for reporting elemental analytes in plant tissue. In-house experiments have determined residual moistures to be typically 5 -7 %. Feed test parameters are reported on a dry weight basis with correction for lost volatiles for silages.

Nitrogen

Nitrogen is determined by the Dumas method of combustion. 200mg of dried & ground plant material is combusted with oxygen at 900°C and the resultant gas determined by thermal conductivity detector.

1. VarioMAX CN Macro Element Analyzer Operating Instructions, April 2000

2. User manual for the Elementar VarioMAX Combustion Analyzer

Microwave Digestion of Plant Material

200mg of dried & ground plant material is digested with Hydrogen Peroxide and Nitric Acid (2:1) by closed-vessel microwave-assisted digestion.

The digests are diluted with deionised water and analysed for B, Ca, Cu, Fe, K, Mg, Mn, Na, P, S and Zn by ICP-OES. Mo, Co and Se are analysed by ICP-MS.



TECHNICAL NOTES

Phosphorus

Phosphorus is determined by ICP-OES from the Basic Plant digest.

1. Metson, A.J.. Determination of some major elements in plant materials. New Zealand, NZ DSIR. (NZ Soil Bureau Scientific Report 10B.
2. Anderson, K.A. (1996). Micro-digestion and ICP-AES analysis for the determination of macro and micro elements in plant tissue. Atomic Spectroscopy. Jan/Feb p 30.

Sulphur

Sulphur is determined by ICP-OES from the Basic Plant digest.

1. Garrido, L. (1964). The determination of sulphur in plant material. Analyst. 89:91.
2. Anderson, K.A. (1996). Micro-digestion and ICP-AES analysis for the determination of macro and micro elements in plant tissue. Atomic Spectroscopy. Jan/Feb p 30.

Metals

Potassium, calcium, magnesium, sodium, iron, manganese, zinc and copper are determined by ICP-OES from the Basic Plant digest.

1. Anderson, K.A. (1996). Micro-digestion and ICP-AES analysis for the determination of macro and micro elements in plant tissue. Atomic Spectroscopy. Jan/Feb p 30.

Boron

Boron is determined by ICP-OES from the Basic Plant digest.

1. Wolf, B. (1971). The determination of boron in soil extracts, plant materials, composts, manures, waters and nutrient solutions. Comm. Soil Sci. and Plant Anal. 2:363.
2. Anderson, K.A. (1996). Micro-digestion and ICP-AES analysis for the determination of macro and micro elements in plant tissue. Atomic Spectroscopy. Jan/Feb p 30.

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Molybdenum, Cobalt, Selenium

Mo, Co and Se are determined by ICP-MS from the Basic Plant digest.

Iodine

Iodine is extracted from plant tissue using a dilute solution of tetramethylammonium hydroxide (TMAH) at an elevated temperature of 90°C. The extract is filtered for analysis by ICP-MS.

1. Chiung-Seng Hsiung, J.D. Andrade, R. Costa and K. Owen Ash. *Clinical Chemistry*, 1997, 43:12, 2303-2311.
2. Pruszkowski E., Neubauer, K. and R. Thomas. *Atomic Spectroscopy*, 1998, 19(3), 111-115.
3. Fecher P.A., Goldman, I. and A. Nagengast. *Journal of Analytical Atomic Spectrometry*, 1998, 13, 977-982.
4. Larsen, E.H. and S. Sturup. *Journal of Analytical Atomic Spectrometry*, 1994, 9, 1099-1105.
5. Moxon, R.E.D and E.J. Dixon. *Analyst*, 1980, 105, 343.
6. Niu, H.S and R.S. Hook. *Spectrochem. Acta, Part B*, 1996, 51, 779.

Nitrate-N

Nitrate is extracted from the dried and ground plant tissue using acetic acid (2%, 1:250 w/v tissue:extractant ratio, 45 minute shaking). The nitrate is then determined by FIA using cadmium reduction.

1. Cataldo, D.A., Haroon, M., Shroder, L.E. and Younger, V.L. (1975). Rapid Colorimetric Determination of Nitrate in Plant Tissue by Nitration of Salicylic Acid. *Communication in Soil and Science and Plant Analysis*. 6, 71-80.

Sulphate-S

Sulphate-sulphur is extracted with acetic acid (2%, 1:25 w/v tissue:extractant ratio, 30 minutes shaking), and the extract is treated with activated carbon to remove organic matter. SO₄-S is determined by ICP-OES

1. Garrido, L. (1964). The Determination of Sulphur in Plant Material. *Analyst*. 89, p 61.
2. Blanchar, RW., Rehm, G., Caldwell, AC. "Sulphur in Plant materials by Digestion with Nitric and Perchloric Acids." *Soil Sci proc*. Page 71, 1965

Chloride

Chloride is determined from a nitric acid extraction (2%, 1:50 w/v tissue:extractant ratio, 1 hour shaking), by titration with silver nitrate and with potentiometric end-point detection.

1. APHA (1985). *Standard Methods for the Examination of Waters and Wastewaters*. 16th Edition, APHA Method 407C.
2. Page, A.L. et al (Eds) (1982). *Methods of Soil Analysis, Pt 2. Chemical and Microbiological Properties*. Second Edition, SSSA., p 455.

Aluminium, Titanium

Aluminium and titanium are determined by ICP-OES from the Basic Plant digest.

1. Anderson, K.A. (1996). Micro-digestion and ICP-AES analysis for the determination of macro and micro elements in plant tissue. *Atomic Spectroscopy*. Jan/Feb p 30.

Crude Protein

Crude protein is calculated from plant Nitrogen using the industry standard conversion factor of 6.25

1. National Forage Testing Association - Forage Analysis Procedures 3.3 Nitrogen Determination by Combustion Method.
2. Protein (Crude) in Animal Feed: Combustion Method. (990.03) *Official Methods of Analysis*. 1990. Association of Official Analytical Chemists. 15th Edition.



TECHNICAL NOTES

Ash

The ash content of plant samples is determined by ashing at 600°C in porcelain crucibles for 3 hours.

- 1.AOAC (1984) 7.009
- 2.National Forage Testing Association - Forage Analysis Procedures 7 – Total ash in forages.
- 3.Ash of Animal Feed. (942.05) Official Methods of Analysis. 1990. Association of Official Analytical Chemists. 15th Edition.

Soluble Sugars

Soluble sugars are extracted from plant material by extraction with aqueous alcohol and determined by phenol-sulphuric acid colorimetry.

- 1.Dubois, Gillies, Hamilton, Rebers & Smith.1956. Analytical Chemistry. 28,p350.
- 2.MB Hall, WH Hoover, JP Jennings and TK Miller Webster.A method for partitioning neutral detergent-soluble carbohydrates. 1999. Journal of the Science of Food and Agriculture.79, p2079

Starch

Starch in the sample is degraded to its constituent sugars by starch-degrading enzymes (amylglucosidase) and the resultant sugars are determined by phenol-sulphuric acid colorimetry. A pre-treatment to remove any soluble-sugars in the sample is necessary before 'hydrolysis' of the starch.

- 1.AOAC Method 996.11
- 2.AACC Method 76.13
- 3.ICC Standard Method No.168

Acid Detergent Fibre

An acidified quaternary detergent solution is used to dissolve cell soluble hemicellulose and soluble minerals leaving a residue of cellulose, lignin, potential heat damaged protein and a portion of cell wall protein and minerals. The ADF is determined gravimetrically as the residue remaining after extraction.

- 1.AOAC (1990) 7.074
- 2.MAFF: Bulletin RB 427- The Analysis of Agricultural Materials (1981) Method 33.62
- 3.National Forage Testing Association Procedures manual (1997)

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Neutral Detergent Fibre

A neutral detergent solution is used to dissolve the easily digested pectins and plant cell contents (proteins, sugars and lipids), leaving a fibrous residue that is primarily cell wall components of plants i.e. cellulose, hemicellulose and lignin.

- 1.AOAC (1990) 7.074
- 2.MAFF: Bulletin RB 427 – The Analysis of Agricultural Materials (1981) Method 33.62
- 3.National Forage Testing Association Procedures Manual (1997).

Digestibility (DOMD) and Metabolisable Energy (ME)

In vitro digestibility is the measure of organic matter disappearance simulated in the laboratory and involves treating feed samples with commercially available enzymes. The pepsin-cellulase technique attempts to simulate the ruminant digestion process for the determination of in vitro digestibility. Samples are treated with a sequence of acidified pepsin, alpha amylase and buffered cellulase solutions. The digest residue is ashed to provide organic matter digestibility by gravimetric determination. In vivo organic matter digestibility is predicted from regression equations derived in conjunction with Lincoln University Feed Testing laboratory. Organic matter digestibility is converted to dry organic matter digestibility (DOMD) for reporting.

Metabolisable Energy (ME) is derived from DOMD by calculation.

- 1.Clarke, T., Flinn, P.C. and McGowan, A.A. 1982. Low cost pepsin-cellulase assays for prediction of digestibility of herbage. *Grass and Forage Sciences* 37:147-150.
- 2.Method 7R: Determination of digestibility using the pepsin-Cellulase Method. *Fodder Analysts Laboratory manual*. AFIA, 2005.
- 3.Kaiser, A., Freer, M., Flinn, P., Black, J. Recommendations for Australian Laboratories, AFIA Quality Evaluation Meeting, Adelaide, 17th Feb 2005. prediction of metabolisable energy content of forages and concentrates from measurements of digestibility.
- 4.AFRC (1993) Energy and Protein Requirements of Ruminants. An advisory manual prepared by the AFRC Technical Committee on responses to Nutrients. CAB International, Wallingford, UK.

pH (Silages)

Fresh silage sample is extracted with water (1:5 w/v sample:extract) for four hours then measured for pH.

- 1.Kaiser, A.G. and Piltz, J.W. (2003). 12. Feed testing: assessing silage quality. In: "Successful Silage", eds A.G. Kaiser, J.W. Piltz, H.M. Burns and N.W. Griffiths (Dairy Research and Development Corporation and NSW Agriculture: Australia), 24pp.

Ammonium-N (Silages)

Fresh silage sample is extracted with water (1:5 w/v sample:extract) for four hours then measured for NH₄-N by segmented flow analysis. Results are reported on a dry matter basis.

- 1.Kaiser, A.G. and Piltz, J.W. (2003). 12. Feed testing: assessing silage quality. In: "Successful Silage", eds A.G. Kaiser, J.W. Piltz, H.M. Burns and N.W. Griffiths (Dairy Research and Development Corporation and NSW Agriculture: Australia), 24pp.

Lactic Acid and Volatile Fatty Acids (Silages)

Fresh silage sample is extracted with water (1:5 w/v sample:extract) for four hours then measured for lactic, acetic, butyric, propionic and formic acids by Ion Chromatography. Results are reported on a dry matter basis.

Crude Fibre

Dried & ground feedstuff sample (defatted where necessary) is treated with boiling solutions of sulphuric acid and sodium hydroxide. The residue is washed with boiling water, dried, weighed and ashed. The loss of weight from ashing corresponds to the crude fibre present in the sample.

- 1.AOAC method 962.09 Fibre (Crude) in Animal feed and Pet Food, 18th ed
- 2.MAFF: Bulletin RB 427 – the Analysis of Agricultural Materials (1981) Method 33.62
- 3.National Forage Testing Assoc. Procedures Manual 1997.



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Crude Fat

Samples are extracted with an organic solvent (petroleum spirit, b.p. 40 – 60°C) using a modified Soxhlet procedure. The procedure removes all components of the sample soluble in the solvent, including fats and oils, and other organic components, such as plant pigments. The solvent is then isolated from the extracted components, which are then weighed and expressed as crude fat. Results are reported on a dry matter basis.

1. AOAC Method 960.39, Fat (Crude) or Ether Extract in Meat, 16th Edition modified (dry with sand for 1 hour at 103°C).
2. AOAC Method 991.36, Fat (Crude) in Meat and Meat Products, Solvent Extraction (Submersion) Method, 16th Edition modified (dry sample and residue at 103°C, Soxhlet extraction).

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