Processing and utilization of sorghum. Selected bibliographical references (with abstracts) from 1990 to 1996 (NRI Bulletin 72)

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Bulletin 72

PROCESSING AND UTILIZATION OF SORGHUM

Selected Bibliographical References (with abstracts) from 1990 to 1996

NATURAL RESOURCES INSTITUTE
The University of Greenwich

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Bulletin 72

Natural Resources Institute

The University of Greenwich

The Natural Resources Institute (NRI) is a scientific institute within the University of Greenwich, and is an internationally recognized centre of expertise in research and consultancy in the environment and natural resources sector. Its principal aim is to increase the productivity of renewable natural resources in developing countries in a sustainable way by promoting development through science.

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Summaries

SUMMARY

The purpose of this bibliography is to bring together, under one reference document, information from very many different sources covering recent research (from 1990 onwards) on post-harvest processing and utilization of sorghum. Key books are also noted. It contains more than 390 references. To simplify classification, references have been grouped under seven headings according to the main focus of the reference.

- **General** **31 references**
- **Primary Processing** **28 references**
- **Secondary Processing** **59 references**
- **Food Quality** **86 references**
- **Industrial Uses** **115 references**
- **Animal Feed and Forage** **61 references**
- **Publications and Books** **12 references**

This publication will be of considerable benefit to researchers, students, NGOs and aid agencies requiring up to date information on the post-harvest aspects of sorghum processing and utilization. It will be of particular help to researchers who do not have access to electronic data bases for literature search.

RESUME

L'objet de la présente bibliographie est de rassembler dans un document de référence une information, provenant d'un très grand nombre de sources, couvrant les recherches récentes (à partir de 1990) dans le domaine du traitement d'après-récolte et de l'utilisation du sorgho. Les livres-clés sont également mentionnés. La bibliographique contient plus de 390 références. Pour simplifier la classification, les références ont été regroupées dans sept rubriques selon le thème principal de la référence.

- **Généralités** **31 références**
- **Traitement primaire** **28 références**
- **Traitement secondaire** **59 références**
- **Qualité des aliments** **86 références**
- **Utilisations industrielles** **115 références**
- **Aliments pour animaux et Fourrage** **61 références**
- **Publications et Ouvrages** **12 références**

Cette publication sera d'un intérêt considérable pour les chercheurs, les étudiants, les ONG et les agences d'aide qui requièrent une information récente sur les aspects du traitement d'après-récolte et l'utilisation du sorgho. Elle sera particulièrement utile aux chercheurs qui n'ont pas accès à des bases de données électroniques pour la recherche des publications.

RESUMEN

Esta bibliografía tiene como objetivo reunir informaciœn, procedente de fuentes muy diversas, relativa a trabajos recientes de investigaciœn (desde 1990 en adelante) sobre el tratamiento post-recolecciœn y la utilizaciœn del sorgo, en un solo documento de consulta. También se seþalan los vocablos clave. El documento contiene más de 390 referencias, que han sido clasificadas, para simplificar su consulta, bajo siete títulos, dependiendo del enfoque principal de la referencia, a saber:

- **General** **31 referencias**
- **Tratamiento primario** **28 referencias**
- **Tratamiento secundario** **59 referencias**
- **Calidad alimenticia** **86 referencias**
- **Usos industriales** **115 referencias**
- **Piensos y forrajes animales** **61 referencias**
- **Publicaciones y libros** **12 referencias**

Esta publicacicen será de gran utilidad para investigadores, estudiantes, ONGs y organizaciones de ayuda que requieran informacicen actualizada sobre los aspectos post-recoleccicen del tratamiento y utilizacicen del sorgo. También será particularmente útil para investigadores que carecen de acceso a bases electrcenicas de datos para realizar consultas bibliográficas.

Introduction

SORGHUM

Sorghum and millets (the small grains) are key staple cereals for many millions of people, particularly in Africa, India and central Asia, as major sources of starch and protein. They are often considered as subsistence crops because of their unique and notable tolerance to drought, and are grown mostly by farmers on small plots in the semi-arid tropics (SAT) which encompasses parts of 48 developing countries. Approximately one sixth of the world's population live in the SAT. Sorghum (*Sorghum bicolor* (L.) Moench) is a tropical grass grown primarily in semi-arid areas. It is highly variable, there being more than 30,000 collected accessions. It can be classified most easily into two variety types:

- **brown sorghum** which is high in tannin due to the presence of a pigmented testa (subcoat); the pericarp is usually brown, but may also be white, yellow-pink, orange, red or bronze;
- **white sorghum** which has no tannin due to the absence of a pigmented testa; the pericarp colour may appear translucent, white, yellow, pink, orange, red or bronze.

Tannins help protect the grain against bird attack, insects, weathering and moulds, but impart a bitter taste and cause antinutritional effects. Removal of the pigmented testa and the pericarp are generally accepted as improving food quality by reducing the tannin and fibre contents. Varieties of sorghum may be hard (i.e., have a high proportion of corneous endosperm relative to floury endosperm) or soft (with mainly flourly endosperm); many high tannin varieties are soft.

Sorghum is used locally in a wide range of food preparations (thick and thin porridges, steam-cooked and boiled rice-like products, fermented and unfermented breads and snack foods): alcoholic beverages (traditional beers) and low/non-alcoholic beverages (sourings and malted drinks). Several of these have social significance and form part of the traditional life, festivals and religious rites of people. Crop residues are valued as animal fodder, building materials and fuel. Increasingly, sorghum is being used commercially by the brewing industries (for making lager) and as an industrial feedstock for the production of starches and animal feed. In the last two decades, the use of sorghum for food in relation to feed use has declined from 50% to 30% of world production.

PRODUCING COUNTRIES

Sorghum producing countries include:

- developing countries, particularly Asia and Africa where sorghum is grown within traditional farming systems

- developed countries, mainly the US, Australia and South Africa where it is produced on a commercial basis and used almost exclusively for animal feed.
- developing countries, particularly in Latin America and others in Asia (China and Thailand) where sorghum was once a staple, but is increasingly used for animal feed or other non- human food uses such as alcoholic beverages.
- new producers, in particular south European regions where there is increasing interest in producing sweet sorghum for non-food purposes in set-aside lands, mainly as sources of biofuels and raw material for energy production.

PRODUCTION TRENDS

Sorghum together with maize and millet is considered to be one of the coarse grains. In recent years there has been a decline in sorghum production throughout West Africa and the SADC countries, production stagnation in India and Pakistan and decline in other Asian countries and in Australia. In comparison, the consumption of wheat, rice and maize is increasing in many (if not all) developing countries. This shift is not simply the result of supply constraints and price changes, but rather a consequence of rising incomes, the effects of urbanisation, food aid imports, changing preferences, the convenience and pre-packed availability of products and their ease of consumer use. Increases in wheat and rice are largely served through imports from Asia and North America, and this is inevitably placing increasing burdens on many developing countries. Nigeria banned the import of maize and wheat in 1987 for economic reasons and the export of all grains, yams and tubers in 1988. In 1991, the debate on a regional protection zone in the Sahel was again revived.

Around 61,000 million tonnes of sorghum are produced per annum. Table 1 shows recent world production of sorghum which ranks fifth after wheat (528 000 million tonnes): rice (535 000 million tonnes): maize (570 000 million tonnes) and barley (161 000 million tonnes) (1994).

Table 1: Sorghum production (1,000 million tonnes)

Producers (>100 × 10^6/year)	1979-81	1991	1992	1993	1994
World	**65 525**	**54 768**	**69 563**	**57 111**	**60 951**
Africa	**12 408**	**15 430**	**15 537**	**14 565**	**15 833**
Benin	59	115	110	106	113
Burkina Faso	620	1238	1292	1228	1200
Cameroon	301	400	380	390	400
Chad	210	365	387	306	379
Egypt	644	676	766	779	717
Ethiopia	1419	810	1100	1079	1109
Ghana	140	241	259	328	260
Kenya	160	98	129	90	123
Mali	341	770	602	694	903
Mauritania	28	58	50	92	114
Mozambique	181	155	66	143	164
Niger	347	463	387	421	420
Nigeria	3284	4346	4100	4000	4000
Rwanda	178	205	154	109	87
Senegal	131	131	117	99	132
Somalia	167	145	92	80	252
South Africa	540	260	101	478	432
Sudan	2273	3540	4042	2386	3498
Tanzania	543	550	587	719	478
Togo	87	141	112	126	130
Uganda	312	363	375	383	390

Table 1 *contd*

N C America	**24 697**	**19 625**	**28 197**	**18 235**	**21 103**
El Salvador	145	163	214	205	184
Haiti	121	90	100	80	80
Mexico	4991	4250	5353	4085	3869
Nicaragua	80	71	92	105	115
USA	19 157	14 856	22 227	13 569	16 638
S America	**6854**	**4057**	**4525**	**4378**	**3812**
Argentina	5641	2251	2766	2839	2160
Bolivia	21	47	46	120	78
Brazil	172	258	282	251	290
Colombia	488	738	752	633	680
Uruguay	112	136	137	130	130
Venezuela	365	577	511	367	446
Asia	**19 690**	**14 065**	**18 8691**	**8 499**	**18 602**
China	7034	5053	4779	5612	4915
India	11 380	8100	12 597	11 803	12 500
Pakistan	235	225	238	212	230
Saudi Arabia	123	161	162	175	190
Thailand	237	250	250	208	300
Yemen	616	247	459	465	444
Europe	681	743	841	801	606
France	332	394	565	507	266
Italy	731	501	792	262	28
Spain		104			
Oceania	**1087**	**751**	**1448**	**549**	**934**
Australia	1084	1447	1447	548	933

Source: *FAO Yearbook: Agricultural Statistics 1980-1994*

Sorghum grows and produces variable yields in the SAT-areas characterised by inadequate and uncertain rainfall, nutrient-poor and fragile soils, low capital availability and weak institutions and infrastructure. Production areas are increasing in size through changes in climatic patterns, overuse of marginal land by overgrazing and by deforestation. Sorghum (and millets) cannot compete successfully with maize as a cereal in an agroecological system with over 1000 mm of annual rainfall; but it is inconceivable that maize will replace sorghum in areas less than 900 mm of rainfall. Their low input, low risk characteristics give the small grains a decisive advantage over maize and other competing crops. Being grown mainly in marginal environments under moisture stress conditions, average yields have remained low though higher than would have been obtained with other crops under similar conditions. However, when there is improvement of water availability or fertility of the land farmers tend to shift to maize, wheat or rice, as these provide better prices and have better access to established marketing channels and systems, when compared with sorghum.

INCREASING THE UTILIZATION OF SORGHUM

Many researchers comment that increasing the diversification of sorghum, particularly in developing a greater scope of industrial products/feedstock, will increase the utilization of sorghum (or at least reduce the rate of decline in production) and provide more secure markets. This may be true, but the requirements and priorities for industrial use, particularly in terms of agronomic performance and quality criteria, are quite different to the needs and preferences of consumers as a key, low-resource, agricultural staple in rural areas and for food products in urban and peri-urban areas. However, the farmer's acceptance of and preference for growing sorghum are largely influenced by local factors concerned with market price and levels of demand.

As a consequence, it is important that policy-makers, crop improvement programmes and related research into increasing the utilization of sorghum, take account of all of the various factors. Without such understanding and inter-collaboration, the food insecurity situation for many people in the SAT may well worsen. It is hoped that this bibliography will highlight the diversity of interest in sorghum and provide a ready information source for those involved, directly or indirectly, in its processing and the utilization aspects, for the benefit of producers and consumers in the semi-arid tropics.

Classification of references

For ease of use, seven topic headings are presented to broadly identify the principal content of individual references.

1 GENERAL (31 references)

References of a more general nature related to processing and utilization, including economics, marketing and policy.

2 PRIMARY PROCESSING (28 references)

References relating to storage, cleaning, grading, hulling, pounding, milling (dry, semi-wet and wet), grinding, tempering, soaking, boiling, par-boiling, steaming, drying, sieving and the processing of sorghum to products not directly consumable but which require further processing.

3 SECONDARY PROCESSING (59 references)

References relating to baking, composite flour, frying, extruding, popping, blending, fermenting, roasting, weaning foods, drinks and other products.

4 FOOD QUALITY AND NUTRITION (86 references)

References on general quality issues, chemistry and those specifically concerned with research into nutritional and antinutritional aspects and digestibility.

5 INDUSTRIAL USES (115 references)

References relating to malting (for brewing): brewing, starch, alcohol and sugar production from sorghum.

6 ANIMAL FEEDS AND FORAGE (61 references)

References relating to the use of sorghum as feeds and forage for livestock.

7 PUBLICATIONS AND BOOKS (12 references)

Bibliographical references

1 GENERAL

ANONYMOUS (1990)

Recommendations.

p. 47. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, Decemeber 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The major uses of sorghum are summarized The problems associated with its utilization in milling and composite flour production, non-wheat flours and other novel products, beverages, and forage and feed in Nigeria, are also noted.

ANONYMOUS (1993)

Recommendations.

pp. 61-67. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers' Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

Recommendations from the working groups at the consultative meeting are summarized. Group I discussed crop improvement and protection, and Group II discussed alternative uses, production and market linkages.

ALMODARES, A. and ZADEH, A.V. (1993)

Sorghum research in Iran.

pp. 39-42. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers' Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

The emphasis of sorghum research in Iran, which is governed by its decreasing order of importance for forage, feed (poultry), industry (crystalline or liquid sugar), and human consumption (composite flour), is reviewed. Research is concentrated on evaluation of hybrids, agronomic practices, and genetic and breeding programmes.

BANDA, T.E. (1993)

Sorghum and bulrush millet in Tanzania: situation and outlook.

pp. 17-27. In: *National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development, May 1993, Arusha International Conference Centre.* MINDE, L.J. and ROHRBACH, D.D. (eds). Arusha,Tanzania: Sokoine University of Agriculture.

The contribution of sorghum and millet to the food and income security of rural households is examined, and trends in production are determined in order to assess their importance in drought-prone areas. Market trends are analysed to compare their marketability in competition with maize and rice. The grain market structure is reviewed, and the position of sorghum and millet in the liberalized market is assessed.

DEBRAH, S.K. (1993)

The competitiveness of sorghum and millet in the food system of West Africa.

pp. 53-66. In: *National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development, May 1993, Arusha International Conference Centre.* MINDE, L.J. and ROHRBACH, D.D. (eds). Arusha, Tanzania: Sokoine University of Agriculture.

The competitive position of sorghum and millet in the food system in West Africa is examined, with particular reference to Mali. Cereal technology development and constraints to adoption are described, and the prospects and policies which might increase the competitiveness of sorghum and millet in their production and consumption are reviewed.

DELGADO, C.L. and REARDON, T. (1991)

Cereal consumption shifts and policy changes in developing countries: general trends and case studies from West African semi-arid tropics.

pp. 27-39. In: *Proceedings of the INSORMIL CRSP Conference, July 1991, Corpus Christi, Texas, US.*

EGA, L.A., OLATUNDE, A.F. and NWASKIE, C.C. (1993)

Acceptability of improved varieties of sorghum for consumption in northern Nigeria.

Food Nutrition Bulletin, **14**(4): 357-361.

Several new varieties of sorghum were evaluated for consumer acceptability in two foods commonly prepared from sorghum (*kamu* and *tuwo*). All the improved varieties made acceptable products and met the expectations of consumers in terms of colour, appearance, flavour, taste and texture; they did not pose obvious processing and milling problems. There is a need to monitor these varieties for consumer preference using quantitative techniques and other combined acceptance tests.

HENZELL, R.G. (1993)

Grain sorghum in Australia.

pp. 54-59. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers' Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

Grain sorghum production in Australia, where it is used only as stock feed for cattle, pigs and poultry, and in pet foods, is reviewed. Major areas of research are summarized; these are mainly involved with genetic improvement.

HEPWORTH, A. and VANCE, P.N. (1992)

Australian white grain sorghum as a human food.

pp. 367-372. In: *Proceedings of the Second Australian Sorghum Conference, Gatton, February 1992.* FOALE, M.A. and HENZELL, R.G. (eds). *AIAS Occasional Publication 1992,* no. 68. Melbourne, Australia: Australian Institute of Agricultural Science.

Potential markets, and the problems associated with white grain sorghum as a human food, are discussed. Value added opportunities worthy of further investigation are proposed; these include processing and packaging of grain for export, and the production of pearled and/or milled products as raw materials for the food processing industry. Desirable characteristics of white grain sorghum are summarized.

IAMSUPASIT, N. (1993)

Sorghum research and development in Thailand.

pp. 50-53. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers' Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

The constraints to sorghum production in Thailand are reviewed. Current research activities concerned with the development of high yielding varieties are indicated, and improved agronomic and pest control practices are noted. Future areas of research are summarized and include hybrid development, varietal selection for pest and drought resistance, and on-farm adaptive research.

KELLEY, T.G., PARTHASARATHY RAO, P. and SINGH, R.P. (1992)

Trends in Sorghum Production and Utilization in Asia.

Resource Management Program Economics Group: Progress Report 108. Patancheru, India: ICRISAT.

KELLEY, T.G. and PARTHASARATHY RAO, P. (1993)

Production and Research Environment for Sorghum and Millet in Asia.

Resource Management Program Economics Group: Progress Report 114. Patancheru, India: ICRISAT.

The decline in production and development of sorghum in Asia over the past decades is reviewed. The scope for reversing this trend is discussed with particular reference to the development of alternative uses. It is suggested that the key might lie in the significant and sustainable increase in yield. This is discussed and research strategies proposed.

KHA, T. (1993)

Sorghum research and development in Myanmar.

pp. 43-45. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers' Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

Sorghum production constraints in Myanmar, which are mainly low fodder yield, poor fodder storage quality, susceptibility to pest attack, and availability and distribution of quality seeds, are reviewed. Current research themes are summarized. These focus on the development of varieties and crop management techniques to overcome the constraints.

KOLEOSO, O.A. and OLATUNJI, O. (1992)

Sorghum malt/adjunct replacement in clear (lager) beer: policy and practice in Nigeria.

pp. 41-45. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The effect of policy change on the brewing industry in Nigeria, from a gradual and partial substitution of imported industrial raw materials to total substitution, is reviewed. The development of appropriate malting and brewing procedures, and the efforts of brewing houses and federal research institutes to comply with policy, are discussed.

MINDE, I.J. and MBIHA, E.R. (1993)

Production, technology and constraints in the sorghum and millet based farming systems.

pp. 28-44. In: *National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development, May 1993, Arusha International Conference Centre.* MINDE, I.J. and ROHRBACH, D.D. (eds). Arusha, Tanzania: Sokoine University of Agriculture.

The sorghum- and millet-based farming systems in different regions of Tanzania are described. The importance of sorghum and millet in the farming system, the yields compared to maize and rice, and the availability and application of technology, are investigated. Finally, policy constraints to the improvement of the farming system are discussed.

MOSHA, A.C. (1990)

Sorghum and millet processing and utilization in the Southern Africa Development Co-ordination Conference Area.

pp. 15-18. In: *Research and Development Issues in Grain Post-Harvest Problems in Africa. GASGA Executive Seminar Series Volume 1.* Eschborn, Germany: GTZ.

The processing aspects of the utilization of sorghum and millet, and their interaction with food security in the Southern Africa Development Co-ordination Conference (SADCC) region, are examined. The three main small grains grown in SADCC countries are sorghum, pearl millet and finger millet. For each of these, the nutritional composition, processing technologies, food products, competition, and research and development, are investigated.

MORAPEDI, N.T. (1993)

Sorghum and millet marketing and utilization: the case of Botswana.

pp. 67-74. In: *National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development, May 1993, Arusha International Conference Centre.* MINDE, I.J. and ROHRBACH, D.D. (eds). Arusha, Tanzania: Sokoine University of Agriculture.

The current situation regarding sorghum and millet marketing and utilization in Botswana is described. Issues of crop production, processing, recent improvements in marketing, utilization and distribution, pricing, and expanded utilization, are discussed.

MORRIS, W.C., JENKINS, R.P., McCARTY, I.E. and COLLINS, J.L. (1993)

Practices of Tennessee growers in producing and marketing sweet sorghum.

Tennessee Farm and Home Sciences, **166**: 9-16.

The results of a questionnaire aimed at identifying the agronomic, processing and marketing practices used by growers producing sweet sorghum syrup are presented. It was found that 62% of producers use stainless steel evaporator pans for production of syrup whereas some still use galvanized evaporators. Larger-scale producers were more likely to use the recommended purification and instrumental methods. Although the use of plastics and glass containers appears to be gaining in popularity, 42% of producers still sell sweet sorghum syrup in the traditional cans.

MURTY, D.S. (1992)

The breeder's role in crop utilization: a perspective.

pp. 157-163. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

Advances in utilization and food quality evaluation are reviewed. Grain quality criteria useful in breeding and the selection of important attributes related to utilization are illustrated. The concept of breeding for different end-uses and total plant utilization is discussed. Finally, the need for collaborative effort between breeders, scientists and technologists is emphasized.

MURTY, U.R. and RANA, B.S. (1993)

Sorghum production and utilization in India.

pp. 34-38. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers' Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

The constraints to sorghum production in India, which are mainly due to the effects of drought during both its growing seasons, and to pests and diseases, are reviewed. It is noted that severe problems only occur in endemic pockets. Current research thrusts are summarized; these focus on the development of hybrids for each growing season, multi-cut forage hybrids, and alternate uses of grain and stalks.

MURTY, U.R. (1992)

Sorghum production and utilization in India: the present and the future.

Agricultural Situation in India, **47**(6): 497-506.

The production and utilization of sorghum in India is discussed. Production and productivity trends, production constraints including research, the coverage of high-yielding varieties, the potential for increasing production, and present and future utilization, are reviewed.

MWAIPYANA, H.A. (1993)

Sorghum and millet in the policy agenda of Tanzania.

pp. 13-16. In: *National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development, May 1993, Arusha International Conference Centre.* MINDE, I.J. and ROHRBACH, D.D. (eds). Arusha,Tanzania: Sokoine University of Agriculture.

The development of agricultural policies in Tanzania is reviewed with the focus mainly on grain marketing. Special attention is given to the impact of these policies on sorghum and millet. The review time-frames three major periods: post-independence (1962-1972), the period when food self-sufficiency was the over-riding objective (1973-1983), and the period of economic reforms (1984-1992).

NAEEM, M. and SHOKOOR, A.. (1993)

Sorghum research in Pakistan.

pp. 45-49. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers' Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

Current and future research objectives for sorghum in Pakistan are reviewed. They include the following: germplasm screening for tolerance to drought, heat and salinity; breeding for resistance to major disease; and mechanization of production with regards to tilling, sowing, harvesting and threshing.

NICHOLSON, N.F. (1992)

Processing of sorghum in Botswana for foods and feeds: problems and opportunities.

pp. 99-101. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The problems and opportunities for sorghum in Botswana, where production of maize and sorghum is insufficient to meet the needs of the population, are discussed. Sorghum consumption is in decline, with an increasing trend towards maize products. The trend seems irreversible unless better processing methods can be developed to produce more highly refined products from sorghum.

REARDON, T. (1993)

Cereals demand in the Sahel and potential impacts of regional cereals protection.

World Development, **21**(1): 17-35.

The cross-country consumption patterns of cereals, and the sensitivity of these to policy variables, are discussed. The potential income distribution and efficiency impacts of a rice tariff increase in the Sahel are considered.

The development of maize and sorghum production with regard to substitution and food security in drought years is discussed with reference to the trend for increased rice consumption.

ROONEY, L.W. and SERNA SALDIVAR, S.O. (1991)

Sorghum.

pp. 233-270. In: *Handbook of Cereal Science and Technology.* LORENZ, K.J. and KULP, K. (eds). New York: Marcel Dekker.

After a brief introduction to sorghum types and their uses, particularly in developing countries, the following topics are reviewed: structure of the grain and its physical properties; appearance of the grain and its genetics; market classes; composition; effects of tannins and polyphenols on nutritional value; industrial utilization (wet milling, starches, dry milling, alcohol production, beer and malt production); processing for food (traditional foods, baked and pasta products, sorghum syrup, molasses and sugar); and nutritional value (including effects of processing).

ROONEY, L.W. (1992)

Critical progress in sorghum utilization and improvement.

pp. 8-15. In: *Proceedings of the Fifth Quadrennial Symposium on Sorghum and Millet (at the Ninth International Cereal and Bread Congress), June 1992, Paris.* Vienna, Austria: International Association for Cereal Science and Technology (ICC).

An overview and update is provided on the progress and developments which have occurred in sorghum and millet quality and utilization, with the emphasis on activities in the USA and Africa. Topics include the use of sorghum in brewing, sorghum with improved malting qualities, enhancement of quality through hybrid developments, new products, and processing.

SCHAFFERT, R.E. (1992)

The use of sorghum for food in Brazil.

pp. 95-97. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The potential demand for composite flours in Brazil, and the development and use of new white sorghum varieties for human consumption, are discussed in the light of changes in policy which remove wheat subsidies.

TIISEKWA, B.P.M. and LASWAI, H.S.S. (1993)

The status of sorghum and millet utilization in Tanzania.

pp. 75-78. In: *National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development, May 1993, Arusha International Conference Centre.* MINDE, I.J. and ROHRBACH, D.D. (eds). Arusha, Tanzania: Sokoine University of Agriculture.

The issues affecting the utilization status of sorghum and millet are examined. The basic questions asked were: who uses cereal, how much is used, and why is the use of sorghum and millet limited? The answers can contribute towards the formulation of effective strategies for increasing the industrial use of sorghum and millet.

VASUDEVA RAO, M.J. (1993)

Research-production-market linkages in sorghum - future needs for Asia.

pp. 19-23. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers' Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

The future needs of sorghum research in Asia are reviewed. Topics discussed include hybrid improvement and suitability, and the development of sustainable seed production areas and regions.

YUE, C. and YUXUE, S. (1993)

Sorghum research in China.

pp. 29-33. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers' Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

Sorghum production and research needs in semi-arid regions of China are reviewed. Measures are discussed for improving yield potential and stability under environmental stress, and insect pest and disease pressure; these include integrated research, hybrid development, and the study of mechanisms of tolerance and agronomic practices.

2 PRIMARY PROCESSING

BANGU, N.T.A. (1992)

Traditional technologies in small grains processing: roasting and malting - the Tanzanian experience.

pp. 57-59. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The potential of traditional processing practices for enhancing the acceptability of sorghum by a wider sector of the population in several regions of Tanzania, is discussed.

CECIL, J.E. (1992)

Semi-wet milling of red sorghum: a review.

pp. 23-26. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

Research into the semi-wet milling of sorghum using a conventional wheat roller mill is reviewed. Results have shown that good yields of fine flours with few tannins can be produced. The implications are discussed.

CHIROMA, Z.B. (1990)

Sorghum milling at Zaki flour mills.

pp. 16-17. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

A commercial milling operation in Nigeria by which sorghum, maize, wheat and millet are processed, is described. Problems associated with sorghum milling are presented.

DINAT, S. (1992)

Status of sorghum milling technology at Rural Industries Innovation Centre, Botswana.

pp. 33-39. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

A brief account is given of the development of sorghum milling technology at RIIC, Botswana, and the development of marketing strategies. Problems encountered in research and development are reported, the support structures required for the implementation of a small-scale, agro-industrial programme are outlined, and the requirements for the development of supporting technology in the region are examined.

FLIEDEL, G. and YAJID, M. (1992)

Effect of milling on sorghum tô quality.

pp. 73-86. In: *Proceedings of the Fifth Quadrennial Symposium on Sorghum and Millet (at the Ninth International Cereal and Bread Congress), June 1992, Paris.* Vienna, Austria: International Association for Cereal Science and Technology (ICC).

This study underlined the importance of technology in the quality of flours used for the production of tô, a traditional thick porridge consumed in African countries from Senegal to Ethiopia. A high correlation between tô texture and flour median particle size, or damaged starch, was identified.

GALANI, N.N., LOMTE, M.H. and CHOUDHARI, S.D. (1991)

Juice yield and Brix as affected by genotype, plant density and N levels in high energy sorghums.

Bharatiya Sugar, **16**(4): 23-24.

Two cultivars grown at two plant densities with increasing N rates (0, 40, 80 and 120 kg/ha) had increased average juice yields from 9478 to 11 176 litres/ha. Crops grown at densities of 180 000 and 270 000 plants/ha gave yields of 10 111 and 10 927 litres, respectively. The Brix value (sugar content) of stem juice increased with age from flowering to maturity. Juice Brix was similar for the two cultivars, four N levels, and two plant populations.

HAMMOND, L. (1994)

A comparative study of three methods for milling sorghum grain and an assessment of the quality of the flour produced.

Internal Report of Project A0164. Chatham, UK: Natural Resources Institute.

Flours produced by semi-wet and dry simple roller milling, and dehulling/hammer milling, were compared for yield and particle size. Although dehulling/hammer milling gave the highest yields, a more refined product could be obtained from either multi-pass or simple roller milling. Semi-wet milling proved unsuitable.

HAMMOND, L. (1996)

Report on processing trials to compare sorghum flour produced by dehulling/hammer milling with that produced by simple roller milling.

Internal Report of Project A0436. Chatham, UK: Natural Resources Institute.

Flour produced from two varieties of red sorghum by two different milling techniques were compared for quality. Flours produced by dehulling/hammer milling were higher in fat, mineral matter and fibre than similar products produced by roller milling; total yields were similar.

MATHUR, R.D. (1990)

Sorghum milling techniques.

p. 16. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The modification of wheat milling plants in Nigeria for the milling of sorghum is reported.

MUKURU, S.Z. (1992)

Traditional technologies in small grains processing.

pp. 47-56. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

Traditional grain processing technologies from the semi-arid tropics of Africa and India, including the processing of high-tannin sorghum in Uganda, are reviewed.

MUKURU, S.Z., BUTLER, L.G., ROGLER, J.C., KIRLEIS, A.W., EJETA, G., AXTELL, J.D. and MERTZ, E.T. (1992)

Traditional processing of high-tannin sorghum grain in Uganda and its effect on tannin, protein digestibility and rat growth.

Journal of Agricultural and Food Chemistry, **40**(7): 1172-1175.

The unique traditional processing technology evolved in Uganda to process high-tannin sorghum using wood ash slurry is reviewed in detail. The wood ash treatment effectively detoxifies the grain and raises the nutritional status to the level of low-tannin sorghum.

MULIMANI, V.H. and SUPRIYA, D. (1994)

Tannic acid content in sorghum (Sorghum bicolor M.): effects of processing.

Plant Foods for Human Nutrition, **46**(3): 195-200.

Methods of reducing the tannin content in sorghum grain were investigated in order to improve the nutritional quality of sorghum. The treatments included: overnight soaking in 2% NaHCO3; overnight soaking in alkalis (2% CaO, 2% K2CO3, 2% NaOH and 2% HCHO); overnight soaking in different concentrations of ammonia solution (10, 20, 30 and 40%); and autoclaving. Of the treatments tested, overnight soaking in ammonia solution was the most effective for the complete removal of tannins.

NAVITA, G. and SUMATHI, S. (1992)

Effect of primary processing on dietary fibre profile of selected millets.

Journal of Food Science and Technology, **29**(5): 314-316.

The effect of primary processing on dietary fibre profiles of sorghum, bajri, ragi and wheat is reported. Total dietary fibre of sorghum bran was found to be much lower than the bran from other grains. Processing produced a significant decrease in total dietary fibre in all samples.

NGODDY, P.O. (1990)

Sorghum milling in Nigeria: A review of industrial practice and R&D innovations.

p. 14. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

Traditional and industrial milling of sorghum in Nigeria is reviewed, focusing on the impact which the ban on wheat import has had on technical progress.

OBIANA, W.A. (1990)

Dry milling sorghum.

p. 15. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The modification of a wheat mill with an added decomatic decorticator for the dry milling of sorghum in Nigeria, is reported.

PARVATIKAR, S.R. and MANJUNATH, T.V. (1991)

Alternate uses of sorghum-sweet sorghums, a new prospectus for juicy stalks and grain yields.

Journal of the Maharashtra Agricultural Universities, **16**(3): 352-354.

Stalk juice and grain yield of 11 sweet sorghum genotypes were studied. The total sugar content in the juice was maximum at the physiological maturity stage. The stalks appeared to be very active photosynthate sinks until maturity, accumulating more dry matter than other plant parts, but in all genotypes, the juice extractability decreased by 20-25% from anthesis to physiological maturity.

PATKAR, K.L., USHA, C.M., SHETTY, H.S., PASTER, N., KENNEDY, R. and LACEY, J. (1995)

Effect of propionic acid on the incidence of storage fungi in stored rice, sorghum and groundnut under tropical conditions.

Tropical Science, **35**(1): 40-48.

The effect of propionic acid on the mycoflora of rice, sorghum and groundnut during storage at 90% RH was investigated. The treatment reduced infection by all the dominant storage fungi except Eurotium spp., but it also markedly decreased seed germination. The treatment was more effective on sorghum than on rice and groundnut. However, the seed fungi were never totally eradicated. Possible alternatives to propionic acid for the control of storage fungi are indicated.

ROONEY, L.W. (1992)

Wet milling nixtamalization and micronization of sorghum.

pp. 19-21. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The potential of some sorghum hybrids for wet milling is reviewed. Nixtamalization is the conversion of maize into tortillas by cooking and soaking in alkali or the leachate of wood ashes. Sorghum is commonly processed by this method for the production of tortillas in central America and southern Mexico. The process has good potential for adoption in other areas where maize and sorghum are consumed.

SAHAY, K.M. (1990)

Evaluation of a general purpose abrasive mill for pearling of coarse cereals and dehusking of pulses.

International Journal of Food Science and Technology, **25**: 220-225.

The performance of a general purpose abrasive mill for several grains including sorghum, pearl millet, maize and pigeon peas, was evaluated. The mill was considered to be affordable by small-scale processors in rural and semi-rural areas.

SASHIDHAR, R.B., RAMAKRISHNA, Y. and BHAT, R.V. (1992)

Moulds and mycotoxins in sorghum stored in traditional containers in India.

Journal of Stored Products Research, **28**(4): 257-260.

Mould and mycotoxin contamination in sorghum stored in kotlu (storage rooms), earthenware pots, gunny bags and reed baskets was investigated. Aspergillus and Fusarium spp. were the prominent genera of fungi, and the kotlu was the most susceptible to fungal attack. Storage treatment (ash or dried neem leaves) had little effect on fungal contamination. However, mycotoxin contamination was very low.

SCHMIDT, O.G. (1992)

An analysis of progress and achievements in regional dehulling projects.

pp. 9-18. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The relevance of mechanical dehullers to sorghum and millet food systems in the SADDC countries is discussed. The evolution of small-scale dehulling technology is described, and a programme for its development and field testing, leading to wider dissemination in sub-Saharan Africa, is outlined.

SERNA-SALDIVAR, S.O., CLEGG, C. and ROONEY, L.W. (1994)

Effects of parboiling and decortication on the nutritional value of sorghum (*Sorghum bicolor* L. Moench) and pearl millet (*Pennisetum glaucum* L.).

Journal of Cereal Science, **19**(1): 83-89.

The effects of decortication and parboiling on the nutritive value of sorghum were examined. Decortication resulted in the loss of protein, insoluble dietry fibre, fat, ash, lysine and other amino acids. Parbolied grains were decorticated more easily, as was shown by the higher loss of protein, fat and ash. There were only slight differences in chemical composition and nutritional value between parboiled and raw grains decorticated to the same extent.

SINGH, D.S. and SINGH, D. (1990)

Effect of moisture content and time on pearling efficiency of sorghum.

pp. 619-624. In: *Proceedings of the International Agricultural Engineering Conference and Exhibition, Bangkok, Thailand, December 1990.* SALOKHE, V.M. and ILANGANTILEKE, S.G. (eds). Bangkok, Thailand: Asian Institute of Technology.

A grain pearler developed in India was used in experiments to determine the effect of moisture content (m.c.) and time on the pearling efficiency of sorghum. Five time periods (1, 2, 3, 4 and 5 min) and five m.c. levels (10.6, 12, 13, 14 and 15%) were used. Pearling efficiency increased with increase in pearling time and in sorghum with up to 12% m.c., whereas husk content decreased. The best pearling efficiency was obtained at 12% m.c. and a 5 min pearling time.

ULIWA, P. (1993)

The impact of sorghum and millet dehullers in Tanzania sorghum dehulling programme by SIDO/IDRC.

pp. 79-88. In: *National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development, May 1993, Arusha International Conference Centre.* MINDE, I.J. and ROHRBACH, D.D. (eds). Arusha, Tanzania: Sokoine University of Agriculture.

The work of the Small Industries Development Organization in introducing and disseminating dehulling technology in Tanzania since 1979 is reviewed. Dehullers have still not been accepted for a combination of reasons which include technical constraints, entrepreneurial management deficiency and socio-cultural problems. However, the future of sorghum and millet depends on its acceptance.

WILLS, R.B.H. and ALI, M.R. (1992)

Evaluation of cultivar characteristics, milling properties and processing of sorghum for food use as boiled whole grain.

pp. 3-7. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT. .

The suitability of a wide range of high-yielding sorghum cultivars for food use as bioled whole grain was studied. Variation in grain size was common and undesirable, having a marked detrimental effect on milling chracteristics. Cooking time, which varied with the extent of milling, was related to the type of endosperm but was generally longer than for rice. Sorghum usage would benefit from breeding programmes to develop cutivars with the desirable traits.

WONGO, L.E. and PEDERSEN, J.R. (1990)

Effect of threshing different sorghum cultivars on *Sitotroga cerealella* (Oliv.) and *Sitophilus oryzae* (L.) (Lepidoptera: Gelechiidae and Coleoptera: Curculionidae).

Journal of Stored Products Research, **26(2)**: 89-96.

The effect on *Sitotroga cerealella* and *Sitophilus oryzae* of threshing various sorghum cultivars was studied in the laboratory at 25 ¤C and 67% RH. Generally, unthreshed sorghum was more suitable than threshed sorghum for the development of *S. cerealella*, but the reverse was true for *S. oryzae*. Threshing did not affect the duration of development of either species.

YOUNG, R., GOMEZ, M.H., MCDONOUGH, C.M., WANISKA, R.D. and ROONEY, L.W. (1993)

Changes in sorghum starch during parboiling.

Cereal Chemistry, **70**(2): 179-183.

The effects of parboiling on starch crystal, pasting properties, and dispersion in hot water of cultivars with different endosperm textures and starch compositions, were evaluated. The physical characteristics of the cultivar were changed after parboiling, but starch crystalinity and solubility decreased only slighty. Pasting properties of waxy sorghum were not changed as dramatically by parboiling as those of non-waxy cultivars.

YOUNG, R., HAIDARA, M., ROONEY, L.W. and WANISKA, R.D. (1990)

Parboiled sorghum: development of a novel, decorticated product.

Journal of Cereal Science, **11**(3): 277-289.

The effect of parboiling on the milling and cooking quality of whole sorghum kernels was investigated. Parboiling increased the yield of decorticated grain while reducing breakage, resulting in a cooked product of acceptable appearance. The process is reported to require a low level of technology and no specialized equipment, and it is considered to be a practical method of producing stable products while enhancing decortication yields.

3 SECONDARY PROCESSING

AKINGBALA, J.O. and ROONEY, L.W. (1990)

Effect of flour particle texture and size on the consistency of sorghum tuwo.

Nigerian Food Journal, **8**: 48-55.

Softness and stickiness of sorghum tuwo (traditional thick porridge consumed in many African countries) were significantly correlated with the particle size index of the flour, as determined by the texture of the grain. Hardness or corneousness of the particle, and not size per se, appeared to be the cause of the softness and stickiness.

ALMEIDA-DOMINGUEZ, H.D., GOMEZ, M.H., SERNA-SALDIVAR, S.O., WANISKA, R.D., ROONEY, L.W. and LUSAS, E.W. (1993)

Extrusion cooking of pearl millet for production of millet-cowpea weaning foods.

Cereal Chemistry, **70**(2): 214-219.

The production of porridges from extruded millet, pressed dried cowpea and sorghum malt was examined. Porridges had high nutritional quality and acceptable properties for weaning foods; treatment with sorghum malt made the products more fluid.

ALMEIDA-DOMINGUEZ, H.D., SERNA-SALDIVAR, S.O., GOMEZ, M.H. and ROONEY, L.W. (1993)

Production and nutritional value of weaning foods from mixtures of pearl millet and cowpeas.

Cereal Chemistry, **70**(1): 14-18.

The production of weaning food from press-dried millet and cowpea flakes was examined. The results suggested that mixing millet with cowpea can produce a significantly improved weaning food, and that the addition of sorghum malt (5%) can enhance the nutrient density and the ease with which the product can be consumed.

ALMEIDA-DOMINGUEZ, H.D., SERNA-SALDIVAR, S.O. and ROONEY, L.W. (1991)

Properties of new and commercial sorghum hybrids for use in alkaline-cooked foods.

Cereal Chemistry, **68**(1): 25-30.

The cooking characteristics of 12 sorghum varieties with different grain characteristics for producing baked tortillas was evaluated. With the exception of waxy sorghum, all samples tested produced fresh tortillas of acceptable quality. Grains with a white thick pericarp, tan plant colour and yellow endosperm were considered to have excellent potential for the manufacture of tortillas and other foods.

ALUKO, R.E. and OLUGBEMI, L.B. (1990)

Sorghum as a raw material in the baking industry.

p. 21. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The baking quality of wheat and sorghum composite flour, and the nutritional quality of the resultant bread, were determined; the results are reported.

ASIEDU, M., NILSEN, R., LIE, O. and LIED, E. (1993)

Effect of processing (sprouting and/or fermentation) on sorghum and maize. I: Proximate composition, minerals and fatty acids.

Food Chemistry, **46**(4): 351-353.

The effects of preparatory methods on the proximate composition, and mineral and fatty acid characteristics, of sprouted and/or fermented sorghum and maize used in infant weaning foods, were compared. Preparatory methods had no effect on proximate composition. Porridges made from these cereals need to be supplemented with other foods.

ASIEDU, M.; LIED, E., NILSEN, R. and SANDES, K. (1993)

Effect of processing (sprouting and/or fermentation) on sorghum and maize. II: Vitamins and amino caid composition. Biological utilization of maize protein.

Food Chemistry, **48**(4): 201-204.

The use of sprouted and fermented maize and sorghum for improving weaning food nutrient quality was investigated. Germination improved the vitamin content but fermentation had no effect. Amino acid composition was slightly improved but germination and/or fermentation had no effect on overall protein quality. In vitro protein synthesis was not affected by processing.

BANGU, N.T.A., MTEBE, K. and NZALLAWAHE, T.S. (1994)

Consumer acceptability of stiff porridge based on various composite flour proportions of sorghum, maize and cassava.

Plant Foods for Human Nutrition, **46**(4): 299-303.

Consumer acceptability of porridge made from composite flours of sorghum and maize, or sorghum, maize and cassava, was determined. Results suggested that adding a small amount (less than 10%) of sorghum to maize flour reduces consumer acceptability. However, adding more than 10% has no significant effect on consumer acceptability until a level of 30% is exceeded. In sorghum, maize and cassava composite flours, a formulation of 30:40:30 of each component, respectively, was most acceptable.

BEDOLLA, S., SERNA-SALDIVAR, S.O. and ROONEY, L.W. (1992)

Potential and actual uses of grain sorghums in foods and related research in Mexico.

pp. 103-112. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

An overview of the current uses of sorghum in Mexico is given, and suggestions are made for potential alternative uses in the future. Descriptions of studies on dry milling and the preparation and cooking of tortillas are included.

BOGUNJOKO, T. (1990)

Fermented infant or weaning food formulations.

p. 39. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

Guiding principles for the formulation of weaning foods using sorghum, maize, rice, millet, cowpeas, groundnut and soybean, balanced with milk and sugar for taste, are presented.

BUSOLO, D. (1995)

Indigenous fermented cereal snacks in Kenya.

Food Chain, no. 15: 14.

The traditional household technology for producing fermented flour and snack foods from maize, millets and sorghum, and their consumption and importance, are reviewed. Fermentation imparts the desired flavour to the flour and increased lactic acid content prolongs shelf-life.

CHAVAN, U.D. and CHAVAN, J.K. (1991)

Utilization of malted sorghum, mung bean and black gram in preparation of bhakari.

Journal of the Maharashtra Agricultural Universities, **16**(1): 141-142.

The preparation of traditional products from malted meals of sorghum, mung bean and black gram was investigated. The results suggest that up to 80% malted sorghum, and up to 30% mung bean or black gram, can be blended with normal sorghum flour to obtain acceptable products.

CHIGUMIRA, P. (1992)

The potential for extruded sorghum food products in Zimbabwe and the regional market.

pp. 89-94. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The potential for, and advantages of extrusion cooking for producing novel products from sorghum in Zimbabwe are discussed. However, the demand for such products is considered to be limited by price, quality and culture.

DAHLIN, K.M. and LORENZ, K.J. (1993)

Carbohydrate digestibility of laboratory-extruded cereal grains.

Cereal Chemistry, **70**(3): 329-333.

The effects of extrusion processing on the in vitro digestibility of carbohydrate from whole grain cereals (wheat, rye, maize, millet, and low- and high-tannin sorghum) are examined. An extrusion tempertaure of 37.7-65.5 °C, and a feed moisture content of 25%, had the greatest effect on improving the digestibility of all the cereals. Digestibility appeared to depend very strongly on cereal type.

DENDY, D.A.V. (1992)

Composite flour - past, present and future: a review with special emphasis on the place of composite flour in the semi-arid zones.

pp. 67-73. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The opportunities which exist for composite flours in situations where wheat is available locally or can be imported, and where local cereal flours, including sorghum and millet, can be blended into wheat flour for bread-making, are reviewed. Opportunities for blending indigenous cereal flours into products from exotic grains, such as maize, are also considered.

DENDY, D.A.V. (1993)

Review of composite flour technology in the context of Tanzania.

pp. 89-102. In: *National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development, May 1993, Arusha International Conference Centre.* MINDE, I.J. and ROHRBACH, D.D. (eds). Arusha, Tanzania: Sokoine University of Agriculture.

The work carried out on composite flour, particularly bread flour, is reviewed with special emphasis on sorghum and millets in Tanzania. Composite flour technology is discussed and it is noted that up to 30% sorghum could be used, with an optimum of 20%. Previous composite flour projects are also discussed and criteria for successful implementation are outlined.

FAURE, J.C. (1992)

Sorghum and maize pasta and extruded products.

pp. 75-82. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The characteristic requirements and technology for the production of pasta from sorghum, maize and composite flours are reviewed. Pregelatinization of 25% sorghum flour before blending with the remaining 75% gave good cooking characteristics, but the colour was unacceptable to the consumer. Alternative cooking treatments and formulations are suggested.

FLIEDEL, C.G. (1994)

Evaluation de la qualité du sorgho pour la fabrication du tô.

Agriculture et Développement, **4**: 12-19.

The quality of sorghum flours for making tô (tradition thick porridge consumed in many African countries) was evaluated using laboratory methods and the firmness of the product was appraised. A strong positive correlation was found between firmness and amylose content and starch solubility at 85 °C.

GOMEZ, M.I. (1992)

Evaluation of 3 sorghum varieties M 35-1, SPV 472 and WS 1297 in composite flour products, baked bread, steamed bread and cookies.

pp. 87-95. In: *Proceedings of the Fifth Quadrennial Symposium on Sorghum and Millet (at the Ninth International Cereal and Bread Congress), June 1992, Paris.* Vienna, Austria: International Association for Cereal Science and Technology (ICC).

Sorghum flours were evaluated in composite formulations of baked bread, steamed bread and cookies at 20%, 30% and 50% wheat substitution. In terms of acceptability and sensory parameters, the hard white grains (M35-1 and SPV 472) performed as well as the wheat control in all the products. However, they resulted in a significant loss of loaf volume.

GUPTA, A., SRIVASTAVA R. and SRIVASTAVA, S. (1995)

Effect of storage conditions on popping quality of sorghum.

Journal of Food Science and Technology, **32**(3): 211-212.

The effect of storage at 50-80% RH and 24-28 °C for 6 and 12 months on the popping quality of sorghum is described. Samples stored at 80% RH had the best popping, popping volume, expansion volume, flake size and organoleptic qualities.

HOLT, S.D., MCWATTERS, K.H. and RESURRECCION, A.V.A. (1992)

Validation of predicted baking performance of muffins containing mixtures of wheat, cowpea, peanut, sorghum and cassava flours.

Journal of Food Science, **57**(2): 470-474.

The performance of seven muffin formulations using cowpea, peanut, sorghum and cassava flour, which were predicted by computer models to perform similarly to a 100% wheat flour control, was studied. No significant differences were observed between formulations for 22 of 31 sensory, physical and compositional characteristics. Significant correlations between some sensory attributes and physical and compositional measurements were observed.

IDOWA, A. (1990)

Bread from composite flours.

p. 22. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The production and characteristics of bread made from wheat and sorghum composite flours in Nigeria were compared to those of bread made from 100% wheat.

IGBEDIOH, S.O. and DUNMADE, V.B. (1990)

Use of sorghum in infant weaning practices: the AERLS experience.

p. 39. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

Weaning practices in Nigeria are briefly reviewed. It is recognized that sorghum grains contain poor quality protein which can lead to nutritional deficiency. The Agricultural Extension and Research Liaison Service recommends the use of a range of sorghum-based weaning foods supplemented with soybean, cowpea and groundnuts.

JIDEANI. V.A. and WEDZICHA, B.L. (1994)

Reaction of sorbic acid in millet and sorghum doughs: reaction with thiols.

Food Additives and Contaminants, **11**(5): 539-548.

The use of sorbic acid as a preservative in pearl millet and sorghum doughs and breads, and as a measure of the extent of the reaction of sorbic acid at each stage of preparation, is reported. Around 40% of the sorbic acid added to the flour while making dough is lost; more is lost after cooking. The acid, which reacts when it is cooked, is irreversibly bound to components of the baked product.

KEREGERO, M.M. and MTEBE, K. (1994)

Acceptability of wheat-sorghum composite flour products: an assessment.

Plant Foods for Human Nutrition, **46**(4): 305-312.

Bakery products were prepared using sorghum flour composited with wheat flour in the following proportions: 100% brown sorghum flour, and 80:20%, 60:40%, 40:60% and 20:80% wheat:sorghum. Preference for composite flour bread increased as the amount of sorghum flour decreased. Buns prepared from 100% white or brown sorghum flour showed promise for improving the acceptability of sorghum products.

KEYA, E.L. (1992)

Utilization implications of pasting viscosity profiles on sorghum starches.

pp. 16-35. In: *Proceedings of the Fifth Quadrennial Symposium on Sorghum and Millet (at the Ninth International Cereal and Bread Congress), June 1992, Paris.* Vienna, Austria: International Association for Cereal Science and Technology (ICC).

The pasting viscosities of 26 cultivars of sorghum from Kenya and ICRISAT, India, were determined. Native starches had distinctly different pasting profiles by which they could be categorized. The results are explained in terms of their possible implications for sorghum flour utilization in uli and ugali (popular food preparations in Kenya).

KIM, C.T., KIM, C.J., KIM, D.C. and KWON, T.W. (1990)

Tempeh fermentation from a mixture of soybean and sorghum grain.

Korean Journal of Food Science and Technology, **22**(6): 668-674.

KULKARNI, K.D., KULKARNI, D.N. and INGLE, U.M. (1991)

Sorghum malt-based weaning food formulations: preparation, functional properties and nutritive value.

Food Nutrition Bulletin, **13**(4): 322-327.

Studies on a low-cost, nutritive, bulk-reduced weaning food are reported. A formulation containing 60% sorghum malt, 30% green gram malt and 10% sesame flour was found to have satisfactory functional characteristics and nutritive value.

KUMAR, L.S., DAODU, M.A., SHETTY, H.S. and MALLESHI, N.G. (1992)

Seed mycoflora and malting characteristics of some sorghum cultivars.

Journal of Cereal Science, **15**(2): 203-209.

The influence of seed mycoflora on the malting characteristics of 26 sorghum cultivars was investigated. *Aspergillus flavus, Cladosporium cladosporioides* and *Fusarium moniliforme* were dominant. Seeds with higher moisture contents after steeping exhibited higher incidences of mould infection during germination. Malts from heavily mould-infected samples showed slightly higher amylase activities during germination.

KUMAR, L.S., PRAKASH, H.S., SHETTY, H.S. and MALLESHI, N.G. (1991)

Influence of seed mycoflora and harvesting conditions on milling, popping and malting qualities of sorghum.

Journal of the Science of Food and Agriculture, **55**(4): 617-625.

The milling, malting and popping characteristics of sorghum grains from cultivars inoculated with *Fusarium moniliform* conidia at flowering were studied. Grains harvested at physiological maturity possessed superior milling and malting qualities whereas late harvest grains had superior popping characteristics.

LABELL, F. (1992)

Sorghum syrup - old and new sweetener.

Food Processing, **53**(2): 50-52.

The renewed interest in sorghum syrup as a natural sweetener in the food industry, and new technologies for the industrial production of sorghum syrup, are reviewed.

LORRI, W. and SVANBERG, U. (1993)

Lactic acid-fermented cereal gruels: viscosity and flour concentration.

International Journal of Food Sciences and Nutrition, **44**: 207-213.

Traditional lactic acid fermentation techniques were used in the preparation of cereal gruels from maize, low- and high-tannin sorghums, bulrush and finger millet to improve dietary bulk. Fermentation with added flour of germinated sorghum seeds increased the flour concentration from 10-14% to 30-35% in the unfermented semi-liquid gruels.

MARFO, E.K., SIMPSON, B.K., IDOWU, J.S. and OKE. O.L. (1990)

Effect of local food processing on phytate levels in cassava, cocoyam, yam, maize, sorghum, rice, cowpea and soybean.

Journal of Agricultural and Food Chemistry, **38**(7): 1580-1585.

Phytate contents were determined in the raw state, during processing, and in the ready-to-eat products, of a number of staple foods used in West Africa. Results are tabulated, together with proximate compositions of the cereals, legumes and tubers and of the intermediate and final products. It is concluded that local methods of processing staple foods (fermentation, drying, frying and cooking) can substantially reduce phytate contents and minimize concern over metal chelation.

MBOFUNG, C.M.F. and NDJOUENKEU, R. (1990)

Influence of milling method and peanut extract on *in vitro* iron availability from maize and sorghum flour gruels.

Journal of Food Science, **55**(6): 1657-1659, 1675.

The effect on maize and sorghum flours of milling by four different methods (traditional, semi-traditional, mechanical and industrial), and the effect on *in vitro* iron availability, is reported. Iron availablity in the gruels prepared after traditional milling was greater than that for other gruels.

MTEBE, K., NDABIKUNZE, B.K., BANGU, N.T.A.. and MWEMEZI, E. (1993)

Effect of cereal germination on the energy density of togwa.

International Journal of Food Sciences and Nutrition, **44**: 175-180.

Research into the preparation of togwa (a traditional sweet gruel in Tanzania) from germinated maize, bulrush millet, sorghum and finger millet grains, is reported. Nutrient contents were evaluated and compared. Sensory analysis indicated that germination caused a significant increase in sweetness which improved the flavour and acceptability.

MWESIGYE, R.K. and OKURUT, T.O. (1995)

A survey of the production and consumption of traditional alcoholic beverages in Uganda.

Process Biochemistry, **30**(6): 497-501.

The manufacture and consumption of traditional alcoholic beverages in Uganda (including tonto from banana, ajon from finger millet, omuramba from sorghum, kweete from maize and millet, and waragi from molasses) is discussed. Production at subsistence level is cheap and labour-intensive, and brewing techniques are passed down through generations. It is concluded that there is a strong need to document the methods by which these Ugandan alcoholic beverages are produced, and to devise scientific means of improving their quality and optimizing their production methods.

NOUT, M.J.R. (1991)

Ecology of accelerated natural lactic fermentation of sorghum-based infant food formulas.

International Journal of Food Microbiology, **12**(2/3): 217-224.

Accelerated natural lactic acid fermentation of mixed sorghum-cowpea and sorghum-milk powder infant food formulae was achieved by repeated use of the previous batch as an inoculum at a rate of 10%. The method resulted in the gradual establishment of a mixed population of lactic acid bacteria and yeasts.

NOUT, M.J.R. (1992)

Accelerated natural lactic fermentation of cereal-based formulas at reduced water activity.

International Journal of Food Microbiology, **16**: 313-322.

The influence of reduced moisture content on the efficacy of accelerated natural lactic acid fermentation in mixed cereal food formulae (maize/sorghum/soya and maize/sorghum/milk powder) was investigated. Generally, the levels of functional microflora were unaffected but the final pH was increased.

NOUT, M.J.R. (1993)

Processed weaning foods for tropical climates.

International Journal of Food Sciences and Nutrition, **43**: 213-221.

The requirements, practices and problems associated with producing processed weaning foods in tropical countries from staple cereals and starchy tubers (including sorghum) are reviewed.

NYANGERI, J.B. and JAMES, A.W. (1993)

Development of improved flavour in sorghum thin porridge (uji) by malting and toasting.

East African Agricultural and Forestry Journal, **59**(2): 155-161.

The improvement of thin sorghum porridge by malting and toasting the grains is described. Although mould growth was encountered during grain germination, it was non-toxic.

OBIZOBA, I.C. and ATII, J.V. (1991)

Effect of soaking, sprouting, fermentation and cooking on nutrient composition and some anti-nutritional factors of sorghum (Guinesia) seeds.

Plant Foods for Human Nutrition, **41**(3): 203-212.

The effect of soaking, sprouting, fermentation and cooking on nutrient composition and some anti-nutritional factors of sorghum was investigated. A combination of cooking and fermentation improved the nutrient quality and reduced anti-nutritional factors to safe levels.

OGUNDIPE, H.O. and OMASEVWERHA, O. (1990)

Processing and acceptability studies of soy-enriched non-wheat biscuits.

p. 24. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The dough characteristics of corn/soy, sorghum/soy and rice/soy flour blends were compared. Taste panel acceptability of biscuits produced with these combinations is reported. Overall, acceptability decreased as the level of soy in the flour blend increased.

OLATUNJII, O., ADESINA, A.A. and KOLEOSO, O.A. (1990)

Use of sorghum as composite flour in baking.

p.21. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

Wheat, sorghum and soybean flours were blended in the proportion 65, 30 and 5% to make bread, and 40, 55 and 5% to make biscuits; the products were reported to be acceptable to consumers.

OLATUNJII, O. and DAODU, A.M. (1990)

Potentials of using sorghum in the production of weaning foods.

p. 37. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The production of weaning foods using sorghum, and cowpea, sorghum and soybean, is described and the products evaluated. The products compared well with commercially-available weaning foods.

OLATUNJIl, O., KOLEOSO, O.A. and ONIWINDE, A.B. (1992)

Recent experiences on the milling of sorghum, millet and maize for making non-wheat bread, cake and sausage in Nigeria.

pp. 83-88. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

Investigations into the use of sorghum, millet and maize flour in non-wheat bread, cakes and sausages are described. Flour of 300 µm produced the best bread, while flour of 150 µm produced the best cakes and sausages. A blend of 70% sorghum or millet flour with 30% cassava flour gave better quality products; those made from sorghum were considered to be more acceptable.

OLATUNJIl, O., OSIBANJO, A., BAMIRO, E., OJO, O. and BURENG, P. (1992)

Improvement in the quality of non-wheat composite bread.

pp. 45-54. In: *Proceedings of the Fifth Quadrennial Symposium on Sorghum and Millet (at the Ninth International Cereal and Bread Congress), June 1992, Paris.* Vienna, Austria: International Association for Cereal Science and Technology (ICC).

The inclusion of sorghum and cassava starch in non-wheat bread was investigated. Six formulations were tested and in terms of overall quality, the formulation containing 70% sorghum, 20% gelatinized starch and 10% raw starch was thought to produce the best loaf.

OREWA, G.O. and ILOH, A. (1990)

Current status of composite flour technology and prospects with particular reference to the production of biscuits in Nigeria.

p. 22. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The prospects and problems associated with the substitution of wheat flour with sorghum flour in the production of biscuits are reviewed.

PRIYOLKAR, V.S. (1990)

Use of sorghum flour in biscuit and water production: the Nasco experience.

p. 23. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The experiences of Nigerian biscuit manufacturers when they substituted wheat with maize and sorghum are reported. Substitution of wheat with up to 25% sorghum flour for the production of short and hard dough biscuits and wafers was cost-effective without affecting quality, breakages and plant efficiency.

SANNI, A.I., LOENNER, C., MARKLINDER, I., JOHANSSON, M.L. and MOLIN, G. (1994)

Starter cultures for the production of ogi, a fermented infant food from maize and sorghum.

Chemie Mikrobiologie Technologie der Lebensmittel, **16**(1/2): 29-33.

Starter cultures (*Lactobacillus plantarum, L. jensenii, L. agilis,* unidentified *Lactobacillus sp.,* and the yeast *Debaryomyces hansenii*) were used to ferment maize and sorghum for ogi production either singly or as mixed cultures. All cultures produced ogi with acceptable organoleptic properties; L. *plantarum* gave the best results. Production of ogi using a single starter culture is an improvement on traditional processing and can reduce preparation time considerably.

SINGH, M. and SRIVASTRAVA, S. (1993)

Sorghum grain moisture: its effect on popping quality.

Journal of Food Science and Technology, **30**(4): 296-297.

The effect of grain moisture content on the popping quality of sorghum was studied. Popping percentage of cultivars differed significantly at different levels of grain moisture.

SINGH, U. and SINGH, B. (1991)

Functional properties of sorghum-peanut composite flour.

Cereal Chemistry, **68**(5): 460-463.

Raw and heat-processed, partially-defatted peanut flour, sorghum flour, and composite flour containing both, had different functional properties (water and oil absorption, viscosity, gelation, emulsion capacity, nitrogen solubility index and protein dispersibility index). The implications of these results may be realized in the design of protein-enriched products based on sorghum flour.

SOLABI, G.A. (1990)

Uses of sorghum in fermented foods and drinks.

p. 37. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The potential for using sorghum malt extract in the manufacture of food drinks, baby foods and dietary foods is reviewed. The need to select and produce suitable cultivars and enforceable quality standards and specifications in collaboration with researchers and users is noted.

SUBRAMANIAN, V., HOSENEY, R.C. and BRAMEL-COX, P. (1994)

Shear thinning properties of sorghum and corn starches.

Cereal Chemistry, **71**(3): 272-275.

The paste viscosities and shear-thinning of maize and sorghum starches were investigated. Sorghum starches gave higher paste viscosities and were found to shear thin more than maize starches. Gelatanization characteristics did not seem to be related to shear-thinning.

SUBRAHMANYAM, S.N. and HOSENEY, R.C. (1995)

Shear thinning properties of sorghum starch.

Cereal Chemistry, **72**(1): 7-10.

The causes of variations in shear-thinning properties of sorghum starch were investigated. The greater swelling and solubility of starches appears to be responsible for the high shear-thinning from some sorghum cultivars.

THORAT, S.S., SATWADHAR, P.N., KULKARNI, D.N., CHOUDHARI, S.D. and INGLE, U.M. (1990)

Varietal differences in popping quality of sorghum grains.

Journal of the Maharashtra Agricultural Universities, **15**(2): 173-175.

The popping performance of 19 Indian sorghum cultivars at different moisture contents was assessed. Maximum popping percentage was observed at 18% mositure, while the maximum pop volume and expansion ratio was measured at 15%.

TORRES, P.I., RAMIREZ-WONG, B., SERNA-SALDIVAR, S.O. and ROONEY, L.W. (1993)

Effect of sorghum flour addition on the characteristics of wheat flour tortillas.

Cereal Chemistry, **70**(1): 8-13.

Wheat flour tortillas were produced from composite flours containing up to 30% decorticated sorghum flour. Decorticated sorghum flour could replace up to 20% of the wheat flour in hot-press wheat flour tortillas. The sorghum should be milled to remove the hilum, and finely ground.

TORRES, P.I., RAMIREZ-WONG, B., SERNA-SALDIVAR, S.O. and ROONEY, L.W. (1994)

Effect of decorticated sorghum addition on the rheological properties of wheat tortilla dough.

Cereal Chemistry, **71**(5): 509-512.

Experiments on the replacement of wheat flour in tortillas with course, medium and fine sorghum flour at levels of 15% and 30% are reported. Particle size affected both water absorption and rheological properties. Dough viscosities were increased when sorghum flour replaced 30% of wheat flour.

TORRES MONTALVO, H. and SUBRAMANIAN, V. (1992)

Evaluation of sorghum cultivars and maize-sorghum blends for tortilla making quality.

Sorghum Newsletter, **33**: 71.

The suitability for tortilla preparation of flour from five sorghum varieties, or maize-sorghum flour mixtures (1:1 ratio), was evaluated. Three of the five varieties produced tortillas that were very similar in colour and appearance to maize tortillas. Protein content of sorghum tortillas was not appreciably different from that of maize tortillas. The sorghum varieties used were characterized by cream-coloured grain, low phenol content and lack of tannins.

YOUSSEF, A.M.M., MOHARRAM, Y.G., MOUSTAFFA, E.K., BOLLING, H., EL-BAYA, A. and HARMUTH, A.E. (1990)

New extruded products from sorghum.

Food Chemistry, **37**(3): 189-199.

The physical, chemical, nutritional and organoleptic properties of 16 new extruded products from sorghum were evaluated. The results indicate the importance of sorghum and its flour, alone, or as a substitute for other flours, in the preparation of acceptable extruded products.

4 FOOD QUALITY AND NUTRITION

ADEWUSI, S.R.A. and ILORI, M.O. (1994)

Nutritional evaluation of spent grains from sorghum malts and maize grit.

Plant Foods for Human Nutrition, **46**(1): 41-51.

The potential use of the high protein by-product of beer production (from 77% sorghum malt and 23% corn grit) was investigated. The crude protein, dietary fibre, tannin, mineral and fatty acid composition of red and white sorghum spent grains is presented. Results of feeding trials on rats are also given.

ADEWUSI, S.R.A., ORISADARE, B.O. and OKE, O.L. (1992)

Studies in weaning diets in Nigeria. I: carbohydrate sources.

Cereal Chemistry, **68**(2): 165-169.

Ogi, a fermented cereal porridge prepared from maize and white and red sorghum, was compared with two other carbohydrate sources, breadfruit and cassava, in simulated weaning diets. Ogi had a high protein and energy content and low fat content; tannin and phytate contents were also low compared to the grains. Protein digestibility was high for all diets. Weight gain and starch digestibility were lowest in white sorghum ogi.

ADEYEYE, A. and AJEWOLE, K. (1992)

Chemical composition and fatty acid profiles of cereals in Nigeria.

Food Chemistry, **44**: 41-44.

The proximate composition and mineral and fatty acid contents of sorghum, millet, maize and rice cultivated in Nigeria were investigated. Sorghum had the highest protein and essential fatty acid content.

AHMED, A.M., SINGH, B. and SINGH, U. (1993)

Improvement of sensory and nutritional qualities of sorghum-based kisra by supplementation with groundnut.

Journal of Food Science and Technology, **30**(2): 121-126.

The feasibility of supplementing sorghum flour with groundnut flour, at rates up to 30%, in the preparation of kisra (fermented unleavened bread forming the staple diet in sorghum-growing regions of Sudan) was assessed. The qual-

ity of the kisra was found to be acceptable at all levels of supplementation, and *in vitro* protein digestibility was increased; these findings have implications for the improvement of nutritional status.

AHMED, R.U., KABIRULLAH, M. and KHAN, S.A. (1991)

Effect of traditional processing on the nutritive value of sorghum.

Bangladesh Journal of Scientific and Industrial Research, **26**(1/4): 195-199.

Growing rats were fed on diets containing fish protein concentrate (control), skim milk powder (reference), or untreated, boiled or fried sorghum. Of the sorghum diets, untreated sorghum had the highest protein and energy efficiency ratio, followed by boiled sorghum and fried sorghum, comparable to those of fish protein and skim milk. Frying sorghum reduced its nutritive value more than boiling.

ALI, H.I. and HARLAND, B.F. (1991)

Effects of fibre, phytate in sorghum flour on iron and zinc in weanling rats. A pilot study.

Cereal Chemistry, **68**(3): 234-238.

The effect of dietry fibre and phytate in sorghum flours from Somalian decorticated grains on iron and zinc concentrations in selected tissues of weanling rats was investigated. The total weight gain of rats fed sorghum flour was found to be lower than that of the control. Consumption of sorghum-containing diets may result in lower mineral concentrations in the bone.

ANSARI, A.A. and SHRIVASTAVA, A.K. (1990)

Natural occurrence of *Alternaria* mycotoxins in sorghum and ragi from North Bihar, India.

Food Additives and Contaminants, **7**(6): 815-820.

The natural occurrence of major *Alternaria* mycotoxins was investigated in sorghum and ragi collected from North Bihar. Nine of 20 sorghum samples, and three of eight ragi samples, were found to be contaminated with one to three *Alternaria* toxins. The toxin-elaborating potential of A. *alternata* isolated from sorghum and ragi was also investigated. Of 16 isolates of A. *alternata,* mycotoxins were detected in only 10.

ARCOT, J. and CHITTEMMA RAO, K. (1992)

Sorghum food quality.

pp. 96-105. In: *Proceedings of the Fifth Quadrennial Symposium on Sorghum and Millet (at the Ninth International Cereal and Bread Congress), June 1992, Paris.* Vienna, Austria: International Association for Cereal Science and Technology (ICC).

The quality of several sorghum cultivars was investigated in terms of hardness and swelling capacity. Flour and dough characteristics, such as water-uptake, kneading and rolling quality, were measured, and the acceptability of traditional food preparations (roti, sankati, rice and dosa) was evaluated.

ARORA, A., SRIVASTAVA, S., CHAUHAN, G.S. and CHAUHAN, S.S. (1992)

Quality characteristics of popped sorghum.

Sorghum Newsletter, **33**: 69-70.

The chemical composition, popping quality, organoleptic quality and net protein retention in seven sorghum genotypes was studied. Genotypes with good popping quality were characterized by a corneous endosperm, greater grain hardness values and lower starch concentration than those of poor popping quality (floury endosperm).

AXTELL, J.D. (1992)

Digestibility of sorghum and millets in foods and feeds: the effects of processing.

pp. 179-181. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

Information on the digestibility of sorghum and the effects of processing is reviewed. The data clearly show that fermented breads and other traditional processing techniques significantly improve the nutritional value of sorghum. The mechanism responsible for the observed differences between sorghum and other cereals is probably related to the cross-linked kafirin fraction in sorghum.

BABIKIR, E.E. and EL TINAY, A.H. (1992)

Effect of alkali on tannin content and *in vitro* protein digestibility of sorghum cultivars.

Food Chemistry, **45**(1): 55-60.

The effect of imbibing alkali into whole grains, and incubating them at different temperatures, on the extractable tannin contents of two sorghum cultivars found in the Sudan was determined. The percentage of tannin extracted, and percentage *in vitro* digestibility, increased with increased time of treatment and alkali concentration. High temperature also reduced time of treatment.

BABIKIR, E.E. and EL TINAY, A.H. (1993)

Effect of soaking in water or in sodium carbonate on tannin content and *in vitro* protein digestibility of sorghum cultivars.

International Journal of Food Science and Technology, **28**(4): 389-395.

Research on the effects of steeping whole grains in water or sodium carbonate solution, and incubating them at different temperatures, on extractable tannin contents of two sorghum cultivars found in the Sudan is reported. The percentage of tannin extracted, and percentage *in vitro* digestibility, increased with increased time of treatment and alkali concentration, but the degree of change differed between cultivars.

BADI, S., PEDERSEN, B., MONOWAR, L. and EGGUM, B.O. (1990)

The nutritive value of new and traditional sorghum and millet foods from Sudan.

Plant Foods for Human Nutrition, **40**(1): 5-19.

The nutritive value of different sorghum- and millet-based baby foods and kisra (some fortified with chickpeas or groundnut) was examined by chemical analysis and rat balance studies. Baby foods were considered to provide safe levels of protein for children of more than one month old; kisra can be used as a well-balanced food for infants of over one year old.

BANDA-NYIRENDA, D.B.C. and VOHRA, P. (1990)

Nutritional improvement of tannin-containing sorghums (Sorghum bicolor) by sodium bicarbonate.

Cereal Chemistry, **67**(6): 533-537.

Broiler chicks were fed on diets containing either maize or tannin-containing sorghum. Tannin-containing diets depressed growth, but this could be overcome by supplementing feeds with sodium bicarbonate at levels of 0.25% and 0.5%, depending on the cultivar.

BEELO, A.B., ROONEY, L.W. and WANISKA, R.D. (1990)

Factors affecting quality of sorghum tô, a thick porridge.

Cereal Chemistry, **67**(1): 20-25.

The physical and chemical properties of sorghums, and the quality of tô from West Africa and Honduras, were evaluated. Endosperm hardness, amount of pericarp remaining after decortication, flour particle size, pH of the cooking water and presence of non-flour particles, all affected tô quality.

BELLO, A.B., WANISKA, R.D., GOMEZ, M.H. and ROONEY, L.W. (1995)

Starch solubilization and retrogradation during preparation of tô (a food gel) from different sorghum cultivars.

Cereal Chemistry, **72**(1): 80-84.

Tô was prepared from flours of four sorghum cultivars with different endosperm textures and starch solubilization; retrogradation was then studied. Amylose and amylopectin starch was only partially solubilized in fresh tô. Aged tô contained even less soluble starch. Retrogradation in fresh tô appeared to be faster for higher molecular weight polymers than for those with lower molecular weights.

BRESSANI, R. and TUNA, E. (1993)

[Improvement of the protein quality of popped sorghum with soybeans.]

Archivos Latinoamericanos de Nutricion, **43**(1): 46-49 [in Spanish].

The nutritional content of popped sorghum prepared by dry heating was evaluated. Studies with weanling rats showed raw and popped sorghum to have protein efficiency ratios of 32% and 8%, respectively, of the value for casein. When popped sorghum was supplemented with 5, 10 and 15% roasted soyabeans, net protein ratio did not increase but weight gain increased. With 15% soyabeans, the protein efficiency ratio increased significantly to 74% of the casein value.

BUTLER, L.G. (1990)

Tannins and other phenols: effects on sorghum production and utilization.

pp. 140-144. In: *INTSORMIL (CRSP) Annual Report 1990.* Lincoln, Nebraska, USA: INTSORMIL.

The following research results are reviewed: development of simple laboratory assays to screen sorghum crosses resistant to striga; identification of sorghum genotypes which are bird resistant but do not contain tannins; comparison of the anti-nutritional effects of chewing betel quid with sorghum in India and the Far East.

BUTLER, L. G. and PUSHPAMMA, P. (1991)

Tannins in betel nut and its products consumed in India: comparison with high-tannin sorghum.

Journal of Agriculture and Food Chemistry, **39**(2): 322-326.

Samples of popular types of betel nuts and powder, catechu and betel quid were obtained from a market and analysed for polyphenols. Results are compared with corresponding results for tannin-free and high-tannin sorghum. It is concluded that consumption of betel nuts and betel products has adverse nutritional consequences, particularly for those on marginal diets.

CARCEA, M., CUBADDA, R. and ACQUISTUCCI, R. (1992)

Physicochemical and rheological characterization of sorghum starch.

Journal of Food Science, **57**(4): 1024-1025, 1028.

Starch was isolated from three sorghum cultivars and compared with commercial wheat starch. Amylose content of sorghum starches was in the range of 22.0-27.8%. Sorghum starches had 1.66% less total lipids than wheat starch . Differences in swelling power were observed over a range of temperatures. Sorghum starches showed single-step viscoamylographic curves with pronounced pasting peaks, good pasting stability and good set-back on cooling.

DHINGRA, M., SRIVASTRAVA, S. and CHAUHAN, G.S. (1992)

Nutrient composition and relationship between physico-chemical and sensory qualities of sorghum genotypes.

Journal of Food Science and Technology, **29**(2): 97-100.

Amino acid and tannin contents, and physicochemical characteristics, were estimated in eight sorghum genotypes. Chapattis made from flours of all genotypes were evaluated for sensory properties. Results revealed a significant positive correlation between grain hardness and chapatti texture. Amylose had a significant positive correlation with overall acceptability of chapatti.

EL KHALIFA, A.O. and EL TINAY, A.H. (1994)

Effect of fermentation on protein fractions and tannin content of low- and high-tannin cultivars of sorghum.

Food Chemistry, **49**: 265-269.

The effect of fermentation on protein fractions and tannin content in low- and high-tannin cultivars of sorghum from Sudan was studied. Fermentation decreased the tannin content of the protein fractions of both cultivars, reaching 92% reduction in the high-tannin variety.

FANNON, J.E., SHULL, J.M. and BEMILLER, J.N. (1993)

Interior channels of starch granules.

Cereal Chemistry, **70**(5): 611-613.

Microscopic evidence suggests that the pores previously observed on the external surface of sorghum starch garnules are openings to serpentine channels that penetrate into the granular interior.

FAPOHUNDA, S.O. and OGUNDERO, V.W. (1990)

Malted *Sorghum bicolor* grains and physiology of associated microfungi.

Nahrung, **34**(3): 241-246.

Studies on two isolates from malted grain showed that *Fusarium pallidoroseum* utilizes more nitrogen-free extract in an acid medium than *Alternaria tenuissima,* and A. *tenuissima* degrades hemicellulose more effectively. Optimum temperature for protease production was 20 °C in F. *pallidoroseum* and 50 °C in A. *tenuissima.* The implications of the results are discussed.

HAMAD, S.H., BOECKER, G., VOGEL, R.F. and HAMMES, W.P. (1992)

Microbiological and chemical analysis of fermented sorghum dough for kisra production.

Applied Microbiology and Biotechnology, **37**(6): 728-731.

Sorghum flour fermented in the traditional way for kisra production was analysed microbiologically and chemically. Strains of *Lactobacillus fermentum, L. reuteri* and *L. amylovorus,* or *L. fermentum* and *L. amylovorus,* were the dominant organisms in doughs inoculated with wet or dry sorghum preparations, respectively. Maltose content of dough decreased, whereas glucose accumulated during fermentation. Relative amino acid contents in doughs did not change significantly.

HAMAKER, B.R., MERTZ, E.T. and AXTELL, J.D. (1994)

Effect of extrusion on sorghum kafirin solubility.

Cereal Chemistry, **71**(5): 515-517.

The digestibility of porridge prepared from sorghum flour after decortication and extrusion was increased. In vitro digestibility of cooked decorticated extruded sorghum was 79%. For porridge prepared from plain decorticated sorghum flour, digestibility was 57%. Analysis suggests a relationship between karafin solubility and digestibility with extruded sorghum.

HASSAN, I.A.G. and EL TINAY, A.H. (1995)

Effect of fermentation on tannin content and *in vitro* protein and starch digestibilities of two sorghum cultivars.

Food Chemistry, **53**: 149-151.

The effect of fermentation on tannin content and *in vitro* digestibility of two sorghum cultivars (intermediate- and high-tannin contents) was investigated. Tannin contents were reduced after fermentation, and *in vitro* protein and starch digestibility increased by around 10% and 13%, respectively.

IKEDIOBI, C.O., TERRY, D.E. and UKOHA, A.I. (1994)

The use of sorghum (*Sorghum bicolor* L. Moench) dhurrinase-enriched preparation in the determination of total cyanide in sorghum and sorghum products.

Journal of Food Biochemistry, **18**: 17-29.

Purified dhurrinase (sorghum β-glucosidase II) from sorghum seeds, which catalyses the hydrolysis of dhurrin, proved to be more efficient in releasing free assayable cyanide than alkali hydrolysis for the determination of total cyanide in sorghum and derived products.

JEWERS, K. and JOHN, A.E. (1990)

***Alternaria* mycotoxins - possible contaminants of new sorghum varieties?**

Tropical Science, **30**: 397-409.

The major mycotoxins produced by *Alternaria* spp. are reviewed, and some of the toxicology and disease conditions associated with the ingestion of foods contaminated with these mycotoxins, particularly alternariol, alternariol methyl ether, altenuene and tenuazonic acid, are highlighted. Some of the methods available for the analysis of the *Alternaria* metabolites are also outlined.

JOOD, S., KAPOOR, A.C. and SINGH, R. (1992)

Mineral contents of cereal grains as affected by storage and insect infestation.

Journal of Stored Products Research, **28**(3): 147-151.

Infestation of wheat, maize and sorghum grains by *Trogoderma granarium* and *Rhyzopertha dominica*, separately or in a mixed population, resulted in substantial changes in the contents of calcium, phosphorus, zinc, iron, copper and manganese. Damage caused by *R. dominica* increased the mineral matter of wheat and sorghum grains significantly, owing to the loss of endosperm contents. Mixed populations caused intermediate changes in the mineral content of the three grain types.

JOOD, S., KAPOOR, A.C. and SINGH, R. (1993)

Biological evaluation of protein quality of sorghum as affected by insect infestation.

Plant Foods for Human Nutrition, **43**(2): 105-114.

The protein quality of sorghum grains with 25, 50 and 75% infestation of mixed populations of *Trogoderma granarium* and *Rhizopertha dominica* was biologically evaluated by rat growth and nitrogen balance studies. A diet containing insect-infested sorghum grains (50 and 75%) led to a marked decrease in food intake, protein intake, weight gain, food efficiency ratio, protein efficiency ratio, nitrogen consumption and absorption, net protein retention and protein retention efficiency.

KAVITHA, R. and CHANDRASHEKAR, A. (1992)

Content and composition of non-starchy polysaccharides in endosperms of sorghums varying in hardness.

Cereal Chemistry, **69**(4): 440-443.

The polysaccharide content and composition of the endosperm of sorghum grains of varying hardness was estimated. Soft grains contained more water-soluble, non-starchy polysaccharides, whereas hard grains contained more cellulose. Varietal differences in non-starchy polysaccharide contents and composition reflected compositional differences between the two endosperm types.

KIRLEIS, A.W. (1990)

Chemical and physical aspects of food and nutritional qualities of sorghum.

pp. 134-139. In: *INTSORMIL (CRSP) Annual Report 1990.* Lincoln, Nebraska, USA: INTSORMIL.

A review is presented of research carried out in Sudan and Niger on: the quality of kisra and towo from improved sorghum cultivars; the characterization and distribution of the alcohol storage proteins, kafirins, within sorghum; and the identification of *in vitro* pepsin-indigestible proteins of sorghum, predominantly kafirins, which were noted as the least digestible after cooking.

KUMARI, S.R. and CHANDRASHEKAR, A. (1994)

Relationships between grain hardness and the contents of prolamin and three anti-fungal proteins in sorghum.

Journal of Cereal Science, **20**(1): 93-99.

The contents of three anti-fungal proteins were determined for 40 cultivars varying in grain hardness and prolamin content. Statistically significant relationships were observed between the contents of the anti-fungal proteins and prolamin content. Analysis of hard and soft portions of two cultivars showed that all three proteins were present at a higher level in the corneous endosperm than in the floury endosperm.

LORRI, W. and SVANBERG, U. (1993)

Lactic-fermented cereal gruels with improved *in vitro* protein digestibility.

International Journal of Food Sciences and Nutrition, **44**: 29-36.

The effect of different lactic acid fermentation techniques on the *in vitro* protein digestibility of non- and high-tannin varieties of maize, sorghum and bulrush millet was examined. Lactic acid fermentation significantly improved the *in vitro* protein digestibility of gruels, except in the non-tannin maize. There was no difference in protein digestibility between gruels before and after cooking. Unfermented non-tannin gruels had higher *in vitro* digestibility than unfermented high-tannin gruels.

MANJARE, M.R., PATIL, R.B. and SURYAWANSHI, Y.B. (1993)

Up-gradation of quality in rain-damaged seeds of sorghum inbred 296-A after processing.

Journal of the Maharashtra Agricultural Universities, **18**(2): 328-329.

Foundation sorghum seed was grown in a field study during the monsoon. Seed lots were harvested from plots which were caught in the rains either at the physiological or field maturity stage. The seeds were either unprocessed, processed only on an air screen cleaner-cum-grader only, or processed on a gravity separator as well. On average, seed germination was 29 and 44% higher from seeds graded with the latter two seed-processing measures, respectively.

MARFO, E.K., SIMPSON, B.K., IDOWA, J.S. and OKE, O.L. (1990)

Effect of local food processing on phytate levels in cassava, cocoyam, yam, maize, sorghum, cowpea and soybean.

Journal of Agricultural Food Chemistry, **38**: 1580-1585.

Phytate levels in unprocessed, fermented and cooked foods from various staple cereals, legumes and tubers consumed in Africa, were determined. Phytates were substantially reduced by fermentation. Cooking had little effect on phytate levels in whole cereals and legumes but had a considerable reducing effect on tubers.

MAZHAR, H. and CHANDRASHEKAR, A. (1993)

Differences in kafirin composition during endosperm development and germination in sorghum cultivars of varying hardness.

Cereal Chemistry, **70**(6): 667-671.

The content and composition of kafirins in hard- and soft-endosperm sorghum cultivars were studied during endosperm development and germination. Results are presented and discussed. Overall, differences in the rate, type and content of kafirin deposition affected protein degradation during germination.

MAZHAR, H. and CHANDRASHEKAR, A. (1995)

Quantification and distribution of kafirins in the kernels of sorghum cultivars varying in endosperm hardness.

Journal of Cereal Science, **21**(2): 155-162.

Kafirins extracted from the endosperms of seven sorghum cultivars, and those from the vitreous and floury parts of the endosperm, were analysed. The data indicated that both content and distribution of kafirins within the grain differ between grains of varying endosperm hardness.

MAZHAR, H. and CHANDRASHEKAR, A. and SHETTY, H.S. (1993)

Isolation and immunochemical characterization of the alcohol-extractable proteins (kafirins) of *Sorghum bicolor* (L.) Moench.

Journal of Cereal Science, **17**(1): 83-93.

A simple protocol was developed for the purification of the α-, β- and γ-kafirins of sorghum based on extractability differences. The immunological relationship between kafirins and prolamins from other tropical millets and cereals was also investigated. Homologies were thought to exist amongst the prolamins contained in tropical millets and cereals, as all three kafirin antibodies reacted with the specific prolamins.

MBUGUA, S.K., AHRENS, R.A., KIGUTHA, H.N. and SUBRAMANIAN, V. (1992)

Effect of fermentation, malted flour treatment and drum drying on nutritional quality of uji.

Ecology of Food and Nutrition, **28**(4): 271-277.

Experiments were conducted on combinations of fermentation, malt treatment, boiling and drum drying in the preparation of uji, a popular porridge prepared in Kenya. Fermentation and drum drying decreased the extractable tannins, but addition of malted flour decreased them much more. Fermentation improved *in vitro* protein digestibility considerably, while addition of malted flour reduced it.

MNEMBUKA, B.V. and EGGUM, B.O. (1993)

The nutritive value of some selected Tanzanian plant food sources.

Plant Foods for Human Nutrition, **44**(1): 1-10.

The chemical and nutrient composition of different varieties of beans, cowpea, groundnuts and sorghum were determined, and all foodstuffs were tested in balance trials with rats. The nutritive value of plant materials varied considerably between species and varieties. Selection of the most promising varieties requires more evaluation with plant breeding programmes.

MOHAMED, A.A., HAMAKER, B.R. and ABOUBACAR, A. (1993)

Effects of flour-to-water ratio and time of testing on sorghum porridge firmness as determined by a uniaxial compression test.

Cereal Chemistry, **70**(6): 667-671.

A compression test was conducted on specimens of porridge made from seven sorghum cultivars with different endosperm textures. Porridge was prepared using three flour:water ratios and tested 15, 30 or 60 min after cooking. Sticky porridges, which are usually softer than non-sticky ones, scored higher because of frictional or bonding effects. Most cultivars exhibited improved porridge firmness as the flour:water ratio increased. Firmness measured after 60 min correlated significantly with grain vitreousness and amylose content.

MOHAMMED, S.I., STEENSON, L.R. and KIRLEIS, A.W. (1991)

Isolation and characterization of micro-organisms associated with the traditional sorghum fermentation for production of Sudanese kisra.

Applied and Environmental Microbiology, **57**(9): 2529-2533.

Sorghum flour mixed with water in a 1:2 (w/v) ratio was fermented at 30°C for 24 h. The microbial population consisted of bacteria (*Pediococcus pentosaceus, Lactobacillus* sp., *L. confusus, L. brevis, Erwinia ananas, Klebsiella pneumoniae and Enterobacter cloacae*), yeasts (*Candida intermedia* and *Debaryomyces hansenii*), and moulds (*Aspergillus* sp., *Penicillium* sp., *Fusarium* sp., and *Rhizopus* sp.). *P. pentosaceus* was the dominant microorganism.

MONYO, E.S., HASSEN, M., AXTELL, J.D. and EJETA, G. (1992)

Potential methods for improving the nutritive value of high-tannin sorghums in Tanzania.

pp. 61-63. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

A unique mineral soil found in Tanzania possesses certain properties advantageous for the cultivation of high-tannin sorghums. The soil, known as mmbala, is rich in sodium and potassium. Water extracted from mmbala has a pH of 9.7 and is used for the preparation of hard-to-cook legumes. Experiments with high-tannin sorghum varieties indicated the soil's beneficial effect on nutrition.

MORE, H.G., MAGAN, N. and STENNING, B.C. (1992)

Effect of microwave heating on quality and mycoflora of sorghum grain.

Journal of Stored Products Research, **28**(4): 251-256.

The effect of microwave heating on the rise and subsequent fall in grain temperature, reduction in moisture content and quality characteristics, was determined. Temperature attained and moisture loss were affected by grain moisture content and time of exposure. Free fatty acids were unaffected by treatment. All fungi were totally eliminated from the grain by microwave exposure for 30-60 s.

MORE, H.G., STENNING, B.C. and MAGAN, N. (1992)

Effect of high temperature treatment on disinfestation and quality characteristics of sorghum.

Annals of Applied Biology, **120**(1): 161-171.

The effect of heating sorghum grain with modified water contents to 60, 70 and 80 °C for periods of 4, 8 and 12 min was evaluated. Germination, seedling vigour, seedling dry matter, free fatty acid content, fungal contamination, and infestation with the bostrichid *Rhyzopertha dominica,* were all markedly affected by heat treatment. Effectiveness was influenced by the size of the sample used.

MUGULA, J.K. (1992)

The nutritive quality of sorghum-commonbean tempe.

Plant Foods for Human Nutrition, **42**(3): 247-256.

The nutritive quality of sorghum-commonbean tempe manufactured by a mixed culture fermentation was determined. Protein and crude fat increased slightly, while carbohydrates decreased. Dietary fibre of tempe increased by 10%, tannic acid increased by 52%, and phytate content decreased by 44%. The sorghum-bean tempe could be used for supplementary feeding.

MULIMANI, V.H. and SUPRIYA, D. (1993)

Effect of heat treatments on α-amylase inhibitor activity in sorghum (*Sorghum bicolor* L.)

Plant Foods for Human Nutrition, **44**(2): 181-186.

The effects of dry heat, boiling, autoclaving and pressure-cooking on α-amylase inhibitor (an anti-nutritional factor) activity in sorghum were determined. Dry heat did not inactivate α-amylase inhibitor activity but boiling, autoclaving and pressure-cooking did. Soaking in water for 24 h prior to heating significantly increased inactivation.

MULIMANI, V.H. and SUPRIYA, D. (1993)

Alpha-amylase inhibitors in sorghum (*Sorghum bicolor*).

Plant Foods for Human Nutrition, **44**(3): 261-266.

Forty varieties of locally-grown sorghum and four cereals were screened for inhibitory activity against human salivary amylase. Three varieties of sorghum had maximum inhibitory activity. Rice had the lowest inhibitory activity of the cereals. Activity was lost on germination and heating of the seeds.

MULIMANI, V.H. and SUPRIYA, D. (1993)

Alpha-amylase inhibitor activity in sorghum grains: effects of cooking and UV radiation.

Journal of Food Science and Technology, **30**(5): 321-323.

Amylase inhibitory activity in sorghum seeds was analysed and the effects of cooking were studied. Cooking and UV radiation decreased amylase activity, with the loss being greater in pre-soaked seeds than in raw seeds. Cooked products showed no amylase inhibitory activity although it was present in the grains used for making the products.

MULIMANI, V.H. and SUPRIYA., D. (1994)

Effects of infrared radiation, solar cooking and microwave cooking on α-amylase inhibitor in sorghum (*Sorghum bicolor* L.).

Plant Foods for Human Nutrition, **46**(3): 231-235.

The effects of three domestic cooking methods on α-amylase inhibitory activity in sorghum grains were studied. In all treatments, seeds soaked overnight lost their activity much faster. All three treatments reduced the inhibitory activity. The solar cooker was very economic and efficient.

MULIMANI, V.H. and VADIRAJ, S. (1991)

Proteinase inhibitors of sorghum.

Journal of Science of Food and Agriculture, **54**(3): 485-488.

Proteinase inhibitory activity in buffer extracts of sorghum grain varied widely in the 30 cultivars tested. Chymotrypsin inhibitory activity was more pronounced than trypsin inhibitory activity in all cultivars. Activity of both inhibitors decreased during germination.

MULIMANI, V.H. and VADIRAJ, S. (1991)

Determination of trypsin and chymotrypsin inhibitory activities in sorghum grain.

Journal of Food Science and Technology, **28**(3): 185-187.

Trypsin and chymotrypsin inhibitory activity was investigated in various sorghum products. The losses of trypsin and chymotrypsin inhibitory activities were: in unleavened bread, 55% and 45%; in kichadi, 45% and 54%; and in idli, 55 and 75%. Grinding also decreased trypsin and chymotrypsin inhibitory activities because of the heat generated during the process.

MULIMANI, V.H. and VADIRAJ, S. (1993)

Effects of heat treatment and germination on trypsin and chymotrypsin inhibitory activities in sorghum (*Sorghum bicolor* (L.) Moench) seeds.

Plant Foods for Human Nutrition, **44**(3): 221-226.

The effects of heat treatment (moist and dry) and germination on trypsin and chymotrypsin inhibitory activities in sorghum seeds were investigated. Dry heat treatment had no effect on proteinase inhibitory activity. Moist heat treatment reduced trypsin and chymotrypsin inhibitors effectively. Germination completely eliminated proteinase inhibitory activity.

MULIMANI, V.H. and VADIRAJ, S. (1994)

Changes in trypsin and chymotrypsin inhibitory activity on soaking of sorghum (*Sorghum bicolor* (L.) Moench).

Plant Foods for Human Nutrition, **46**(1): 27-31.

The changes in trypsin and chymotrypsin (anti-nutritional factors) inhibitory activity of sorghum seeds which occur after soaking in distilled water, different salt solutions and mixed salt solution, were investigated. A greater reduction in proteinase inhibitory activity was observed after soaking in salt solution than after soaking in distilled water. Maximum loss of activity was observed after soaking seeds in mixed salt solution.

MURANGA, F.I. (1993)

Correlation of product quality of extruded sorghum products to extent of starch gelatinization.

Uganda Journal of Agricultural Sciences, **1**(1): 45-53.

Extrudates made from pure sorghum flour, wheat flour, and composites of the two flours containing various percentages of sorghum, were compared. Results indicated that for sorghum products, there is a direct relationship between extent of product expansion and extent of gelatinization, loss of shear and extent of gelatinization, increase in expansion and increased moisture content, and decrease in colour (tannin content) and increased gelatinization. The ability of wheat and sorghum to gelatinize at different temperatures was identified as the main obstacle to the production of good composite extrudates.

OKEKE, A.O. (1993)

Effect of sprouting and kilning temperatures and germination time on cyanide content in sprouted sorghum: a statistical approach.

Journal of Food Science and Technology, **30**(4): 283-285.

The effects of sprouting, germination time and drying temperature on cyanide content of sorghum were studied. Drying temperature, sprouting temperature and period of sprouting all had a significant effect on cyanide levels. The highest cyanide levels were obtained with a drying temperatureof 65 °C. Cyanide content increased during the first four days of sprouting.

ORIA, M.P., HAMAKER, B.R. and SHULL, J.M. (1995)

***In vitro* protein digestibility of developing and maturing sorghum grain in relation to α-, β- and γ-kafirin disulfide crosslinking.**

Journal of Cereal Science, **22**: 85-93.

Sorghum was harvested on selected days after half bloom and at maturity and analysed for protein, moisture content, protein digestibility and kafirin contents. All kafirins were present 40 days after half bloom and at maturity. Protein digestibility was about 90% and dropped to 73% at maturity. It is suggested that the decrease in digestibility in maturing grains is due to the drying effect and formation of complexes of kafirins.

PARASHER, R.C., CHAUHAN, G.S. and SINGH, D. (1992)

Varietal differences in some physical and chemical characteristics of grain sorghum (*Sorghum bicolor* (L.) Moench).

Bulletin of Grain Technology, **30**(2): 159-162.

Nine varieties of sorghum were evaluated for their physical and chemical characteristics; they were classified as small, medium and large, and on thousand kernel weight.. Depending on variety, mineral and sugar contents varied widely. Glutelin and prolamin were the major protein fractions in all varieties. The flour yields were directly proportional to thousand kernel weight.

PRADEEP, K.U., GEERVANI, P. and EGGUM, B.O. (1991)

Influence of spices on utilization of sorghum and chickpea protein.

Plant Foods for Human Nutrition, **41**(3): 269-276.

The influence of eight common Indian spices on the protein quality of sorghum and chickpea was studied. The addition of spices did not affect protein digestibility. The biological value of sorghum diets was higher than that of the control diet. The addition of spices did not have any effect on the protein digestibility and biological value of chickpeas.

RAO, A. and VIMALA, V. (1993)

Efficacy of tricalcium phosphate on the storage quality of sorghum flour.

Journal of Food Science and Technology, **30**(1): 58-59.

The efficacy of tricalcium phosphate (2%) as a pre-storage treatment for whole and dehulled sorghum flour was studied. The treatment controlled insect infestation and the changes associated with fat acidity, alcoholic acidity and lipase activity. A positive correlation between fat acidity and lipase activity was observed. Dehulling prior to milling contributed to the better storage quality.

ROM, D.L., SHULL, J.M., CHANDRASHEKAR, A. and KIRLEIS, A.W. (1992)

Effects of cooking and treatment with sodium bisulfite on the *in vitro* protein digestibility and micro-structure of sorghum flour.

Cereal Chemistry, **69**(2): 178-181.

In vitro pepsin digestion assay and scanning electron microscopy were used to examine the effects of cooking and treatment with sodium bisulfite on protein digestibility and protein micro-structure. Results showed that protein digestibility decreased in sorghum after cooking. Treatment with sodium bisulfite increased digestibility of both cooked and uncooked flour. Evidence from scanning electron micrographs is used to explain the results.

ROONEY, L.W. (1990)

Food and nutritional quality of sorghum and millet.

pp. 145-154. In: *INTSORMIL (CRSP) Annual Report 1990.* Lincoln, Nebraska, US: INTSORMIL.

Research is reviewed on the enhanced utilization of sorghum and millet by the development of new or improved processing methods (parboiling, and production of weaning food from millet, cowpea and sorghum malt), and through co-operation with breeding programmes for the development of better quality sorghum and millets (with built-in head bug resistance).

ROONEY, T.K., ROONEY, L.W. and LUPTON, J.R. (1992)

Physiological characteristics of sorghum and millet brans in the rat model.

Cereal Foods World, **37**(10): 782, 784-786.

The effects of sorghum and millet bran on blood and liver cholesterol, and colonic physiology, were examined in a feeding experiment using rats. Serum cholesterol levels of rats fed brown and white sorghum brans were not significantly different from those fed wheat bran. Rats fed sorghum, millet or wheat bran diets had significantly higher liver cholesterol than those fed on an oat bran diet. Sorghum and millet were excellent bulking agents; they appeared to be poorly fermented, and did not increase caecal surface area.

SEETHARAMAN, K., WANISKA, R.D. and ROONEY, L.W. (1994)

Screening anti-fungal proteins in sorghum cultivars - preliminary results.

International Sorghum and Millets Newsletter, **35**: 136.

Screening trials were carried out in several sorghum cultivars to determine the presence of anti-fungal proteins using antibodies raised against zeamatin, barley chitinase and bean chitinase. Preliminary results are presented.

SERNA-SALDIVAR, S.O., ROONEY, L.W. and GREENE, L.W. (1991)

Effect of lime treatment on the bioavailability of calcium in diets of tortillas and beans: rat growth and balance studies.

Cereal Chemistry, **68**(6): 565-570.

Quality protein maize, regular maize and sorghum were lime-cooked and processed into tortillas. Rats were fed on raw grain or tortilla-based diets supplemented with dry, cooked pinto beans and a calcium-free or calcium-rich mineral premix. Rats consuming calcium-supplemented products and raw grains consumed more feed and gained more weight than rats fed un-supplemented feed. The negative effect of the lack of calcium was more noticeable as time progressed.

SERNA-SALDIVAR, S.O., ROONEY, L.W. and GREENE, L.W. (1991)

Effect of lime treatment on the bioavailability of calcium in diets of tortillas and beans: bone and plasma composition in rats.

Cereal Chemistry, **69**(1): 78-81.

The properties and composition of femurs and plasma of rats fed on raw grains of quality protein maize or sorghum, or tortilla-based diets with and without calcium supplement, were estimated. The femurs of rats fed on the tortilla diet had better properties and mineral composition than those fed on raw grains. Quality protein maize tortillas produced the best bones, followed by sorghum and regular maize tortillas. Calcium supplementation improved the properties and mineral composition of the femur and serum considerably.

SHULL, J.M., WATTERSON, J.J. and KIRLEIS, A.W. (1991)

Proposed nomenclature for the alcohol-soluble proteins (kafirins) of *Sorghum bicolor* (L. Moench) based on molecular weight, solubility and structure.

Journal of Agricultural and Food Chemistry, **39**: 83-87.

Using the results of differential solubility analyses of sorghum kafirins and maize zeins isolated from field-grown sorghum seeds and commercial maize flaking grits, a nomenclature for sorghum kafirins is proposed based on similarities in molecular weight, solubility and structure.

SHULL, J.M., WATTERSON, J.J. and KIRLEIS, A.W. (1992)

Purification and immunocytochemical localization of kafirins in *Sorghum bicolor* (L. Moench) endosperm.

Protoplasma, **171**: 64-74.

Kafirins from sorghum were purified and their amino acid composition determined. Immunolocalization methods were used to determine the organization of the protein bodies and distribution of kafirins throughout the endosperm.

SIWAWEJ, S. (1990)

Vermicelli from sorghum and soya.

Food Australia, **42**(5): 224-225.

The nutritional value of sorghum vermicelli was increased by the inclusion of soya flour. Levels of 10, 20 and 30% soya flour gave acceptable colour, flavour and texture. Higher levels improved rehydration capacity but decreased the strength of the pasta products.

SIWAWEJ, S. and SUWANCHEWAKORN, P. (1993)

Sorghum vermicelli.

Food, **23**(2): 98-106.

Sorghum vermicelli was made by mixing sorghum with broken rice and glutinous rice flour or food additive. The quality was significantly affected by different ratios of the ingredients. While acceptability decreased with increased amounts of sorghum, the addition of food additive improved quality. Sorghum vermicelli is much darker in colour than rice vermicelli.

SOOD, N., SACHDEVA, S.K. and RAHEJA, R.K. (1991)

Fatty acid and free amino acid profiles in six species of *Sorghum* (L.) Moench.

Journal of Plant Science Research, **7**(1/4): 12-13.

The fatty acid composition of the seeds of six sorghum varieties was determined. The total lipid percentage, and fatty acid and free amino acid profiles for all varieties, are presented.

SOPADE, P.A. and AJISEGIRI, E.S. (1994)

Moisture sorption study on Nigerian foods: maize and sorghum.

Journal of Food Process Engineering, **17**: 33-56.

Adsorption-desorption behaviour of maize and sorghum between water activities of 0.1 and 0.98 at temperatures of 20, 25 and 40 °C was studied. The heat of sorption decreased with an increase in moisture content; an exponential equation was used to describe the relationship.

SUBRAMANIAN, V. and JAMBUNATHAN, R. (1992)

Laboratory procedures for evaluating grain and food quality of sorghum and pearl millet: problems and prospects.

pp. 143-150. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

Methods currently available for evaluating the various grain characteristics which influence food quality are described. Problems associated with laboratory methods, and areas for further research, are discussed; suggestions for increased utilization, and possible alternative uses, are included.

SUBRAMANIAN, V., SEETHARAMA, N., JAMBUNATHAN, R. and RAO, P.V. (1990)

Evaluation of protein quality of sorghum (*Sorghum bicolor* (L.) Moench).

Journal of Agriculture and Food Chemistry, **38**(6): 1344-1347.

Grain protein content varied between 6.8 and 19.6% in eight sorghum cultivars comprising landraces, hybrids and local cultivars. Two Ethiopian landraces had higher concentrations of lysine, threonine, cystine, isoleucine and tyrosine. Albumin-globulin and glutelin constituted about 41-55% of the protein in the eight cultivars. Prolamin and cross-linked prolamin contents eluci-

dated the pattern of protein synthesis in the grain. Prolamin content increased from 14 to 28 days and declined toward maturity. Glutelin did not change from 14 days after anthesis to maturity.

SUZUKI, H., HAYAKAWA, S. and OHTSUBO, K. (1991)

Effect of extrusion cooking on the nutritive value of proteins in grain sorghum.

Journal of the Japanese Society for Food Science and Technology, **38**(6): 553-555.

Rats were freely fed on diets containing sorghum grain, extruded sorghum, or extruded product containing 10% yeast. Net nitrogen utilization was highest in extruded product, followed by extruded sorghum and grains, respectively. The results suggest that extrusion increases the overall nutritive value of proteins, thereby over-riding the slight disadvantage of reduced lysine availability.

TUNA, E. and BRESSANI, R. (1992)

[Chemical composition of eleven varieties of sorghum (*Sorghum vulgare*) before and after popping.]

Archivos Latinoamericanos de Nutricion, **42**(3): 291-300 [in Spanish].

Chemical composition, availability of lysine and tryptophan, and protein digestibility *in vitro*, were estimated before and after sorghum was processed in a maize popper. Protein content was unaffected but crude fibre increased. Available lysine and tryptophan were decreased, and there was a significant loss of amylase as a percentage of starch. Popping decreased protein digestibility *in vitro* in all but three of the varieties.

VADIRAJ, S. and MULIMANI, V.H. (1993)

Changes in protease and β-amylase activity in germinating seeds of sorghum.

Indian Journal of Plant Physiology, **36**(4): 253-254.

During the germination of sorghum seeds, the activity of protease and β-amylase increased in both the axis and the endosperm; maximum activity was observed on the sixth day of germination. Protease and β-amylase activity decreased during storage, β-amylase decreasing more than protease in the first three months.

VERBRUGGEN, M.A., BELDMAN, G., VORAGEN, A.G.J. and HOLLEMANS, M. (1993)

Water-unextractable cell wall material from sorghum: isolation and characterization.

Journal of Cereal Science, **17**(1): 71-82.

Flours were prepared from whole and polished grains of sorghum cultivars. The components analysed were mainly starch, protein and non-starch polysaccharides and accounted for 84-100% of almost all fractions. They were composed mainly of arabinose, xylose, glucose and uronic acid. The polysaccharide composition of the outer layers was similar to that of the inner layers

of the grain. Most of the non-starch glucose was present as cellulose and β-D-glucan. The arabinoxylan present in the sorghum was highly substituted and contained uronic acids, acetyl and feruloyl substituents.

VIVAS RODRIGUEZ, N.E., SERNA-SALDIVAR, S.O., WANISKA, R.D. and ROONEY, L.W. (1990)

Effect of tortilla chip preparation on the protein fractions of quality protein maize, regular maize and sorghum.

Journal of Cereal Science, **12**(3): 289-296.

Protein fractions, electrophoretic patterns and protein digestibility of quality protein maize, regular maize, and sorghum were studied during preparation of tortilla chips. Processing reduced levels of all protein fractions, different stages having different degrees of influence on the three cereal types. Protein digestibility was also adversely affected by processing, with sorghum being most negatively affected.

VIVAS, N.E., WANISKA, R.D. and ROONEY, L.W. (1992)

Effects on proteins in sorghum, maize and pearl millet when processed into acidic and basic tô.

Cereal Chemistry, **69**(6): 673-676.

Tô was prepared using traditional acidic and basic conditions to further characterize protein solubility, molecular weight and *in vitro* pepsin digestibility. The proteins in sorghum and millet were more affected by processing than the proteins in maize. Lower *in vitro* digestibility was observed for tô made from sorghum than from tô made from millet or maize.

WANG, R.S. and KIES, C. (1991)

Niacin status of humans as affected by eating decorticated and whole-ground sorghum (*Sorghum* Gramineae) grain, ready-to-eat breakfast cereals.

Plant Foods for Human Nutrition, **41**(4): 355-369.

Niacin utilization from whole-grain ground sorghum flour and decorticated-grain ground sorghum flour was studied in humans. Although whole-ground cereal contained higher amounts of niacin, urinary losses were higher when the decorticated cereal was consumed. It appears that the niacin in the whole-ground cereal is fully absorbed and that the need for niacin is then increased, or its urinary extraction is inhibited.

WANISKA, R.D., HUGO, L.F. and ROONEY, L.W. (1992)

Practical methods to determine the presence of tannins in sorghum.

Journal of Applied Poultry Research, **1**(1): 122-128.

Two qualitative tests, the 'scratch' test and the 'bleach' test, for estimating tannins in sorghum are described.

WATTERSON, J.J., SHULL, J.M. and KIRLEIS, A.W. (1993)

Quantitation of α-, β- and γ-kafirins in vitreous and opaque endosperm of Sorghum bicolor.

Cereal Chemistry, **70**(4): 452-457.

Qualitative and quantitative differences in the protein composition of three sorghum varieties varying in hardness and percentage vitreousness were investigated. Results indicated that the kafirin fraction of opaque endosperm has a higher percentage of β- and γ-kafirins, and a lower percentage of α-kafirins, than vitreous endosperm. Total kafirin content may be more important than the protein-body composition in determining sorghum grain hardness.

WAICHUNGO, W.W. (1995)

Use of ammonium hydroxide to reduce the level of assayable tannin in high-tannin sorghum grain.

Journal of Agricultural Food Chemistry, **43**(3): 728-732.

Sorghum tannin levels were reduced by up to 88% following treatment with ammonium hydroxide (0.01-1M) for periods of up to 20 days. Increased drying temperature decreased ammonia levels in the flour. Sensory evaluation revealed that muffins prepared from treated grain were preferable to those prepared from untreated grain.

5 INDUSTRIAL UTILIZATION

ABASIEKONG, S.F. (1991)

Effect of fermentation on crude protein and fat contents of crushed grains of maize and sorghum.

Journal of Applied Bacteriology, **70**(5): 391-393.

The possibility of producing crude protein by growing micro-organisms on crushed maize and sorghum was investigated. The aim was to obtain protein-enriched grains for providing both energy and protein in animal diets. Highest values of protein were 30.1 and 24.2% for heat-treated sorghum and maize fermented by *Fibrobacter succinogenes,* respectively. Highest values of fat were 13.1 and 10.6% for maize and sorghum, respectively, obtained from fermentation of heat-treated grains using *L. actobacillus brevis.*

ABASIEKONG, S.F. (1991)

Effects of fermentation on crude protein content of brewers dried grains and spent sorghum grains.

Bioresource Technology, **35**(1): 99-102.

Samples of untreated, NaOH-treated and starch-enriched mashes of brewers dried grains and spent sorghum grain were fermented using *Ruminoccus, Lactobacillus, Succinomonas* and a mixed culture of all three micro-organisms. Fermentations with the mixed culture showed the highest yield of crude protein. Enrichment with starch gave a rapid increase in crude protein but did not encourage fibre degradation significantly.

ADEJEMILUA, F. (1995)

Processing and profile of sorghum malt.

Technical Quarterly, Master Brewers' Association of the Americas, **32**(1): 15-18.

The potential of African sorghum cultivars for beer production was investigated. Properties of malts prepared from four sorghum cultivars were analysed and compared with malts from barley and wheat. Results suggest that sorghum is suitable for beer production, provided that barley malt is used as a supplement to improve diastatic power and increase amylase activity during mashing.

AGU, R.C. (1995)

Comparative study of experimental beers brewed from millet, sorghum and barley malts.

Process Biochemistry, **30**(4): 311-315.

Sensory properties of lager beers prepared from millet, sorghum and barley malts were evaluated. Lager beers brewed from millet and sorghum malts were darker in colour and had a different flavour from beer brewed with barley malt. Millet beer had a better foam retention than sorghum beer, but the alcohol content of sorghum beer was higher than that of millet beer. In all the parameters assessed, barley beer out-scored beers brewed from millet and sorghum.

AGU, R.C. (1995)

Influence of potassium bromate on some malting properties of Nigerian sorghum (*Sorghum bicolor*).

Process Biochemistry, **30**(8): 763-766.

The effect of potassium bromate on the malting of sorghum for the production of alcoholic beverages was studied. Potassium bromate increased the filtration rate and cold and hot extract values after four days of germination. No significant decrease in malting loss was observed after addition of potassium bromate at 50-125 mg/litre. It is concluded that addition of potassium bromate at steep-out at a concentration of 50-125 mg/litre can improve some malting properties of sorghum.

AGU, R.C., OKEKE, B.C. and CHIBUKO, C.C. (1993)

Application of microbial enzymes in the mashing of Nigerian millet and sorghum malts.

Bioresource Technology, **44**(1): 53-56.

The use of locally-obtained enzymes for the mashing of millet and sorghum malts was investigated. Eight isolates of bacilli and fungi were used for enzyme production by a submerged fermentation method. Crude enzymes obtained from both micro-organisms were combined in equal ratios and used in the mashing of sorghum and millet. The enzymes had a more pronounced influence in sorghum than in millet.

AGU, R.C., OKENCHI, M.U., ANEKE, G. and ONWUMELU, A.H. (1995)

Brewing properties of Nigerian white and yellow malted sorghum varieties mashed with external enzymes.

World Journal of Microbiology and Biotechnology, **11**(5): 591-592.

The brewing quality of white and yellow sorghum varieties was investigated. Sorghum malts were prepared and mashed using a commercial enzyme preparation (Thermamyl); *Saccharomyces uvarum* was used to carry out the alcoholic fermentation. The properties of unmalted sorghum, malted sorghum, wort and beer were assessed. Data suggest that white sorghum has better brewing properties than yellow sorghum.

AGU, R.C., UGWU, A.H., OKENCHI M.U., ANEKE, G. and ANYANWU, T.U. (1995)

Effect of low kilning temperatures on diastase and cellulase development of Nigerian malted sorghum (*Sorghum bicolor*).

Process Biochemistry, **31**(1): 63-68.

One of the major problems encountered when using sorghum malt for beer production is poor wort filtration which is attributed to insufficient production of cell wall-degrading enzymes. The effects of kilning temperature on levels of diastase and cellulase in malting sorghum were investigated. Lowering the temperatures resulted in a significant increase in the level of diastase and cellulase activities of the malt. However, kilning at very low temperature resulted in beer with an unacceptable flavour.

AISIEN, A.O. (1990)

Utilization of sorghum in brewing lager beer in Nigeria.

p. 29. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The use of sorghum in brewing, and the problems associated with the production process, are reviewed. It is concluded that selection and breeding of cultivars with high extract yield and soluble proteins, and low polyphenol and fat content, is required. Improved malting techniques and brewing processes also need to be developed and adapted.

AJERIO, K.O., BOOER,C.D. and PROUDLOVE, M.O. (1993)

Aspects of the malting of sorghum.

Ferment, **6**(5): 339-341.

The malting of sorghum was investigated with the aim of promoting chitting, control of fungal growth during malting to enhance malt quality, and β-amylase production. A mixture of 0.375% (w/v) boric acid and 0.375% (w/v) borax added to steep water acts as an effective anti-fungal agent. Air rest periods during steeping increased the evenness of chitting. Temperature control, good bed drainage and periodic loosening of the grain bed during germination all helped to limit fungal growth and improve the modification of sorghum malt.

AKINGBALA, J.O. (1990)

Use of sorghum in the preparation of weaning foods.

p. 38. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The use of sorghum in the production of ogi, a popular weaning food in Nigeria, is reviewed. It is concluded that quality can be enhanced by co-fermenting sorghum with soya bean. The production on an industrial scale of ready-to-eat weaning foods made from sorghum by drum-drying the cooked paste, extrusion and baking, is discussed.

ANICHE, G.N. (1990)

Studies on the effects of germination and drying conditions on the cyanide content of sorghum sprouts.

Journal of Food Science and Technology, **27**(4): 202-204.

The effect of germination and drying on the cyanide content of sorghum sprouts was investigated by germinating sorghum of the local red variety. It was concluded that sorghum sprouts germinated at 30 °C for six days, and dried at 55 °C for 24 h, contained acceptable levels of HCN and could be used in lager beer brewing.

ANICHE, G. N. and ANIH, A.C. (1994)

Malting properties of two sorghum cultivars and the effect of mashing schemes on their wort properties.

Process Biochemistry, **29**(5): 369-371.

Malting properties, and the effect of mashing schemes on their wort properties, were investigated for two sorghum varieties selected and grown in Nigeria. Both produced worts with lower maltose concentrations than those in barley malt wort. The type of mashing scheme used did not significantly affect the amount of maltose formed in the sorghum malt worts. Saccharification was always incomplete, irrespective of the type of mashing scheme used.

ANICHE, G.N. and NWOKEDI, H. (1990)

Preliminary studies on the effect of drying temperature and time on the dimethyl sulphide content of sorghum in wort.

Process Biochemistry, **25**(1): 7-8.

The effects of drying temperature and time on the dimethyl sulphide content of sorghum wort were studied. Samples of malt germinated for five days were dried at 50, 60 and 70 °C for 24 h. Dried malt samples were collected at 4 h intervals and mashed using a three-stage decoction method. Dimethyl sulphide content was determined by GC using FID. Results indicated that dimethyl sulphide levels decreased as drying temperature and time increased.

ANICHE, G.N. and NWOKEDI, H. (1990)

Preliminary studies on the effect of drying temperature and time on the concentration of dimethyl sulphide content of sorghum wort.

Journal of Food Science and Technology, **27**(1): 13-14.

Samples of sorghum malt germinated for five days were dried at 50, 60 and 70 °C for 24 h. Samples were collected at 4 h intervals and mashed using a three-stage decoction method. Dimethyl sulphide content in the head space of samples was determined by a GC method. Dimethyl sulphide levels decreased as drying temperature and time increased.

ANICHE, G.N. and PALMER, G.H. (1990)

Development of amylolytic activities in sorghum and barley malt.

Journal of the Institute of Brewing, **96**(6): 377-379.

As sorghum cultivars vary in their diastatic power, diastatic and amylolytic properties of a new cultivar of Nigerian sorghum, regarded as having good malting potential, were compared with those of a Scottish barley cultivar. Barley malt had more diastatic power and β-amylolytic activity than sorghum malt, although kilned barley malt generally retained less α-amylolytic activity than kilned sorghum malt.

ANICHE, G.N. and PALMER, G.H. (1990)

Microscopic assessment of increasing moisture treatments on endosperm modification in sorghum.

Ferment, **3**(6): 378-380.

The effects of different moisture treatments on the pattern of endosperm breakdown in sorghum were assessed microscopically. In general, the failure of sorghum to soften during malting may be caused by natural starch compaction of the outer tissue of the endosperm, and resistance of this area of the grain to enzymic breakdown, even when high levels of water are added. Limited attack on cell walls of the starchy endosperm may also contribute to the failure to soften.

ARIBISALA, A.O. (1990)

Industrial utilization of sorghum in Nigeria.

p. 13. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

This review concluded that the production of biscuits and confectionary, beverages, weaning foods and beer are the principal uses of sorghum as an industrial raw material in Nigeria.

ARRI, B.K. (1990)

Problems associated with the use of sorghum for lager beer production.

p. 29. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The problems associated with producing beer from 100% sorghum grain, including equipment, sorghum malting, mash gelatinization, saccharification, lautering, wort fermentability, body fullness and acceptability of the final product, are reviewed. It is concluded that the development of sorghum cultivars with low gelatinization temperatures, low polyphenols, low lipid, high diastatic power and readily-soluble proteins, is required.

AYOOLA, G.B. and IDACHABA, F.S. (1990)

The Nigerian grain market and industrial utilization of sorghum: a perspective.

p. 13. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria. Patancheru, India: ICRISAT.*

An economic perspective of the cereal grain market and the increasing industrial utilization of sorghum in Nigeria is presented. The main intervention instruments in the market are surveyed, and the implication of these factors in the industrial utilization of sorghum is discussed.

BAJOMO, M.F. and YOUNG, T.W. (1992)

Development of a mashing profile for the use of microbial enzymes in brewing with raw sorghum (80%) and malted barley or sorghum malt (20%).

Journal of the Institute of Brewing, **98**(6): 515-523.

The effects of different time and temperature programmes, and the activities of 17 commercial enzyme preparations, on the production of hot water extract and free amino nitrogen (FAN) from mashes containing 80% raw sorghum and 20% malted barley, or 20% malted sorghum, were investigated. Results suggest that using malted sorghum alone to replace malted barley is inefficent; exogenous enzymes are also required.

BAJOMO, M.F. and YOUNG, T.W. (1993)

The properties, composition and fermentabilities of worts made from 100% raw sorghum and commercial enzymes.

Journal of the Institute of Brewing, **99**(2): 153-158.

Fermentable extracts were produced from 100% raw sorghum in 85 min using minimum levels of a heat-stable α-amylase, an amyloglucosidase and a proteolytic enzyme. Differences in the composition of malted barley worts, and worts produced with sorghum and enzymes, are discussed.

BAJOMO, M.F. and YOUNG, T.W. (1994)

Fermentation of worts made from 100% raw sorghum and enzymes.

Journal of the Institute of Brewing, **100**(2): 79-84.

Fermentation performance of the commercial lager yeast strain, *Saccharomyces uvarum,* on worts prepared from raw sorghum and microbial enzyme preparations was studied. Successful fermentation was observed, even though the free amino nitrogen present in the sorghum worts was below that required for fermentation of worts from barley malt. The results are discussed.

BOBOYE, B.E. and ADETUYI, F.C. (1994)

Fungal population associated with raw materials and intermediate products of lager beer produced from Nigerian sorghum grains.

Journal of Food Science and Technology, **31**(2): 148-150.

Fungi were counted on potato dextrose agar, malt extract agar, Czapek Dox agar, and wort agar during the processing of sorghum for the production of lager beer. Samples of sorghum grains, water, malted sorghum, hop pellets and yeast were used. Samples from the mash, wort, and unpasteurized and

pasteurized beer were also collected but were negative for fungi in all the media tested. Sorghum grains and malted sorghum had total fungal counts of 5×10^{-3} and 8×10^{-3} cfu/g, respectively.

BOGUNJOKO, J.S.T. (1992)

Industrial uses of sorghum in Nigeria.

pp. 115-119. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The experience of Cadbury Nigeria Ltd in pioneering the industrial use of sorghum, and the present state of sorghum usage by industries in Nigeria, is discussed. The lower price variation of sorghum compared to that of malted barley and glucose syrup, and increased agricultural production, have brought the use of sorghum in the beer and food industries into prominence.

BRYAN, W.L. (1990)

Solid-state fermentation of sugars in sweet sorghum.

Enzyme and Microbiological Technology, **12**(6): 437-442.

Fermentaion studies on cut, shredded and pressed stalks of sweet sorghum are reported. The unsterilized products all readily underwent anaerobic solid-state fermentation, presumably by wild yeasts. Inclusion of *Saccharomyces cerevisiae* accelerated fermentation, increased the yields of ethanol, glycerol, acetic acid and gas (mass loss), and decreased the yields of lactic acid, dextrans and mannitol. Ratios of mass losses to yields were higher than expected and all fermentations gave a strong odour of acetaldehyde.

CHITSIKA, J.M. and MUDIMBU, M.W. (1992)

Quality criteria for opaque beer in Zimbabwe.

pp. 151-155. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The quality of sorghum and millet is discussed with reference to their four main uses in the brewing industry: as an alternative starch based adjunct, as a source of malt proteolytic and amylolytic enzymes, as a source of lactobacilli, and as a source of the nutrients required for lactic acid fermentation and desirable taste and colour characteristics.

CHRISTAKOPOULOS, P., LI, L.-W., KEKOS, D. and MACRIS, B.J. (1993)

Direct conversion of sorghum carbohydrates to ethanol by a mixed microbial culture.

Bioresource Technology, **45**(2): 88-92.

The carbohydrates of sweet sorghum cultivars were directly converted to ethanol by a mixed culture of *Fusarium oxysporum* and *Saccharomyces cerevisiae*. Factors affecting this bioconversion were studied. The highest ethanol yield obtained was 33.2 g/100 g of total sorghum carbohydrates, corresponding to 10.3 g/100 g of fresh stalks. These values represented 68.6% of the theoretical yield. The results demonstrate that more than 50% of the sorghum polysaccharides are directly fermented to ethanol.

CHUKWURA, E.N. (1990)

Brewhouse performance of sorghum grain and malt: problems and prospects.

p. 30. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The brewhouse performance of sorghum grain in Nigeria is reviewed. It is concluded that appropriate choice of grain lots by screening, better milling procedures and improved mashing techniques, combined with good exgenous enzymes, would improve performance.

CUNDIFF, J.S. and WORLEY, J.W. (1992)

Chopping parameters for separation of sweet sorghum pith and rind-leaf.

Bioresource Technology, **39**(3): 263-269.

Whole stalks of sorghum were chopped, either immediately after harvesting or after 30 days of storage, using different intervals and knife velocities. Sieved fractions were analysed for moisture and non-structural carbohydrate. The following suggestions were made: for conversion to edible syrup, the chop interval should be 0.5 cm (for high pith yield) and the knife velocity 6 m/s (for minimal shattered rind); and for ethanol production, knife velocity should be 18 m/s (for maximum comminution) and chop interval 1.0 cm (as optimum compromise between yield and productivity).

DALE, C.J., YOUNG, T.W. and OMOLE, A.T. (1990)

Small-scale mashing experiments with grists containing high proportions of raw sorghum.

Journal of the Institute of Brewing, **96**(6): 403-409.

Small-scale experiments were conducted on the behaviour of mashes containing high proportions of raw sorghum supplemented with industrial enzyme preparations. Results indicated the feasibility of brewing lager type beer from grists containing barley malt and raw sorghum. Beers produced from 50% malt /50% polished sorghum, and 20% malt /80% raw sorghum, were acceptable with low colour, light flavour, and good storage potential.

DUFOUR, J.P., MELOTTE, L. and SREBRNIK, S. (1992)

Sorghum malts for the production of a lager beer.

Journal of the American Society of Brewing Chemists, **50**(3): 110-119.

The major difficulties experienced when producing lager beer from sorghum malt were investigated. Data suggested that the cultivars have an effect in determining saccharification, filtration speed, diastatic power and wort amino acid content. It is suggested that all the difficulties can be remedied by selecting brewing sorghum cultivars, adapting the brewing procedure, and using appropriate brewing equipment.

DEMUYAKOR, B. and OHTA, Y. (1993)

Malt characteristics of *Sorghum vulgare* varieties from Ghana.

Journal of the Science of Food and Agriculture, **59**(4): 457-462.

Two local varieties of white and red sorghum cultivated in Ghana were malted using a micro-malting method. Their malt characteristics were studied and compared to those of a commercial barley malt. In terms of varietal superiority, white sorghum yielded higher malt extracts than the red type.

DEMUYAKOR, B. and OHTA, Y. (1993)

Comparison of the malt characteristics of traditional and improved varieties of *Sorghum vulgare from Ghana.*

Journal of the Institute of Brewing, **99**(3): 227-230.

Malt properties of six agronomically-improved sorghum varieties were compared with two traditionally grown, Ghanaian white and red sorghum varieties, in order to identify a sorghum suitable for traditional or western beers. It was concluded that although the malt properties of all the varieties differed considerably, the traditional varieties, particularly white sorghum, gave superior malts.

DEMUYAKOR, B., OHTA, Y., NAKATANI, K., FUKUI, N. and KANAGAWA, K. (1994)

Brewing of beer with Sorghum vulgare malt with minimal malt blending.

Journal of the American Society of Brewing Chemists, **52**(3): 111-115.

The brewing of beer using sorghum malt is discussed. Malting properties of various types of sorghum from Ghana were investigated and a successful pilot-scale brewing of a draft beer was carried out. The 66:34 sorghum/barley malt blend produced the most acceptable beer according to both trained and untrained assessors. Trained panellists rated sorghum beer as slightly sweet, mild and smooth, with a good after-taste.

ETIM, M.U. and ETOKAKPAN, O.U. (1992)

Sorghum brewing using sweet potato enzymic flour to increase saccharification.

World Journal of Microbiology and Biotechnology, **8**(5): 509-511.

The possibility of using sweet potato β-amylolytic flour to complement that of sorghum during mashing was investigated. Substitution of sorghum malt with 20% (w/v) sweet potato gave a higher activity than sorghum malt alone. Maltose in the sorghum/potato wort was 50 mg/ml, similar to that in barley malt.

ETOKAKPAN, O.U. (1992)

Comparative studies of the β-D-glucan released into sorghum and barley worts.

Journal of the Institute of Brewing, **98**(4): 301-304.

Worts were prepared from two sorghum cultivars grown in Nigeria. Analysis of the β-D-glucan contents showed values five to seven times those in barley. Unlike barley, malting the sorghum resulted in increased release of β-D-glucan into the wort. It was concluded that although malted sorghum contains higher levels of β-glucan than unmalted sorghum, the former was preferable for brewing because of its superior flavour and amylolytic activity.

ETOKAKPAN, O.U. (1992)

Comparative studies of the degradation of non-starchy polysaccharides by sorghums and barleys during malting.

Journal of the Science of Food and Agriculture, **58**(1): 129-143.

The fate of the non-starchy polysaccharides in malting sorghums was investigated as these are the substances normally linked to filtration problems in barley. The β-D-glucan content of four sorghum varieties was not significantly reduced during malting. Pentosan level, while enhanced in barley during the same period, dropped in sorghum. Sorghums have very low β-D-glucan degrading endo-β-1-3,1-4-glucanase activity.

ETOKAKPAN, O.U. (1992)

Amylolytic potentials and wort fermenting components of Nigerian sorghums and barley.

World Journal of Microbiology and Biotechnology, **8**(3): 287-289.

The diastatic power of four improved Nigerian sorghum cultivars was due principally to α-amylolytic activity, unlike that of barley which came principally from β-amylolytic activity. The fermentability of sorghum worts ranged from 76 to 79% for the four cultivars, compared to 83% for barley. Maltose in the sorghum worts was about 15 mg/ml compared with 50 mg/ml in the barley wort. Maltotriose in the sorghum worts was 14-16 mg/ml while in barley, it was 11 mg/ml.

ETOKAKPAN, O.U. (1993)

Enzymic degradation and nature of the endosperm cell walls of germinating sorghums and barley.

Journal of the Science of Food and Agriculture, **61**(4): 389-393.

Enzyme extracts from germinated grains containing various β-glucanases were unable to hydrolyse the walls of sorghum to release sugars, but did so after the walls had been solubilized in alkali. Cellobiose accounted for 43% of the hydrolysates of the alkali-solubilized walls when incubated with sorghum malt enzymes, and 79% when barley enzymes were used. Preliminary evidence suggests that fuco-xyloglucan may contribute to the resistance of the sorghum endosperm cell walls to enzymic attack during germination.

ETOKAKPAN, O.U. and PALMER, G.H. (1990)

Comparative studies of the development of endosperm-degrading enzymes in malting sorghum and barley.

World Journal of Microbiology and Biotechnology, **6**: 408-417.

The malting of barley and sorghum was investigated. Malting barley produced endo-β-1,3:1,4-glucanase, endo-β-1,3-glucanase and pentosanase, while malting sorghum developed mainly endo-β-1,3-glucanase and pentosanase. The limited breakdown of the endosperm cell walls of sorghum may be due to sub-optimal activities of β-glucanases. The highly intractable nature and high protein content of sorghum endosperm cell walls may contribute to their low susceptibility to enzymic degradation during malting.

ETOKAKPAN, O.U. and PALMER, G.H. (1990)

A simple diamylase procedure for the estimation of α-amylase and diastatic activity.

Journal of the Institute of Brewing, **96**(2): 89-91.

A single enzyme extract of barley or sorghum malt was used for determination of both the total reducing power, and the reducing power produced by α-amylase alone, in a starch digest. Using commercial barley malts, 98 and 96% correlations were found between the results of this method and recommended methods. Results indicated that the saccharifying contribution of β-amylase was significantly greater in barley than in sorghum malts.

ETOKAKPAN, O.U. and PALMER, G.H. (1994)

Properties of endosperm cell walls isolated from unmalted and malted grains of barley and sorghum.

Process Biochemistry, **29**(7): 559-563.

The effects of malting on the properties of barley and sorghum cell walls were investigated. Enzymic breakdown of endosperm cell walls occurred faster in malted barley. Pentosans were the main polysaccharides lost from malting sorghum whereas in barley, it was the β-D-glucans. It is suggested that the release and degradation pattern of β-D-glucans in malting barley may be an important feature of grain quality, and a part of the controlling mechanism by which the endosperm food reserves are degraded enzymically during malting.

EVANS, D. J. and TAYLOR, J.R.N. (1990)

Extraction and assay of proteolytic activities in sorghum malt.

Journal of the Institute of Brewing, **96**(4): 201-207.

A systematic investigation of the extraction of proteolytic activities from sorghum malt, and their assay using kafirin as substrate, is reported. Extraction and purification of kafirin is described. Proteolytic activities of malt extracts and residues were measured by two assay methods. These assays determined proteinase and carboxypeptidase activities and addressed two of the problems associated with other assays, i.e., enzyme inextractability in NaCl solutions, and use of alien substrates.

EVANS, D. J. and TAYLOR, J.R.N. (1990)

Influence of cultivar and germination conditions on proteolytic activities in sorghum malt.

Journal of the Institute of Brewing, **96**(6): 399-402.

The effects of cultivar, steeping and germination conditions on sorghum malt proteinase and carboxypeptidase activities were studied. Results indicated that cultivar and germination conditions influenced both enzymic activities; steeping had no significant effect. There was no correlation between the proteinase and carboxypeptidase activities of the cultivars tested. Maximum enzymic activity was achieved by germination for four days at 24 °C with a medium level of moisture.

EZEOGU, L.I. and OKOLO, B.N. (1994)

Effects of final warm water steep and air-rest cycles on malt properties of three improved Nigerian sorghum cultivars.

Journal of the Institute of Brewing, **100**(5): 335-338.

The effects of a final warm water steep and air rest cycles on malting loss and other malt quality parameters were investigated for three improved cultivars of Nigerian sorghum; all three had good germinative energies (95-100%) and none were water-sensitive (1-2%). The effects of the final steeping on kernel growth, malting loss, diastatic power, α- and β-amylase, and malt extract, were significantly affected by air resting, cultivars, and pair-wise interactions of cultivars and steep regime. A final warm water steep without air resting led to a decrease in extract recovery and enzyme activity.

EZEOGU, L.I. and OKOLO, B.N. (1995)

Effects of rest periods on malting sorghum response to final warm water steep.

Journal of the Institute of Brewing, **101**(1): 39-45.

A combination of air rests and a final warm water steep can reduce sorghum malting losses and reduce rootlet growth while concomitantly increasing enzyme and extract levels. The effects of length of the air rest on the response of sorghum to the final warm water steep were investigated. All malt quality parameters evaluated were significantly affected by the length of air rest, by the sorghum cultivar, and by their pair-wise interaction.

FALI, C.N., DASMAK, D.A. and ATSUBU, V.A. (1990)

Production of amylases from rice (Oryza sativa) and hydrolysis of guinea corn (*Sorghum bicolor*), millet (*Pennisetum typhoides*) and barley using amylase produced.

Ghana Journal of Chemistry, **1**(3): 151-159.

Unmalted guinea corn, millet and barley were enzyme-hydrolysed using malted rice. Acid hydrolysis showed that hydrolysable sugar content was lower in malted samples than in unmalted ones. Crude protein analysis showed similar values for rice and barley, and amino acid analysis showed similar profiles for rice malted at 120 h and unmalted rice. Optimum malting time for rice was 88 h, and for millet and sorghum, 96 h.

FIGUEROA, J.D.C., MARTINEZ, B.F. and RIOS, E. (1995)

Effects of sorghum endosperm type on the quality of adjuncts for the brewing industry.

Journal of the American Society of Brewing Chemists, **53**(1): 5-9.

The performance of several genotypes of sorghum, corn, rice, and barley as adjunct materials was investigated. Wort viscosity of waxy sorghum and waxy corn adjuncts was lower than that of floury or starchy sorghum, rice, and barley malt. Waxy and hetero-waxy materials had shorter conversion times than normal sorghum. A significant correlation was found between gelatinization temperature and conversion time and wort viscosity. HPLC analyses revealed that the sugars present in sorghum, corn, rice and barley malt worts are fructose, glucose, maltose, maltotriose and maltotetraose. Peaks corresponding to glucose and fructose were absent, or only at trace

levels, in the chromatograms of diluted worts of waxy and hetero-waxy sorghum and waxy corn, which indicates that these adjuncts may produce a wort rich in complex carbohydrates and low in fermentable sugars.

GHANAKAR, A.R., BASARKAR, C.D. and NIMBKAR, N. (1992)

Potential and practice relating to sorghum as a source of sugar in parts of India.

pp. 139-142. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The potential for growing sweet sorghum in sugarcane-growing areas to help extend the processing season of the sugar factories is discussed. The major drawbacks and problems, namely low stalk yields, susceptibility to pests, uneven maturation and perishability of the crop, are examined, and attempts to overcome these are reviewed.

GOMEZ, M.I. (1993)

Malting quality of southern African grain sorghums.

Sorghum Newsletter, **34**: 54.

A total of 120 improved white, red and brown sorghums with varying grain hardness were evaluated. Diastatic activity ranged from 9 to 69.5 sorghum diastatic units. A significant negative correlation existed between sorghum diastatic units and grain hardness, in contrast to the positive correlation between sorghum diastatic units and colour. Red and brown grains had higher sorghum diastatic units than white grains and also required longer steeping times during malting because of their harder texture.

HALLGREEN, L., REXEN, P.B., PETERSON, P.B. and MUNCK, L. (1992)

Industrial utilization of whole crop sorghum for food and industry.

pp. 121-130. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The increasing importance of balanced production of sorghum for food, feed and selected industrial products in developing countries is discussed. The use of sorghum in the production of cellulose and starch for paper and chemicals, as a source of energy, for livestock feed, and as a raw material for many food industries, is also examined.

HORN, C.H., PREEZ, J.C. and KILIAN, S.G. (1992)

Fermentation of grain sorghum starch by co-cultivation of *Schwanniomyces occidentalis* and *Saccharomyces cerevisiae*.

Bioresource Technology, **42**(1): 27-31.

Ethanol fermentations were carried out, using a stationary phase culture of *Schwanniomyces occidentalis* in conjunction with *Saccharomyces cerevisiae*, to ferment liberated sugars from grain sorghum starch by *Schwanniomyces occidentalis* amylases. Increasing the grain sorghum concentration from 8 to 28% (m/v) did not affect the final ethanol yield, although the fermentation

rate decreased considerably. A 28% grain sorghum slurry yielded 12.5% (w/v) ethanol, indicating that nearly 390 litres of ethanol could be produced/tonne grain sorghum.

IKEDIOBI, C.O. (1990)

Industrial production of sorghum malt in Nigeria.

p. 32. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

Recent developments in the Nigerian sorghum malting enterprise are reviewed. The malting process, the desirable properties of sorghum for malting, and the problems encoutered during industrial malting, are noted.

ILORI, M.O. and ADEWUSI, S.R.A. (1991)

Effect of ammonia on the malting losses of some improved Nigerian sorghum varieties.

Journal of the Institute of Brewing, **97**(2): 111-113.

The effect of steeping two Nigerian sorghum varieties in liquor containing ammonia was investigated. Steeping in 0.1N ammonia for 0-18 h reduced malting losses, primarily due to prevention of acrospire growth. However, mould growth was not inhibited and enzyme activity, and cold and hot water extracts of the malt, were significantly decreased by this treatment. Ammonia treatment may be useful for minimizing malting losses if additional enzymes are added during malt processing.

ILORI, M.O., AKINGBALA, J.O., OGUNTIMEHIN, G.B. and OGUNDIWIN, J.O. (1990)

Effect of grain bed thickness, duration of steeping and germination on the malting properties of improved Nigerian sorghum varieties.

Lebensmittel Wissenschaft und Technologie, **23**(6): 505-512.

Seven improved Nigerian sorghum cultivars were steeped for up to 48 h to determine the effect of duration of steeping on water uptake, germination energy and germination capacity; they were then germinated to determine the effect of duration on malting properties. Water uptake, germination energy and germination capacity increased with steeping time to optimum values when seeds were steeped for 18 h. Malting losses and malt colour increased as did diastatic power, cold and hot water extract and sugar contents which were optimum in grain germinated for 96-108 h.

ILORI, M.O., AKINGBALA, J.O., OGUNTIMEHIN, G.B. and OGUNDIWIN, J.O. (1990)

Adaptation of a conventional mashing profile for barley malt to sorghum malt.

Lebensmittel Wissenschaft und Technologie, **24**(1): 29-33.

The temperature-programmed mashing profile for barley malt was adapted to produce beer of acceptable quality using only the endogenous enzymes of sorghum malt during the brewing process. Sorghum and commercial beer were similar in terms of apparent extract, real extract, extract of original

wort, alcohol content, colour, titratable acidity, pH, total sugar, and percentage fermentation. There were no significant differences in mouthfeel, flavour, aroma and overall acceptibility between the commercial and sorghum beers.

ILORI, M.O., FESSEHATZION, B., OLAJUYIGBE, B.O., BABALOLA, G.O. and OGUNDIWIN, J.O. (1991)

Effect of malting and brewing processes on the micro-organisms associated with sorghum grains and malt.

Technical Quarterly, Master Brewers' Association of the Americas, **28**(2): 45-49.

Microbial loads of two Nigerian improved sorghum cultivars popular in the brewing industry were determined by pour plate techniques. All bacteria and fungi found in the grain reoccurred in malted grain, indicating that kilning did not destroy them. None of the micro-organisms withstood wort cooking. Bitter leaf extract used as a hop substitute had no inhibitory effect on yeast activity. There is a need for chemical treatment of grain to prevent microbial contamination during malting.

ILORI, M.O., OGUNDIWIN, J.O. and ADEWUSI, S.R.A. (1991)

Sorghum malt brewing with sorghum/maize adjuncts.

Brewing and Distilling International, **22**(3): 10-13.

The effect of additions of sorghum flour or maize grits on brewing quality of Nigerian malted sorghum beer was investigated. The sorghum malt and 20% maize grits mix produced a beer comparable with commercial beer, while the sorghum malt/sorghum flour brew had lower original extract and alcohol content. Both sorghum beers met Nigerian standards, and there were no significant differences in organoleptic properties between sorghum beer and commercial beer

KARVE, A.D. (1993)

Potential for sweet sorghum in Asia.

pp. 16-18. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

The potential for the production of sweet sorghum in Asia in both the tropical and sub-tropical regions is reviewed, and its characteristics, processing, small-scale syrup production and research needs are discussed.

KRISHNAVENI, S., BALASUBRAMANIAN, T. and SADASIVAM, S. (1990)

Potentiality of sweet sorghum (*Sorghum bicolor,* Poaceae) for syrup preparation and alcohol production in India.

Economic Botany, **44**(3): 355-359.

Thirty-eight different cultures of sweet sorghum were screened for sugar content and distribution, syrup preparation, and alcohol production. A highly positive correlation was found between total sugars and sucrose. Chickpea and peanut candies prepared from syrup of 73°Brix resembled those prepared from jaggery. Sweet sorghum syrup may serve as a good substitute for jaggery.

LAI, M.N., CHANG, F.W. and WANG, H.H. (1991)

Application of pseudo-steady state heat conduction model for solid state fermentation of sorghum mash.

Journal of the Japanese Society for Food Science and Technology, **38**(3): 226-234.

A one-dimensional, pseudo-steady heat conduction model was developed and applied to investigations of heat transfer characteristics in solid state fermentation of sorghum mash. The heat conduction model was used to optimize the radius and packed bulk of the bioreactors at surface temperature of 10-25 °C.

LAI, M.N., WANG, H.H., SHIEH, T.C. and CHANG, F.W. (1995)

Improvement of sorghum brewing by a rectangular bioreactor.

Proceedings of the National Science Council, Republic of China, Part B:Life Sciences, **19**(1): 58-65.

A rectangular type bioreactor with a cooling system was used to scale up a new sorghum brewing process from 0.6 tons to 8 tons. The newly designed bioreactor improved sorghum brewing, and it is suggested that consideration be given to the thermal conductivity of solid mashes when designing such bioreactors.

LASEKAN, O.O. (1991)

A preliminary study of the comparative malting qualities of *Sorghum bicolor* and *Sorghum guineensis.*

Food Chemistry, **39**(3): 241-247.

Malting qualities of *S. bicolor* and *S. guineensis* grown in the same field were studied. *S. bicolor,* which exhibited a significantly higher moisture content than S. guineensis, also had a significantly higher protein content, malting loss, enzyme activity and acrospire length. No significant differences were observed in sugar and diastatic activity. Variations in sedimentation rates, moisture contents, protein contents, apparent extracts, and cold and hot water extracts of the sorghum malts are discussed.

LASEKAN, O.O. (1993)

Effect of malt milling energy, sedimentation rates and diastatic power measurement in sorghum selection.

Food Chemistry, **46**(4): 415-417.

Sedimentation rates, diastatic power measurements and electrical energy required to mill samples of sorghum malts were determined in 10 cultivars. Samples with low milling energy ranked highly in sedimentation and diastatic power measurements. Significant negative correlations were obtained between milling energy and sedimentation rate, and between milling energy and diastatic power measurement.

LASEKAN, O.O., IDOWU, M.A. and LASEKAN, W. (1995)

Effect of germination and degree of grind (coarse/fine) on the extract and sugar contents of sorghum malts.

Food Chemistry, **53**: 125-128.

Two sorghum cultivars were macro-malted separately for two, four and six days, and milled into coarse and fine flours. The hot water extract, diastatic activity and sugar contents were increased by an extended malting period and finer milling. While diastatic activity, residual starch and sugar content were highly positively correlated for both types of grind, the hot water extract showed significant differences.

LEZINOU, V., CHRISTAKOPOULOS, P., KEKOS, D. and MACRIS, B.J. (1994)

Simultaneous saccharification and fermentation of sweet sorghum carbohydrates to ethanol in a fed-batch process.

Biotechnology Letters, **16**(9): 983-988.

The simultaneous saccharification and fermentation of sweet sorghum was studied. Under optimum conditions, ethanol yields and concentrations were 29.7 g/100g and 7.5% (w/v), respectively. These values, coupled with the high yield of the crop in Greece, make the process worthy of further investigation for the production of bioethanol.

LEZINOU, V., CHRISTAKOPOULOS, P., LI, S.W., KEKOS, D. and MACRIS, B.J. (1995)

Study of a single and mixed culture for the direct bio-conversion of sorghum carbohydrates to ethanol.

Applied Microbiology and Biotechnology, **43**(3): 412-415.

Fusarium oxysporum, alone or in mixed culture with *Saccharomyces cerevisiae,* fermented soluble and insoluble carbohydrates of sweet sorghum stalk directly to ethanol. As ethanol yields were high and a large proportion of insoluble carbohydrate was converted to ethanol, the process looks promising for bioethanol production.

MALOMO, O. (1990)

Sorghum in lager beer production: progress and prospects.

p. 30. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The status, developments and problems of using sorghum in the Nigerian brewing industry are reviewed.

MELOTTE, L., IGUTI, F., RAOULT, G. and DUFOUR, J.P. (1992)

The protein content of sorghum grain.

pp. 106-116. In: *Proceedings of the Fifth Quadrennial Symposium on Sorghum and Millet (at the Ninth International Cereal and Bread Congress), June 1992, Paris.* Vienna, Austria: International Association for Cereal Science and Technology (ICC).

A procedure for classifying sorghum proteins was established that allows good protein recovery and solubilization. The protein composition of several sorghum cultivars was compared with that of millet and barley.

MSANGULA, E.C. (1993)

Constraints on the expansion of sorghum use by Danbrew (KIBUKU).

pp. 103-104. In: *National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development, May 1993, Arusha International Conference Centre.* MINDE, I.J. and ROHRBACH, D.D. (eds). Arusha, Tanzania: Sokoine University of Agriculture.

The constraints to sorghum utilization by the opaque beer industry are examined, and the continued use or replacement of ingredients previously favoured, such as artificial caramels, emulsifiers and stabilizers, is discussed.

OGBONNA, A.C. (1992)

Developments in the malting and brewing trials with sorghum.

World Journal of Microbiology and Biotechnology, **8**(2): 87-91.

This review highlights research efforts aimed at alleviating the problems associated with the use of sorghum as a brewing material. A comparative study of sorghum and barley grains revealed structural and physiological differences responsible for the observed differences in malting characteristics. Reports on brewing trials with sorghum favour its use as an adjunct to barley malt. The discovery of Nigerian grown sorghum varieties with improved β-amylase activity, as well as high diastatic power, will ensure better fermentable extracts.

OGBONNA, A.C. and EGUNWU, A.L. (1994)

β-Glucan degradation in malting sorghum.

World Journal of Microbiology and Biotechnology, **10**(5): 595-596.

β-Glucan degradation during malting of four Nigerian sorghum varieties was studied. In all four varieties, β-glucan contents decreased by more than 50% after two days' malting time. Varieties with lowest β-glucan concentration produced 120 ml filterable volume of sweet wort after 2 h; the varieties with the highest β-glucan concentration produced only 26 ml.

OGBONNA, A.C. and OBI, S.K.C. (1992)

Use of raphia palm wine yeast strains in sorghum beer brewing.

Journal of the Institute of Brewing, **98**(4): 339-343.

The possibility of using yeast isolates from raphia palm wine for the production of beer using a mixture of sorghum (70%) and barley (30%) malts was investigated. Properties of such beers were compared with those produced using *Saccharomyces carlsbergensis.* Results suggest that *Saccharomyces* strains isolated from palm wine could be used in the brewing of beer, and that substitution of barley malt with sorghum malt (up to 70%) produces beers of comparable quality.

OGUNDIWIN, J.O. and ILORI, M.O. (1991)

Development of stout from sorghum malt.

Lebensmittel Wissenschaft und Technologie, **24**(2): 182-185.

Processing parameters, and physical, chemical and sensory characteristics, were established for sorghum stout using bitter leaf extract and residue as hop substitutes for flavouring. Samples flavoured with 30 g of extract or resi-

due had a slightly darker colour and were rated best in terms of flavour. Apparent percentage of fermentation, pH and titratable acidity of all samples were the same, indicating that the plant has economic potential in the brewing industry in Nigeria.

OGUNDIWIN, J.O., ILORI, M.O., FESSEHATZION, B., BABALOLA, G.O. and OLAJUYIGBE, A.O. (1991)

Effect of chemical treatments on the micro-organisms associated with malting of sorghum grains and sorghum malts.

Journal of Applied Bacteriology, **71**(2): 139-143.

The effect of five chemical preservatives on the micro-organisms associated with sorghum grain and malts was investigated. Sorbic acid, sodium benzoate, nisin, formaldehyde and lime at various concentrations did not adversely affect the malting properties of sorghum grain. Only formaldehyde and lime were sufficiently effective at maximum practicable concentrations to control microbial contamination during malting.

OGUNDIWIN, J.O., ILORI, M.O. and OKELAYE, A. (1990)

Brewing of clear beer from sorghum grains of SK5912 variety without addition of external enzymes to achieve saccharification: a case study.

p. 31. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The quality of products from malting and brewing grains on an industrial scale, without the addition of synthetic enzymes for complete saccharification, is reported. Properties of sorghum malt were, in general, poor compared to barley malt, but wort quality compared favourably. However, malt mashing took longer. Physicochemical properties of sorghum beer were all within acceptable limits of commercial lager beer, and organoleptic properties were acceptable to tasters.

OKOH, I.A., BABALOLA, G. O. and ILORI, M.O. (1995)

Effect of methanol extract of *Vernonia amygdalina* on malting and brewing properties of sorghum

Technical Quarterly, Master Brewers' Association of the Americas, **32**(1): 11-14.

The effects of an extract from the vegetable, bitter leaf (*Vernonia amygdalina*), which is known to have anti-microbial activity, on the brewing properties of sorghum were investigated. Steeping of sorghum grains in water containing 30 mg/ml bitter leaf extract for 18 h reduced the microbial load, but fungi were unaffected. It is concluded that bitter leaf extract can be used as an anti-bacterial agent during sorghum malt processing without any deleterious effect on beer quality.

OLATUNJI, O., JIBOGUN, A.C., ANIBABA, T.S., OLIYIDE,V.O., ONIWINDE, A.B. and KOLEOSO, O. (1993)

Effect of different mashing procedures on the quality of sorghum beer.

Journal of the American Society of Brewing Chemists, **51**(2): 67-70.

Lager was produced from 100% sorghum using three different mashing procedures. Physical, chemical and sensory analysis of the beers produced showed that all three methods yielded good quality beer which compared favourably with commercial brands. Comparative assessment of the procedures showed that gelatinizing the starch before the addition of enzyme gave the best result when compared with existing brands of beer.

OWUAMA, C.I. and ASHENO, I. (1994)

Studies on malting conditions for sorghum.

Food Chemistry, **49**(3): 257-260.

The effects of kilning temperature on moisture, protein and sugar contents of sorghum malts produced from grains steeped for different periods were determined. The non-reducing sugar values varied with kilning temperature and sorghum variety. The percentage moisture content of malt in all varieties increased with reducing sugar and differed with kilning temperature. The percentage protein content of the malts increased with steeping time at all kilning temperatures.

OWUAMA, C.I. and OKAFOR, N. (1987)

Studies on mashing methods for beer brewing with sorghum.

Journal of Applied Microbiology and Biotechnology, **3**(3): 243-253.

The influence of different parameters in the three-stage decoction and infusion mashing methods on the quality of sorghum malt extract of two cultivars for brewing was studied. The effects of holding time at different saccharifying temperatures were monitored by wort analysis. Increase in mash concentration led to an increase in reducing sugars. A longer holding time increased reducing sugars for upward infusion and had little effect on downward infusion, without causing significant changes in protein content.

OWUAMA, C.I. and OKAFOR, N. (1990)

Use of unmalted sorghum as a brewing adjunct.

World Journal of Microbiology and Biotechnology, **6**(3): 318-322.

Hydrolysis of three varieties of unmalted sorghum by endogenous amylases produced sufficient maltose and glucose for subsequent brewing of beer. The optimal temperature and pH of amylase activity varied, but optimal α-amylase activity was between about 72 °C and 75 °C for all three sorghum varieties.

PALMER, G.H. (1991)

Enzymic degradation of the endosperm cell walls of germinated sorghum.

World Journal of Microbiology and Biotechnology, **7**(1): 17-21.

White sorghum grains were soaked and germinated. In the malted grain, holes were present in the endosperm cell walls and amylolytic pitting of the starch granules occurred. It was proposed that amylolytic and proteolytic enzymes enter the endosperm through the holes in the cell walls and hydrolyse starch granules and associated storage proteins. These holes may be produced by proteolytic enzymes.

PALMER, G.H. (1992)

Sorghum - food, beverages and brewing potential.

Process Biochemistry, **27**: 145-153.

The potential of sorghum in the food, beverage and brewing industries is reviewed. It is concluded that sorghum could play a pivotal role in agricultural improvement in some of the poorest countries of the world, if relevant scientific work was carried out to produce the yield, quality and knowledge required by locally-based industries.

RASCHKE, A.M., TAYLOR, J. and TAYLOR, J.R.N. (1995)

Use of falling number and rapid visco analyser instruments to estimate sorghum diastatic power.

Journal of Cereal Science, **21**: 97-102.

Diastatic power is the most important quality criterion of sorghum malt and there is a need for a rapid method to estimate quality. Methods have been developed, using falling number and rapid visco-analyser instruments, which give good estimates of the diastatic power with malts prepared from a single cultivar, but which are less good for those prepared from different cultivars.

RATNAVATHI, C.V. and RAVI, S.B. (1991)

Effect of different durations of steeping and malting on the production of α-amylase in sorghum.

Journal of Cereal Science, **14(3)**: 287-296.

Optimal steeping and germination times for the development of α-amylase in different sorghum genotypes were identified, and regression between α-amylase activity and diastatic activity was established. Optimal malting conditions for comparative evaluation of diverse sorghum cultivars were a steeping time of 20 h and a germination time of 96 h.

REY, J.P., POUSSET, J.L., LEVESQUE, J. and WANTY, P. (1993)

Isolation and composition of a natural dye from the stems of *Sorghum bicolor* (L.) Moench subsp. *americanum caudatum.*

Cereal Chemistry, **70**(6): 759-760.

A simple process for the isolation of natural dye from sorghum stems is described. The process yields 20% dry material and can be extrapolated to an industrial scale for use in the food and cosmetic industries. The dye was found to contain the major anthocyanidin, apigeninidin (17% of extract).

ROBBINS, D.J. and EGAN, B. (1992)

Failure of mercuric chloride to selectively inhibit β-amylase in sorghum malt.

Journal of the Institute of Brewing, **98**(5): 383-385.

The use of mercuric chloride for the determination of a-amylase activity in eight sorghum malts was investigated. Results suggest that mercuric chloride is an unsuitable reagent for this purpose.

RUFFELL, P.L. and TRINDER, D.W. (1990)

A mini-column screening test for aflatoxin in sorghum malt.

Journal of the Institute of Brewing, **96**: 7-10.

The development of a mini-column screening test for aflatoxins in sorghum malt is described. The method is based on a silica cartridge clean-up of a chloroform extract of malt, followed by detection by means of an alumina/ Florisil mini-column. It is concluded that the method is rapid, economical, more sensitive than published methods and suitable for use by semi-skilled personnel. It is recommended for industrial use, provided that positive samples are confirmed by conventional analysis.

SAVICH, I.M. and ZHOLDASPAEVA, G.M. (1994)

Proteolytic cleavage of sorghum grain proteins.

Applied Biochemistry and Microbiology, **29**(6): 665-670.

A solid-phase universal micro-method for the estimation of proteolysis was used to analyse proteolysis of sorghum grain proteins from samples of varying tannin content. Cluster analysis was used to separate samples according to protein digestibility, and it was possible to differentiate between cultivars according to this trait. The tannin content of different sorghum cultivars affected their susceptibility to proteolysis.

SCHAFFERT, R.E. (1992)

Sweet sorghum for industrial alcohol.

pp. 131-137. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The potential use of sweet sorghum as a substrate for the production of industrial alcohol in Brazil is reviewed and research priorities are noted. The integrated use of sweet sorghum for alcohol production, and for food, feed and forage, is discussed.

SMITH, G.A. and BUXTON, D.R. (1993)

Temperate zone sweet sorghum ethanol production potential.

Bioresource Technology, **43**(1): 71-75.

Crop and sugar yields of four sorghum cultivars at two temperate locations were studied in relation to N fertilizer dose (0, 84 or 186 kg/ha). Results showed that sweet sorghum can be grown without N fertilizer in diverse conditions, reliably giving a fairly high sugar/ethanol yield on land marginal for food production. It thus has considerable potential as an energy crop, producing fuel ethanol unaffected by fluctuations in maize prices.

SOLOMAN, B.O., LAYOKUN, S.K., IDOWU, A.O. and ILORI, M.O. (1994)

Prospects for the utilization of the endogenous enzymes in sorghum malt in the hydrolysis of starch: case study with utilization of breadfruit starch for ethanol production.

Food Biotechnology, **8**(2,3): 243-255.

Hydrolysis of breadfruit flour by acid and enzymes of sorghum malt was investigated. The results showed that the enzymes could be used, with supplementation, to hydrolyse starch and yield appreciable amounts of sugar which can be used as a sweetener, a substrate for single cell protein production, and in the production of beverages.

SOMANI, R.B. and PANDRANGI, R.B. (1993)

Alternatives uses of sorghum.

pp. 6-11. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers' Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

Alternative uses of sorghum in India are reviewed. Its consumption as a food is declining as demand for rice and wheat increases. The technology required for the production of starch, sugars, alcohol, beer and malt products from sorghum is discussed.

SUBRAMANIAN, V., HOSENEY, R.C. and BRAMEL-COX, P. (1994)

Factors affecting the colour and appearance of sorghum starch.

Cereal Chemistry, **71**(3): 275-278.

Seven cultivars of sorghum with various seed colours were studied for the presence of light-absorbing substances in the grain and starch. Dullness in sorghum starch appeared to be related to certain alcohol-insoluble components. Dehulling before starch extraction improved colour. A simple alkali test was effective in predicting the dullness of starch.

SUBRAMANIAN, V. and JAMBUNATHAN, B. (1990)

Industrial products from sorghum.

p. 40. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The potential for using sorghum industrially to produce starch, sugars, beverages, alcohols, chemicals, cellulose and papers is reviewed. Increased utilization would benefit farmers by increasing demand for raw materials, and help economies by reducing the need for imports.

SUBRAMANIAN, V., MURTY, D.S., RAO, N.S. and JAMBUNATHAN, R. (1992)

Chemical changes and diastatic activity in grains of sorghum (*Sorghum bicolor*) cultivars during germination.

Journal of the Science of Food and Agriculture, **58**(1): 35-40.

Grain samples from nine sorghum cultivars were germinated for 16, 48, 96 and 144 h and changes in their diastatic activity, protein, starch, soluble sugars, tannin and phenol content noted. Diastatic activity increased up to 96 h of germination, then decreased; it showed significant variation among cultivars. Starch content decreased while soluble sugars increased during germination.

SUBRAMANIAN, V., RAO, N.S., JAMBUNATHAN, R., MURTY, D.S. and REDDY, B.V.S. (1995)

The effect of malting on the extractability of proteins and its relationship to diastatic activity in sorghum.

Journal of Cereal Science, **21**: 283-289.

Diastatic activity, protein content and water-extractable contents in malted grains of several sorghum cultivars varied widely. The data suggest that water-extractable components are good indicators for predicting diastatic activity and indirectly, malting quality. Water-extractable determination is a simple and rapid method of screening large numbers of cultivars for malting quality.

SWANSTON, J.S., RAO, N.S., SUBRAMANIAN, V. and TAYLOR, K. (1994)

The influence of some aspects of grain quality on malting potential in sorghum.

Journal of Cereal Science, **19**: 91-97.

Several grain and malt quality tests were applied to 22 sorghum cultivars. Significant differences were found in all cases. All white and yellow grains showed a relationship between milling energy and extract and nitrogen content. Grains with a high level of extract also showed a higher grinding resistance. This was related to the greater degree of starch damage, facilitating better solubility and overcoming problems of poor endosperm modification and high gelatinization temperatures during malting.

SWANSTON, J.S., TAYLOR, K. and MURTY, D.S. (1992)

Grain and malt milling energies in sorghum and their relationships with extract and diastatic power.

Journal of the Institute of Brewing, **98**(2): 129-131.

Grain milling energy did not indicate likely malting performance of sorghum samples. Close relationships were observed between malt milling energy and both percentage extract and diastatic power when samples with unusually high or low grain nitrogen contents were excluded. Rapid screening of very small malt samples for milling energy and diastatic power could form the basis of malting quality selection in early generations of sorghum breeding programmes.

SWANSTON, J.S., TAYLOR, K., RAO, N.S., SUBRAMANIAN, V. and MURTY, D.S. (1993)

The use of rapid screening tests to compare changes during malting in sorghum.

Journal of the Institute of Brewing, **99**(6): 483-486.

Rapid screening tests (hot water extract, diastase activity, malt milling energy, soluble N and half grain mash percentage) for comparing changes in sorghum during malting were investigated. Up to 35% of N solubilization during malting occurred in the steeping phase. Extracts ranged from very low to high levels after five days of germination and correlated highly with diastase

and half-grain mash results. Greater reductions in milling energy were observed between two and five days of germination in genotypes producing higher extract level.

TAYLOR, J.R.N. (1992)

Mashing with malted grain sorghum.

Journal of the American Society of Brewing Chemists, **50**(1): 13-18.

Sorghum beer mashing was performed with a large quantity of cooked starchy adjunct. Some of this adjunct starch is not saccharified and contributes to the opaque character of traditional sorghum beer. The properties of sorghum malt apparently enable mashing at elevated temperature to produce worts rich in nutritionally-desirable, complex carbohydrates and low in fermentable sugars. It is suggested that sorghum malt could be used to produce novel low-alcohol beers.

TAYLOR, J.R.N. and DEWAR, J. (1992)

Sorghum malting technology.

pp. 55-72. In: *Proceedings of the Fifth Quadrennial Symposium on Sorghum and Millet (at the Ninth International Cereal and Bread Congress), June 1992, Paris.* Vienna, Austria: International Association for Cereal Science and Technology (ICC).

The technology of sorghum malting, and the relative merits of two commonly used processes, floor malting and pneumatic malting, are described. Malt produced pneumatically is of significantly superior quality due to better control; it is, however, capital intensive. Research in South Africa has resulted in the development of an outdoor malting technology enabling better control of the malting conditions.

TAYLOR, J.R.N. and DEWAR, J. (1992)

Role of α-glucosidase in the fermentable sugar composition of sorghum malt mashes.

Journal of the Institute of Brewing, **100**(6): 417-419.

The fermentable sugar composition of sorghum malt worts, and the effects of mashing processes on wort fermentable sugars, were investigated. It was concluded that sorghum α-glucosidase is highly insoluble in water and its activity is associated with insoluble solids. Pre-cooking of sorghum malt insoluble solids inactivates α-glucosidase, thus preventing the hydrolysis of maltose to glucose and producing a malt wort similar to barley malt wort.

TAYLOR, J.R.N. and DEWAR, J. (1993)

Sorghum brewing co-operation growing in southern Africa.

Food Industries, **46**(4): 19, 22.

The use of unmalted maize or sorghum in brewing is discussed with reference to the following: sorghum brewing properties (low degree of protein modification, low levels of diastase); developments in sorghum brewing science; sorghum brewing in South Africa; and education and training initiatives in sorghum brewing.

TAYLOR, J.R.N. and ROBBINS, D.J. (1993)

Factors influencing β-amylase activity in sorghum malt.

Journal of the Institute of Brewing, **99**: 413-416.

Factors affecting β-amylase activity in sorghum were investigated using two direct enzyme assays. Results suggested that β-amylase activity in ungerminated sorghum grain was negligible, and in malted sorghum, less than 25% that of barley malt. Increased β-amylase activity in sorghum malt was associated with increased germination time and high germination moisture content; a germination temperature of 24 °C was associated with highest activity. A significant correlation was observed between β-amylase activity and diastatic power of sorghum malts.

TIISEKWA, B.P.M. and LASWAI, H.S. (1993)

Evaluation of suitability of sorghum and finger millet in the manufacture of opaque and clear beer.

pp. 105-119. In: *National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development, May 1993, Arusha International Conference Centre.* MINDE, I.J. and ROHRBACH, D.D. (eds). Arusha, Tanzania: Sokoine University of Agriculture.

The use of sorghum and millet in the manufacture of opaque beer is evaluated in terms of the biochemical and chemical transformations required in the malt and cereal adjuncts. These transformations occur mainly during the mashing process. The results suggest that both sorghum and millet are potentially useful; the implications are discussed.

UGBOAJA, F.C., BEDNARSKI, W. and BABUCHOWSKI, A.. (1991)

The technology and properties of beer produced from unmalted sorghum or maize grains.

World Journal of Microbiology and Biotechnology, **7**(2): 225-230.

Samples of beer were produced with various brewing adjuncts, and unmalted grains, malt, wort and beer were analysed. Results indicated that use of 15-25% maize or 25% sorghum increased the contents of iso-compounds in the wort. During mashing, the saccharification period was three times longer in samples containing sorghum; filtration of both wort and beer was also slow in these samples. Wort containing 15% maize grits and 10% sucrose had the light colour most preferred. Beers containing up to 25% of the tested adjuncts were not inferior in quality to controls.

VERBRUGGEN, M.A., VORAGEN, A.G.J. and HOLLEMANS, M. (1992)

Enzymic degradation of a glucuronoarabinoxylan from sorghum.

pp. 38-44. In: *Proceedings of the Fifth Quadrennial Symposium on Sorghum and Millet (at the Ninth International Cereal and Bread Congress), June 1992, Paris.* Vienna, Austria: International Association for Cereal Science and Technology (ICC).

The isolation of water-unextractable cell wall material from sorghum, and the extraction of glucuronoarabinoxylan-rich fraction from these materials, is briefly discussed. Some structural characteristics of the fraction are described. A hypothetical structure based on the composition of the sugar and glycosidic linkage has been constructed.

WAESBERGHE, J.W.M. (1990)

Sorghum mash separation on thin bed filter.

Brauwelt International, **2**: 125-126.

Developments in thin bed mash filters for use in breweries are discussed. Topics include: the design of the filters; the sparging pattern; filtration performance (compared to conventional filters); factors of importance for efficient mash filtration; and application of this system to filtration of sorghum mash.

WELBORN, R.E. (1991)

Control scheme for sorghum conversion.

Brewing and Distilling International, **22**(3): 15.

A cereal conversion scheme for producing glucose syrups from sorghum, rather than from malted barley, is outlined. Critical control requirements at the plant at Cadbury, Nigeria, include: milling ratio of fines to husk; batch weighing of grist; control of mashing, liquor volume, temperature and rate of addition; addition of extra enzymes and determination of associated temperature profiles during wort separation; and control of wort separation steps.

WENZEL, W.G. and PRETORIUS, A.J. (1995)

The genetic variability of malt quality and related characteristics in grain sorghum.

South African Journal of Plant and Soil, **12**(1): 38-41.

The genetic variability of diastatic power was investigated, and its relationship with rate of moisture uptake during steeping and malting, malt mass, and endosperm texture, was analysed. For diastatic power and other characteristics, the observed components of variation indicated a lack of genetic variability. Selection for malt mass should be a useful tool for increasing the diastatic power of the sorghum grain as it is a much simpler and cheaper screening method for potential diastatic power.

WORLEY, J.W. and CUNDIFF, J.S. (1992)

System analysis of sweet sorghum harvest for ethanol production in Piedmont.

Transactions of the American Society of Agricultural Engineers, **34**(2): 539-547.

Three systems for harvesting and processing sweet sorghum stalks to produce juice for fermentation to ethanol were compared using computer simulation. The costs are estimated at US$ 0.56, 0.63 and 0.87/litre of potential ethanol for Systems A, B and C, respectively. System A involves a whole crop harvester which cuts the stalks and collects them into bundles. System B uses a hypothesized combine which removes the pith fraction from the stalks. The third System, C, is a combination of A and B.

WORLEY, J.W. and CUNDIFF, J.S. (1992)

Ethanol from sweet sorghum: a comparison of four harvesting/processing systems.

pp. 40-49. In: *Proceedings of the Alternative Energy Conference, Nashville, Tennessee, US, December 1992.* St Joseph, Michigan, US: American Society of Agricultural Engineers.

Four systems for harvesting and processing sweet sorghum to produce ethanol were compared using simulations. Costs for the four systems were: forage chopper, US$ 0.27/litre; forage chopper with juice expression, US$ 0.26/litre; pith combine, US$ 0.37/litre; and whole-stalk storage, US$ 0.41/litre. When compared with the cost of cellulosic feedstocks, sweet sorghum does not appear to be competitive under any of the harvesting/processing options considered in this study.

WORLEY, J.W., CUNDIFF, J.S. and VAUGHAN, D.H. (1990)

Economic valuation of by-products of sweet sorghum for ethanol industry.

American Society of Agricultural Engineers, **90**: 6559-6577.

The economic value of sweet sorghum when used for cattle feed, paper production, cellulose conversion to ethanol, and direct combustion, was determined. Values ranged from US$ 318/ha for cattle feed to US$ 129/ha for cellulose conversion.

6 ANIMAL FEEDS AND FORAGE

ADUKU, A.O. (1990)

Utilization of sorghum grains in livestock feeds.

p. 44. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The potential of, and problems associated with, using sorghum grain in commercial animal feeds were reviewed. The literature suggests that grain sorghum is approximately equal to maize as a feed grain for most classes of livestock. Methods for detoxification of tannins, processing of grain for livestock, and utilization for poultry, rabbit, swine and ruminants, are reviewed.

ALHASSAN, W.S. (1990)

The potential of sorghum straw as a livestock feed in Nigeria.

p. 43. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

Studies on the feeding value of 13 cultivars showed that the high cell wall content, especially of lignin, affected the *in vitro* organic matter digestibility of sorghum straw. Methods for utilizing straw for residue grazing, and stall-feeding of supplemented, treated or untreated straw, were reviewed.

AMIRA, C.D. (1992)

Small grains in monogastric and ruminant feed formulations: prospects and problems.

pp. 183-190. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

The animal feed industry in Zimbabwe is examined, literature on the use of small grains within the livestock industry is reviewed, and recommendations on the use of products from these grains in commercial feeding are given. Poor utilization is attributed to several factors including pricing, poor protein content and cost of processing.

ASELTINE, M. (1993)

Sorghum grain a suitable alternative for grain by-product mixtures in diet.

Feedstuffs, **65**(10): 12.

The feeding of steam-flaked sorghum grain had a beneficial effect on milk yield and milk composition in Holstein cows. Depending on the cost of other available high-energy feedstuffs, sorghum grain processed by steam-flaking could be a suitable alternative to grain by-product mixtures at low levels (15% of diet) if highly processed, or substituted at high levels (30-40% of diet) if moderately processed.

BEN GHEDALIA, D., MIRON, J. and SOLOMON, R. (1993)

The degradation and utilization of structural polysaccharides of sorghum straw by defined ruminal bacteria.

Animal Feed Science and Technology, **42**(3/4): 283-295.

Cell wall preparations of untreated sorghum straw and sulphur dioxide-treated straw were used as substrates for the solubilization and utilization of carbohydrates by pure cultures, or pair-combinations, of defined rumen bacterial strains. Results are presented and discussed.

BRANDT, R.T., Jr, KUHL, G.L., CAMPBELL, R.E., KASTNER, C.L. and STRODA, S.L. (1992)

Effects of steam-flaked sorghum grain or corn and supplemental fat on feedlot performance, carcass traits, longissimus composition and sensory properties of steers.

Journal of Animal Science, **70**(2): 343-348.

Crossbred steers were fed on steam-flaked sorghum or maize with 0 or 4% yellow grease for 100 days. Performance, and estimated dietary net energy for maintenance and net energy for gain values, did not differ between feeds. Beef produced from sorghum grain is similar in quality and sensory properties to that produced from maize. There was no correlation between degree of marbling and tissue cholesterol content, suggesting that for closely trimmed beef cuts, selection for higher quality by consumers will not increase cholesterol intake.

BRUDEVOLD, A.B. and SOUTHERN, L.L. (1994)

Low protein, crystalline amino acid-supplemented, sorghum-soybean meal diets for the 10- to 20-kilogram pig.

Journal of Animal Science, **72**(3): 635-647.

Limiting amino acids (or other nutrients) in low protein (12%), sorghum-soybean meal diets were studied in randomized experiments with pigs. Individual addition of histidene and valine to the diet increased gain, while gain and performance of pigs given all amino acids did not differ from that of pigs given sorghum. However, pigs given sorghum grew faster and had greater apparent N digestibilities.

CHEN, K.H., HUBER, J.T., SIMAS, J., THEURER, C.B., YU, P., CHAN, S.C., WU, Z., SWINGLE, R. and DEPETERS, E.J. (1995)

Effect of enzyme treatment or steam-flaking of sorghum grain on lactation and digestion in dairy cows.

Journal of Dairy Science, **78**(8): 1721-1727.

Holstein cows were fed on diets (7.5% soyabean meal, 34% lucerne hay, 10% whole cottonseed, 3% cottonseed hulls and 1.5% molasses) containing 40% dry-rolled or steam-flaked sorghum with or without an enzyme preparation. Cows fed on steam-flaked sorghum had higher milk yields, milk protein yields, 3.5% fat-corrected milk yields, percentage of milk protein, and efficiency of feed utilization, than those fed on dry-rolled sorghum.

CHEN, K.H., HUBER, J.T., THEURER, C.B., SIMAS, J., SANTOS, F., CHANG, S.C. and SWINGLE, R.S. (1995)

Effect of substituting steam-flaked sorghum for concentrate on lactation and digestion in dairy cows.

Journal of Dairy Science, **78**(2): 362-367.

Lactating cows were given 0, 15, 30 or 45% of dietary matter as steam-flaked sorghum grain in place of equal amounts of a mixture of 40% steam-rolled maize, 13% rolled barley, 20% wheat mill run, and 27% ground beet pulp in four diets. Yields of milk and milk protein, and percentages of milk protein, increased linearly as sorghum increased. Feed efficiencies, and changes in body weight and body condition score, were unaffected by treatment.

CHERNEY, J.H., CHERNEY, D.J.R., AKINS, D.E. and AXTELL, J.D. (1991)

Potential of brown-midrib, low mutants for improving forage quality.

Advances in Agronomy, **46**: 157-198.

The potential of brown-midrib, low-lignin mutants for improving forage quality are reviewed. After a brief history of the trait, and the genetics of mutations found and induced in *Zea mays,* sorghum and *Pennisetum glaucum,* its effects on forage quality are discussed. Leaf and stem anatomies of normal and brown-midrib sorghum and *P. glaucum* are compared and the influence of the trait on animal performance, intake and digestibility is examined.

DEL CURTO, T., COCHRAN, R.C., NAGARAJA, T.G., CORAH, L.R., BEHARKA, A.A. and VANZANT, E.S. (1990)

Comparison of soybean meal/sorghum grain, alfalfa hay and dehydrated alfalfa pellets as supplemental protein sources for beef cattle consuming dormant tallgrass-prairie forage.

Journal of Animal Science, **68**(9): 2901-2915.

In a 35-day digestion trial, steers grazing dormant range forage were given no supplement, soyabean meal/sorghum grain, lucerne hay or dehydrated lucerne pellets. Steers given supplements had at least a two-fold increase in forage intake. In conclusion, lucerne pellets and lucerne hay were as effective as soybean/sorghum as supplementary protein for pregnant grazing cows when given on an equal CP and metabolizable energy basis.

DOUGLAS, J.H., SULLIVAN, T.W., ABDUL-KADIR, R. and RUPNOW, J.H. (1991)

Influence of infrared (micronization) treatment on the nutritional value of corn and low- and high-tannin sorghum.

Poultry Science, **70**(7): 1534-1539.

Micronization (infrared treatment) of maize, and low- and high-tannin sorghum, decreased acid and neutral detergent fibre. The decrease in tannin content of high-tannin sorghum was not enough to alleviate the reducing effects of tannin on weight gain and feed conversion of broilers. *In vitro* starch digestibility, weight gain and feed conversion were improved for all grains. Broilers fed on maize and low-tannin sorghum showed no differences in weight gain and feed conversion.

DOUGLAS, J.H., SULLIVAN, T.W., BOND, P.L., STRUWE, F.J., BAIER, J.G. and ROBESON, L.G. (1990)

Influence of grinding, rolling and pelleting on the nutritional value of grain sorghums and yellow corn for broilers.

Poultry Science, **69**(12): 2150-2156.

Yellow maize and low- and high-tannin sorghums, finely ground or rolled and with supplements, were given to broilers. Results indicated that adequate grinding was needed for maximum utilization of the grain, and that pelleting improved the performance of broilers fed diets that were isoenergetic and isonitrogenous.

ECONOMIDES, S., KOUMAS, A., GEORGHIADES, E. and HADJIPANAYIOTOU, M. (1990)

The effect of barley-sorghum grain processing and form of concentrate mixture on the performance of lambs, kids and calves.

Animal Feed Science and Technology, **31**(1/2): 105-116.

The effects of grain processing and form of concentrate mixture were studied in lambs, calves and kids from weaning. Feeding whole grain to lambs increased dietary matter and nitrogen digestibilities, but had no effect on gain or feed-to-gain ratios compared with lambs fed on processed grains. Calves on the pelleted diet had similar growth rates to those on the whole grain diet,

but feed utilization was better for the pelleted diet. Growth rate and feed-to-gain ratio of kids on the pelleted diet was better than that of kids on the whole grain diet.

EL ZUBEIR, E.A., EL BASHIR, T.E. and SALIH, A.M. (1990)

Sorghum gluten feed in poultry diets: effect on broiler performance and sensory evaluation of carcasses.

Journal of the Science of Food and Agriculture, **52**(2): 215-219.

Chickens were randomly allocated one of four diets: mash control, and three others with increasing levels of added sorghum gluten feed. Dietary sorghum had no significant effects on feed intake, weight gain, feed conversion efficiency and mortality rate throughout the experimental period. Chickens given sorghum diets had significantly lower meat:bone ratios. Sorghum had no detectable effects on the colour, flavour or texture of roasted chicken meat.

EL ZUBEIR, E.A. and JUBARAH, S.K. (1993)

Nutritional evaluation of sorghum germ meal as a substitute for sorghum in broiler diets.

Animal Feed Science and Technology, **44**(1/2): 93-100.

Starter and grower diets containing sorghum gluten meal were given to 360 commercial strain chicks. The feeding of increasing levels of sorghum gluten meal had no significant effect on weight gain at four weeks old but at 12 and 18 weeks, liveweight gain decreased. Diets containing sorghum gluten meal at 300 g/kg delayed the start of egg production, and age at 25% egg production, by 18 and 16 days, respectively, when compared with controls.

EL ZUBEIR, E.A. and MUSTAFA, E.A. (1992)

The replacement value of sorghum gluten meal for soybean meal in broiler chick diets.

Animal Feed Science and Technology, **36**(3/4): 339-342.

Broiler chickens were fed on diets containing sorghum gluten meal (SGM) and soyabean meal (SBM) in various ratios plus L-lysine and DL-methionine. Increasing the proportion of sorghum meal protein reduced weight gain, feed intake and feed conversion efficiency. Liver relative weight was increased whereas bursa relative weight was decreased with sorghum meal protein. The results suggest that SGM is not equivalent to SBM as a source of protein in broiler chicken diets.

ESIEMOKAI, A.O. (1990)

Sorghum: feed grain of the future in Nigeria.

pp. 45-46. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

Following a review of facts and figures, it is concluded that within the next five years, sorghum will replace maize entirely as the energy source in the Nigerian feed industry.

ESMAIL, S.H.M. (1990)

Fermentation studies on inoculated grain sorghum and soybean silages.

Agribiological Research, **43**(2): 95-102.

The effects of an inoculant containing *Pediococcus cerevisiae* and *Lactobacillus plantarum* on the fermentation of silages made from mixtures of grain sorghum cultivars and soyabeans cultivars were determined. In the first year, the greatest response to the inoculant was observed for the milk stage intercrop where silage pH decreased, and lactic acid increased, more rapidly than in the other treatments. In the second year, no maturity or sowing pattern effects were observed.

ESMAIL, S.H.M., BOLSEN, K.K. and KIRCH, B. (1992)

Performance of growing beef cattle fed grain sorghum and soybean silage.

Wirtschaftseigene Futter, **38**(1): 5-11.

Crossbred beef calves were fed on diets containing 87.6% grain sorghum silage or grain sorghum-soyabean silage and 12.4% soyabean meal/urea supplement. Calves were treated with Rumensin to provide 200 mg/day. Dry matter intake and rate of gain were increased for the grain sorghum silage diet. Efficiency of feed conversion was better for the grain sorghum silage than the intercropped silage. The differences reflected the higher fibre content of intercropped silage which reduced intake and thus reduced silage energy to promote gain.

ESMAIL, S.H.M., BOLSEN, K.K. and PFAFF, L. (1991)

Maturity effects on chemical composition, silage fermentation and digestibility of whole plant grain sorghum and soy-bean silages fed to beef cattle.

Animal Feed Science and Technology, **33**(1): 79-85.

Chemical composition, fermentation characteristics, and nutritive value of interseeded whole plant grain sorghum and soyabean silages harvested at late-bloom, milk and late-dough stages of sorghum maturity, were compared. Diets containing 87.6% of interseeded silages were fed to growing beef cattle, and grain sorghum silage harvested at the late-dough stage was fed as a control. Maturity stage affected chemical composition and fermentation of interseeded silages, but not digestibilities.

GIESEMANN, M.A., LEWIS, A.J., PEO, E.R., Jr, GRABOUSKI, H.A. and DANIELSON, A.D. (1992)

Acid steeping of corn and grain sorghum: effect on nutrient digestibility in growing pigs.

Animal Feed Science and Technology, **37**(3/4): 233-243.

The effect of acid-steeping on nutrient digestibility in pigs was investigated In general, it is concluded that steeping maize and grain sorghum without recovery of soluble or suspended substances from the steeping solutions results in little improvement in nutrient digestibility.

GUALTIERI, M. and RAPACCINI, S. (1990)

Sorghum grain in poultry feeding.

World's Poultry Science Journal, **46**(3): 246-254.

The main studies from the last 30 years on the chemical and nutritional features of sorghum grain are reviewed. The problems related to the tannins which lower, to various extents, its metabolizable energy value, palatability and protein utilization for chickens, is described. It is emphasized that new sorghum cultivars with low tannin contents and nutritive values similar to maize are suitable for use as the only cereal component of commercial poultry diets.

HAMID, I.I. and EL ZUBIER, E.A. (1990)

Effect of graded levels of sorghum gluten meal on the performance of broiler chicks.

Animal Feed Science and Technology, **29**(3-4): 289-294.

Babcock broiler chickens were given diets containing 0, 5, 10, 15, 20 or 30% sorghum gluten meal from one to eight weeks old. Growth rate and feed intake decreased, and feed conversion ratio increased, with increasing sorghum meal. As carcass protein content decreased, carcass fat increased and moisture decreased. Hot and cold carcass dressing-out percentage, and meat to bone ratio, were decreased by inclusion of sorghum meal in the diet.

HANSEN, J. A., KNABE, D.A. and BURGOON, K.G. (1993)

Amino acid supplementation of low-protein sorghum-soybean meal diets for 20- to 50-kilogram swine.

Journal of Animal Science, **71**(2): 442-451.

In growth experiments (28 or 35 days duration), pigs were given a control diet with 15% crude protein, or diets based on sorghum and soyabean meal with 12, 13 and 14% crude protein fortified with lysine hydrochloride and threonine. Results suggest that for maximum performance, a minimum of 14% crude protein is needed in lysine-threonine fortified, sorghum-soyabean meal diets for growing pigs.

HANSEN, J. A., KNABE, D.A. and BURGOON, K.G. (1993)

Amino acid supplementation of low-protein sorghum-soybean meal diets for 5- to 20-kilogram swine.

Animal Science, **71**(2): 452-458.

In four 28-day experiments, pigs were given a 21% crude protein diet, or sorghum/soyabean meal diets with 15, 17 or 19% crude protein fortified with lysine and supplemented with threonine, methionine, isoleucine and tryptophan. The results indicate that a 17% crude protein, sorghum-soyabean meal diet fortified with lysine, methionine and threonine can produce performance equal to that obtained by pigs fed a 21% crude protein diet. Tryptophan and isoleucine had no benefit.

HART, S.P. (1990)

Effects of altering the grain content of sorghum silage on its nutritive value.

Journal of Animal Science, **68**(11): 3832-3842.

The effect of increasing grain content of sorghum silage at the soft dough or mature stage was studied using 12 steers. Increasing the height of cut did not increase dry matter digestibility of the silage. Supplementation of silages with grain did not increase digestibility. The failure to increase digestibility was not due to decreased fibre or starch digestion but rather, to increased faecal excretion of cell contents. The digestibility of grain sorghum silage was not improved by increasing the height of cut or adding supplemental grain.

HEALY, B.J., HANCOCK, J.D., KENNEDY, G.A., BRAMEL-COX, P.J., BEHNKE, K.C. and HINES, R.H. (1994)

Optimum particle size of corn and hard and soft sorghum for nursery pigs.

Journal of Animal Science, **72**(9): 2227-2236.

Weaned pigs were fed *ad libitum* on pelleted diets containing maize, hard endosperm sorghum and soft endosperm sorghum milled to different particle sizes. It was concluded that response to reducing particle size is greatest during the first two weeks post-weaning, and that optimal particle size for maize and sorghums increases with age in nursery pigs.

HILL, T.M., SCHMIDT, S.P., RUSSELL, R.W., THOMAS, E.E. and WOLFE, D.F. (1991)

Comparison of urea treatment with established methods of sorghum grain preservation and processing on site and extent of starch digestion by cattle.

Journal of Animal Science, **69**(11): 4570-4576.

Crossbred steers were fed on dry, reconstituted and ensiled, reconstituted and acid-treated and urea-treated, high moisture sorghum grain. Diets consisting of 69% ground sorghum grain were fed every 2 h in equal portions (8.2 kg/daily). It was concluded that urea-treated sorghum grain was equivalent to reconstituted, ensiled sorghum in digestion characteristics and was superior to dry sorghum.

JOSHI, D.C. and KHAN, M.Y. (1991)

Nutritive evaluation of Pusa Chari fodder varieties as sources of energy for ruminants. IV. Pusa Chari 45 (*Sorghum bicolor* L. Moench) and 68 (*Sorghum bicolor* x *Sorghum sudanense*).

Journal of Veterinary Physiology and Allied Sciences, **10**(1/2): 38-42.

Herbages of *Sorghum bicolor and S. bicolor x S. sudanense* harvested at the pre-flowering stage contained gross energy of 4.2 and 4.18, digestible energy of 2.27 and 2.2, and metabolizable energy of 1.85 and 1.8 kcal/g dry matter. They also contained 17.4 and 20.4% dry matter and 8.9 and 8.01% crude protein, respectively. Bulls were given the herbages ad libitum, or at maintenance in a digestibility trial, for one month. Dry matter intake was 90.16 and 96.07 g/kg, respectively.

JUBARAH, S.K. and EL ZUBEIR, E.A. (1992)

Effect of dietary sorghum germ meal on performance and meat quality of broiler chicks.

Journal of the Science of Food and Agriculture, **58**(3): 301-305.

Broiler chickens were freely fed on diets containing sorghum germ meal with added lysine and methionine to provide the recommended levels for starter broiler chickens. Increasing sorghum in the diet had negative linear effects on body weight, feed intake, weight gain, feed:gain ratio and dressing percentage, and a positive linear effect on liver and viscera relative weights. Sorghum meal had no detectable effect on colour, juiciness, tenderness or flavour of the meat..

KELLEY, T.G., PARTHASARTHY RAO, P. and WALKER, T.S. (1991)

The relative value of cereal straw fodder in the semi-arid tropics of India: implications for cereal breeding programs at ICRISAT.

Resource Management Program Economics Group, Progress Report no.105. Patancheru, India: ICRISAT.

The results of on-going surveys on how much importance farmers attach to sorghum fodder yield and quality are presented. These findings should be of interest to crop improvement scientists when deciding how much emphasis to place on fodder in breeding programmes. In view of the likely increased emphasis on fodder in the future, a multiple strategy approach based on region-specific needs is proposed.

KHALIFA, N.A., EL ZUBEIR, E.A. and MUSTAFA, E.A. (1994)

Use of sorghum gluten feed as a substitute for soyabean meal in layer diets.

Animal Feed Science and Technology, **48**(1-2): 165-168.

In four 28-day periods, hens were fed on diets containing 51% sorghum, 22% soyabean meal and 12% wheat bran, or on diets in which 0, 25, 50, 75 or 100% sorghum gluten feed replaced soybean meal. Substitution of soybean meal on a nitrogenous basis reduced rate of egg laying and feed intake and increased the feed conversion ratio. Results suggest that sorghum protein is not equivalent to soybean but may replace 50% of soybean protein in the diets of laying hens.

LODHI, G.P. (1993)

Potential for forage sorghum in Asia.

pp. 12-15. In: *Collaborative Sorghum Research in Asia: Report of the Asian Sorghum Researchers' Consultative Meeting, September 1993, ICRISAT.* GOWDA, C.L.L. and STENHOUSE, J.W. (eds). Patancheru, India: ICRISAT.

MAKAMA, S.M. (1990)

Feeding value of sorghum and its by-products to livestock.

p. 44. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

A comparative analysis of various feed grains as economical sources of nutrients indicated that sorghum is the cheapest source of energy. The feeding value of sorghum compared to corn is reviewed.

MEESKE, R., ASHBELL, G., WEINBERG, Z.G. and KIPNIS, T. (1993)

Ensiling forage sorghum at two stages of maturity with the addition of lactic acid bacterial inoculants.

Animal Feed Science and Technology, **43**(3/4): 165-175.

Whole crop forage sorghum was harvested at the late bloom and soft dough stages of maturity, chopped, and ensiled after treatment with commercial silage inoculants. At both stages of maturity, inoculants caused a more rapid rate of pH decline and a higher amount of lactic acid production. Sorghum ensiled at late bloom was stable after aerobic exposure, whereas sorghum ensiled at the soft dough stage deteriorated on aerobic exposure. It is concluded that addition of lactic acid bacteria inoculants to mature sorghum at ensiling might impair the aerobic stability of the silage.

MILLER, T.P., TUCKER, W.B., LEMA, M., SHIN, I.S., HOUGE, J.F. and ADAMS, G.D. (1993)

Influence of dietary buffer value index on the ruminal milieu of lactating dairy cows fed sorghum silage and grain.

Journal of Dairy Science, **76**(11): 3571-3579.

Lactating Holstein cows were given diets with grain and sorghum silage ratios of 50:50, 60:40 and 70:30 dry matter basis. 12 h after feeding, the acid-base status of the diets had not influenced the acid-base status of the rumen. Therefore, dietary acid-base status may not be an accurate predictor of need for buffers in diets of lactating dairy cows.

MOORE, J.A., POORE, M.H., ECK, T.P., ARANA, M.J., SWINGLE, R.S. and HUBER, J.T. (1990)

Influence of sorghum grain processing and buffer inclusion on performance and digestibility by lactating Holstein cows.

Journal of Dairy Science, **73** (Supplement 1): 127.

Lactating cows were fed lucernce hay-based mixed diets with 17% crude protein and 42% sorghum to compare sorghum grain processing methods (dry-rolled or steam-flaked to 0.40 or 0.27 kg/litre). Milk production and digestibility of starch was improved by flaking to 0.40 kg/litre, but there was no advantage in processing more extensively. Intake and milk fat percentage were lower for the 0.27 kg/litre diet than for the dry-roll diet. Steam-flaking improved performance, but processing beyond 0.40 kg/litre was not advantageous under the conditions of this trial.

MOORE, J.A., POORE, M.H., ECK, T.P., SWINGLE, R.S., HUBER, J.T. and ARANA, M.J. (1992)

Sorghum grain processing and buffer addition for early lactation cows.

Journal of Dairy Science, **75**(12): 3465-3472.

Lactating cows were fed lucerne hay-based mixed diets with 15% crude protein and 42% sorghum to compare sorghum grain processing methods (dry-rolled or steam-flaked to 0.40 or 0.27 kg/litre), with or without 1% sodium sesquicarbonate as buffer. Steam-flaked grain to a density of 0.40 kg/litre increased milk yield and feed conversion efficiency without decreasing feed intake or milk fat percentage. Further processing of grain to a flake density of

0.27 kg/litre reduced intake and milk fat percentage; these problems were not alleviated by adding buffer. It is concluded that compared with dry-rolling, steam-flaking sorghum grain to 0.40 kg/litre improved performance, but the lowest flake density was detrimental and effects were not alleviated by inclusion of 1% buffer in the diet.

MORRIS, D.R. and MCCORMICK, M.E. (1994)

Ensiling properties of sweet sorghum.

Communications in Soil Science and Plant Analysis, **25**(15/16): 2583-2595.

Sweet sorghum was grown under field conditions to determine nutritional quality and the subsequent animal performance of silage from the yield. Sweet sorghum was compared to common cultivar, medium-tall, forage sorghum with regard to agronomic characteristics and chemical composition; it was harvested at early and late reproductive stages and stored in experimental silos. Results showed that to maximize yield, sweet sorghum should be ensiled at the hard-dough stage. The resulting silage may be higher in digestible dry matter than that of medium-tall forage sorghums which produce grain.

MUSHARAF, N.A. and LATSHAW, J.D. (1991)

Effect of tannin extraction on the feeding value of grain sorghum in broiler starter diets.

Sudan Journal of Animal Production, **4**(1): 53-64.

The effects of different tannin extraction methods for brown grain sorghum, compared to low-tannin varieties, on the performance of broiler chicks from one to 21 days, were studied using isonitrogenous and isoenergetic diets. Tannin extraction by alkaline hot water or hot water soaking increased feed conversion. Compared with tannin-extracted diets, methionine supplementation of untreated brown grain diets increased feed intake and weight gain, and reduced the incidence of leg abnormalities.

NIR, I., MELCION, J.P. and PICARD, M. (1990)

Effect of particle size of sorghum grains on feed intake and performance of young broilers.

Poultry Science, **69**(12): 2157-2164.

Sorghum grains were ground (fine, medium or coarse) with a hammer mill or a roller and fed to chickens. In all studies, feed intake was inversely related to the calculated surface area of the ground sorghum, independent of method of grinding. Feed intake and body weight gain were positively related to the coarseness of the feed.

OLIVEIRA, J.S., HUBER, J.T., BEN GHEDALIA, D. and PESSARAKLI, M. (1990)

Effect of sorghum grain processing on the performance of lactating dairy cows (LDC).

Journal of Dairy Science, **73** (Supplement 1): 127.

Steam-rolled maize, dry-rolled sorghum, steam-flaked sorghum and 50:50 dry-rolled sorghum/steam-flaked sorghum were compared for performance of lactating dairy cattle. There were no significant differences in full cream milk

yield or fat percentage, but steam-flaked sorghum increased milk protein, lactose and feed utilization. Digestibility of organic matter was higher for steam-flaked sorghum, while that of crude protein was highest for dry-rolled sorghum. Starch digestion was lowest for dry-rolled sorghum and highest for steam-flaked sorghum.

OLIVEIRA, J.S., HUBER, J.T., BEN GHEDALIA, D., SWINGLE, R.S., THEURER, C.B. and PESSARAKLI, M. (1993)

Influence of sorghum grain processing on performance of lactating dairy cows.

Journal of Dairy Science, **76**(2): 575-581.

Holstein cows were fed in controlled experiments to compare diets of steam-rolled maize, steam-flaked sorghum grain, dry-rolled sorghum grain, and an equal mixture of dry-rolled and steam-flaked sorghum grain. Milk yield for cows given steam-flaked sorghum grain was equal or superior to that of cows given steam-rolled maize. Steam-flaking of sorghum grain markedly increased starch digestibility and percentage milk protein compared with dry-rolling.

OLIVEIRA, J.S., HUBER, J.T., SIMAS, J.M., THEURER, C.B. and SWINGLE, R.S. (1995)

Effect of sorghum grain processing on site and extent of digestion of starch in lactating dairy cows.

Journal of Dairy Science, **78**(6): 1318-1327.

Four lactating Holstein cows were fed ad libitum on diets (23% lucerne hay, 7.3% cottonseed meal, 9% whole cottonseed meal, 10% cottonseed hulls and 3.2% dry molasses) containing 42.9% steam-rolled maize, dry-rolled sorghum, steam-flaked sorghum grain or an equal mixture of dry-rolled and steam-flaked sorghum. The digestibility of starch in the rumen (81% v 60%) and small intestine (83% v 63%), and digestible starch intake (6.4% v 5.9 kg/day), were higher in cows fed on steam-flaked sorghum than in those fed on dry-rolled sorghum; values for steam-rolled maize were intermediate.

PAGE, T.G., SOUTHERN, L.L. and WATKINS, K.L. (1993)

Threonine supplementation of low-protein, lysine-supplemented sorghum-soybean meal diets for growing-finishing pigs.

Livestock Production Science, **34**(1/2): 153-162.

A study was carried out to determine whether low protein, lysine-supplemented, sorghum-soyabean meal diets are deficient in threonine for pigs fed ad libitum on grower and finisher diets containing 13.7 and 15.0% crude protein. It was concluded that the diets may be deficient in threonine.

RAMIREZ, R.G., GARZA, J., MARTINEZ, J. and AYALA, N. (1991)

Wood ash, sodium hydroxide and urine to increase sorghum straw utilization.

Small Ruminant Research, **5**(1/2): 83-92.

Lambs were fed on diets containing sorghum straw either untreated (control), or treated with 20% wood ash solution, NaOH, 20% wood ash solution plus urea, 20% wood ash solution plus urine, or urine only. Results suggest that

treatment of sorghum straw with 20% wood ash solution or with urine can increase fibre utilization by lambs in amounts comparable to the increase observed with NaOH treatment.

REED, J.D. (1992)

Sorghum and millets as forage crops in the semi-arid tropics.

pp. 173-178. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

Sorghum and millet are grown primarily as forage crops in the US and Australia but in smallholder farming systems in the semi-arid tropics, they are multi-purpose, providing food, feed, construction materials and fuel. This paper reviews the properties and characteristics of sorghum and millet in terms of both positive and negative benefits as forage crops in the semi-arid tropics.

ROONEY, L.W. (1990)

Methods of processing sorghum for livestock feeds.

p. 45. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The following aspects of sorghum processing are reviewed: dry-grinding, steam-flaking, popping, micronozing, reconstitution, and high moisture storage and the effects on feeding value and efficiency.

ROONEY, L.W. (1992)

Methods of processing sorghum for livestock feeds.

pp. 167-171. In: *Utilization of Sorghum and Millets. Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988.* GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds). Patancheru, India: ICRISAT.

Processing methods for the production of animal feed from sorghum in the US are examined. Experience has shown that sorghum must be more vigorously processed than maize; this has led to sophisticated processes which include reconstitution, early harvesting and high moisture storage, steam-flaking, popping, micronizing and exploding to improve feed efficiency.

RUDE, B.J. and RANKINS, D.L., Jr (1993)

Evaluation of Bermudagrass (*Cynodon dactylon*) and Johnsongrass (*Sorghum halepense*) as alternatives for ensiling with poultry litter.

Animal Feed Science and Technology, **44**(1/2): 101-111.

Forage maize, Johnsongrass and Bermudagrass were ensiled with poultry litter. Dry matter and pH increased as the percentage of poultry litter increased. Results indicate that Johnsongrass is not equal to forage maize although it is palatable, digestible, and supports liveweight gain in sheep when ensiled with up to 20% poultry litter.

RUKANTABULA, A.A. (1993)

The prospects of sorghum and millet use in the stockfood industry.

pp. 120-123. In: *National Workshop on Sorghum and Millet Marketing and Utilization for Food Security and Development, May 1993, Arusha International Conference Centre.* MINDE, I.J. and ROHRBACH, D.D. (eds). Arusha, Tanzania: Sokoine University of Agriculture.

In Tanzania, sorghum and millets are used mainly as human food and in brewing. Only very small quantities are used in the animal feed industry, although millet is a favourite feed for birds. Sorghum lags behind maize, wheat and barley in the stockfood industry. The prospects and constraints for the use of sorghum and millet are considered.

SANDERSON, M.A. (1993)

Aerobic stability and in vitro fibre digestibility of microbially inoculated corn and sorghum silages.

Journal of Animal Science, **71**(2): 505-514.

Maize and sorghum forages were inoculated with lactic acid bacteria or potassium sorbate (anti-fungal agent) and ensiled for 40 or 186 days for maize, and 30 or 160 days for sorghum. Inoculation reduced silage pH but did not prevent aerobic deterioration of the silages, and it did not affect acid detergent fibre concentration and digestibility of neutral detergent fibre in maize, although these increased with time of ensiling in sorghum silage.

UMUNNA, N.N. and ALAWA, J.P. (1990)

Feed uses of sorghum grain and stover.

p. 43. In: *Industrial Utilization of Sorghum: Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, December 1989, Kano, Nigeria.* Patancheru, India: ICRISAT.

The prospects for using sorghum in the livestock feed industry were reviewed with reference to the current nutritive value of the crop.

WHEELER, J.L., MULCAHY, C., WALCOTT, J.J. and RAPP, G.G. (1990)

Factors affecting the hydrogen cyanide potential of forage sorghum.

Australian Journal of Agricultural Research, **41**(6): 1093-1100.

The effect of plant maturity, N fertilizer, P fertilizer, water stress, light intensity and temperature on HCN potential of sorghum were investigated. Neither the application of superphosphate, nor change in light intensity and temperature, had direct significant effects on HCN potential. It is concluded that breeding and selection for low HCN potential is a promising approach to ensuring that sorghum plants will provide non-toxic forage from an early stage of growth.

WHITE, J.S., BOLSEN, K.K., POSLER, G. and NEILL, J.W. (1991)

Forage sorghum silage dry matter disappearance as influenced by plant part proportion.

Animal Feed Science and Technology, **33**(3): 313-322.

In vitro dry matter disappearance dynamics of forage sorghum silage was studied in five hybrids harvested at the hard dough stage of maturity. At ensiling, five plants/hybrid were separated into grain, leaf, sheath and stalk parts, chopped, put into nylon bags and ensiled with their respective silages in pilot

silos. Regression equations were generated to predict silage *in vitro* dry matter disappearance dynamics based on the proportion of plant parts for each hybrid. Grain had a positive effect on silage dynamics whereas the sheath component had a negative effect; grain also had the greatest effect.

XIONG, Y., BARTLE, S.J. and PRESTON, R.L. (1990)

Improved enzymatic method to measure processing effects and starch availability in sorghum grain.

Journal of Animal Science, **68**(11): 3861-3870.

A modified enzymic method to measure processing effects and starch availability in steam-flaked sorghum grain was developed after preliminary experiments determined the required enzyme concentration, colour reagents, precipitants, sample particle size, shaking frequency and buffer pH. The method is relatively simple, fast and sensitive.

XIONG, Y., BARTLE, S.J. and PRESTON, R.L. (1990)

Density of steam-flaked sorghum grain, roughage level and feeding regimen for feedlot steers.

Journal of Animal Science, **69**(4): 1707-1718.

Steam-flaked sorghum grain at different bulk densities, two roughage levels and two feeding strategies (*ad libitum* or multiple of maintenance) were given to steers. Results are discussed and a simple cost/benefit analysis for steam-flaked sorghum grain is presented.

XIONG, Y., BARTLE, S.J., PRESTON, R.L. and MENG, Q. (1990)

Estimating starch availability and protein degradation of steam-flaked and reconstituted sorghum grain through a gas production technique.

Journal of Animal Science, **68**(11): 3880-3885.

Steam-flaked sorghum grain, reconstituted sorghum grain and control samples were analysed for gas production kinetics and enzymic glucose release. Protein degradation was estimated from 6 h gas production and residual ammonia in the liquid. Rate of gas production increased as processing degree increased. Protein degradation decreased with degree of processing of steam-flaked sorghum but increased with reconstitution time. A technique based on 6 h gas production and residual ammonia in the liquid is proposed to estimate both rumen starch availability and rumen protein degradability for processed sorghum grain.

ZHUGE, Q., YAN, Z., KLOPFENSTEIN, C.F. and BEHNKE, K.C. (1990)

Nutritional value of sorghum grain depends upon processing.

Feedstuffs, **62**(9): 18,55.

A chick feeding study was used to measure the nutritional impact of hammer mill-grinding, dry-rolling, steam-flaking or extrusion processing on sorghum grain. After five weeks of feeding, feed efficiencies and weight gains were lower in chicks fed extruded sorghum than in chicks fed other diets. Particle size reduction made no difference to the nutritional quality of the grain.

ZINN, R.A. (1991)

Comparative feeding value of steam-flaked corn and sorghum in finishing diets supplemented with or without sodium bicarbonate.

Journal of Animal Science, **69**(3): 905-916.

A growth performance and metabolism trial using steers evaluated steam-flaked maize and sorghum in finishing diets, with or without 0.75% sodium bicarbonate. It was concluded that steam-flaked sorghum had 92% of the net energy for maintenance of maize; differences in total tract starch digestibility were small and could not explain the higher feeding value of maize. The lower rumen degradation of sorghum N (roughly 20%) should be considered in diet formulation to avoid a deficit in ruminally-available N. 0.75% NaHCO3 supplementation increased dry matter intake and average daily gain of cattle fed on highly processed grain-based diets.

7 PUBLICATIONS AND BOOKS

ANONYMOUS (1995)

Sorghum and millets in human nutrition.

Food and Nutrition Series no. 27. Rome, Italy: Food and Agriculture Organization.

The preparation, nutritional composition and quality of various popular foods made from sorghum and millet are described. An annex gives many recipes from regions where sorghum and millet are important dietary staples. An extensive bibliography is included. The book will be of interest to nutritionalists, food scientists, agronomists, extension workers, educators and others interested in these foods.

ALAGARSWAMY, G., STENHOUSE, J.W. and PATTANAYAK, C.M. (eds) (1992)

Sorghum research and development network for Asia.

Report of the Consultative Meeting to Consider the Establishment of a Sorghum Research and Development Network for Asia, September 1991, ICRISAT. Patancheru, India: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

The consultative group meeting to discuss sorghum production, utilization, constraints and research in Asian countries is reported The proceedings of the meeting are summarized under the following headings: utilization of end products; common production constraints and future prospects; research priorities; co-operative research and recommendations.

AXTELL, B., KOCKEN, E. and SANDHU, R. (1994)

Cereal Processing.

United Nations Development Fund for Women (UNIFEM) Food Cycle Technology Source Books. London: Intermediate Technology Publications Ltd.

This booklet focuses on the processing of four cereal grains: maize (corn), rice (paddy), sorghum and millet. Traditional and improved methods for the harvesting, threshing, winnowing, shelling, drying, storing, milling, grinding

and hulling of maize, rice, sorghum and wheat are described. Secondary processing methods, such as baking or fermenting, are outlined, and case studies from Africa, Asia and Latin America are described. Checklists and case studies are provided to help those intending to set up a cereal processing enterprise make informed decisions about processes and technology.

BENCINI, M.C. and WALSTON, J.P. (1991)

Post-Harvest and Processing Technologies of African Staple Foods: a Technical Compendium.

FAO Agricultural Services Bulletin no. 89; Rome, Italy: Food and Agriculture Organization.

Post-harvest aspects of cereals, legumes, fruit and vegetables, oilseeds, and roots and tubers, are brought together. One section briefly describes the processing and uses of sorghum. Local recipes and production statistics are included.

BYTH, D.E. (1993)

Sorghum and Millets: Commodity and Research Environments.

Patancheru; India: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

The production and research environments for sorghum and pearl millet (*Pennisetum glaucum*) in West Africa, sorghum and millets (principally pearl millet and finger millet (*Eleusine coracana*)) in South and East Africa, sorghum in Latin America, and sorghum and millets (principally pearl, finger and foxtail (*Setaria italica*) millets) in Asia, are outlined. The aim is to provide a guide to the research required in order to achieve sustained improvements in production.

CHANTEREAU, J. and NICOU, R. (1994)

The Tropical Agriculturalist: Sorghum.

Basingstoke, UK: CTA/MacMillan Press.

In this booklet, the characteristics and cultivation of sorghum are examined. Details are given of morphology, planting, control of pests and diseases, growing conditions, harvesting and economics; two of the chapters briefly cover harvesting, drying and threshing, and the uses of sorghum

DENDY, D.A.V. (ed.) (1995)

Sorghum and Millets: Chemistry and Technology.

St Paul, Minnesota, US: American Association of Cereal Chemists.

This book brings together contributions from leading researchers around the world. There are 13 chapters covering many key aspects of sorghum and millet including: history, production and importance, agronomic principles, structure and chemistry, nutritional properties, storage, traditional uses, new milling technologies, lager beers, opaque beers, forage and feed, sweet sorghum for industrial alcohol, quality evaluation and trading standards.

GEERVANI, P. and VIMALA, V. (1993)

Rural Food Enterprises, Operational Research on Development of Sorghum Food Enterprises for Alternate Uses and Supplementary Feeding.

Hyderabad, India: Andhra Pradesh Agricultural University/IDRC.

A compilation of the work carried out by the Andhra Pradesh Agricultural University with IDRC on the understanding of sorghum-based food systems in Andhra Pradesh, and the identification of constraints and opportunities for enhancing sorghum utilization in rural and urban diets, is presented.

GOMEZ, M.I., HOUSE, L.R., ROONEY, L.W. and DENDY, D.A.V. (eds) (1992)

Utilization of Sorghum and Millets.

Proceedings of Workshop, Bulawayo, Zimbabwe, February 1988. Patancheru, India: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

This is a compilation of the 28 papers and working group discussions concerning policy, practice and potential relating to the uses of sorghum and millets throughout the world.

JONSSON, L.O., DENDY, D.A.V., WELLINGS, K. and BOKALDERS, V. (1994)

Small-Scale Milling: a Guide for Development Workers.

London: ITDG Publications.

The small-scale milling of wheat, maize, rice, sorghum, millet, barley and oats, cassava, legumes and condiments, salt and bone meal is examined. The technical, economic, social and nutritional/health aspects of milling are included.

LORENZ, K.J. and KULP, K. (eds) (1991)

Handbook of Cereal Science and Technology.

Food Science and Technology Series no. 41. New York: Marcel Dekker.

This handbook comprises a series of reviews on cereal chemistry and technology written by a variety of specialists with common interests in the raw materials, processes and products of the cereals industries. The first 10 chapters review the major cereals; others review the chemical constituents of cereals and examine cereal products. The book is intended as a text and reference book for students and research workers involved with the cereal industry.

PUSHPAMMA, P. (1993)

Sorghum as Food in the Semi-Arid Tropics: Studies in the Dryland Communities of Andhra Predesh, India.

Ottawa, Canada: International Development and Research Centre.

Chapters are included on: choosing foods in the semi-arid tropics; understanding sorghum as a food system; establishing the feasibility of milling technology; establishing viable rural and urban markets for sorghum products. The need to increase the use of sorghum is explained, and the current

food system using sorghum is described; improved cultivars, marketing, storage, current processing and utilization methods, and the nutritional status of sorghum foods, are discussed. The effects of dehulling on product quality and nutrient status are considered; it is emphasized that flour from sorghum milled in the right way can compete with wheat and rice flours, at much lower cost, in areas where sorghum is extensively grown. Finally, the problems associated with using sorghum as a substitute in popular and traditional cereal foods are considered, and details of successful food enterprises based on sorghum, with active support from Andhra Pradesh Agricultural University, are described.

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Each Bulletin presents a detailed synthesis of the results and conclusions within one specialized area, and will be of particular relevance to colleagues within that field and others working on sustainable resource management in developing countries.

The purpose of this bibliography is to bring together, under one reference document, **Processing and Utilization of Sorghum**, information from many different sources covering recent research (from 1990 onwards) on post-harvest processing and utilization of sorghum.

This publication will be of considerable benefit to researchers, students, NGOs and aid agencies requiring up-to-date information on the post-harvest aspects of sorghum processing and utilization. It will be of particular help to researchers who do not have access to electronic data bases for literature search.