PST | PEDIATRIC SURGERY IN TROPICS

SOLUBLE FIBER SELECTION FOR PEDIATRIC BOWEL MANAGEMENT: EXPERIMENTAL COMPARISON AND PRACTICAL GUIDELINES

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Keywords	**Abstract**
soluble fiber, bowel management, pediatric, dietary supplements, colorectal disorders	**Introduction:** Soluble fiber dietary supplements are used to optimize bowel management in patients with colorectal disorders causing both constipation and incontinence. Availability, effectiveness and cost of these in South Africa is. The aim of this study was to identify the most absorptive and cost-effective commercially available sources of soluble fiber in South Africa. **Methods:** Swelling and water retention capacity of 18 soluble fibers were measured under room temperature and boiling water conditions at three dwell times (10, 60, 120 minutes). Cost and texture comparisons were also made. **Results:** Psyllium husks, guar gum, flaxseed flour and chia seeds had the best water retention capacity at room temperature. Heat improved the water retention of most substrates, notably Agar Agar and flaxseed powder. The most cost-effective options that had good water retention properties were flaxseed powder, psyllium husks and chia seeds. Oat bran was cheaper but notably less retentive.

	While xantham gum, guar gum, pectin and Agar Agar have moderate to good water retention properties, high costs and limited availability preclude their widespread use in the South African setting. Digestive bran, whole flaxseeds, cacao, resistant maltodextrin, baobab powder and pectin-kaolin mix had relatively poor water retention. **Conclusion:** This bench study identified the most effective and affordable soluble fiber in South Africa as psyllium (ispaghula) husk, flaxseed flour (powder) and chia seeds. Clinical research on their tolerance and use in the pediatric population for bowel management is recommended. These findings inform dietary guidelines and support the integration of effective, low-cost soluble fiber sources into pediatric bowel management strategies
Abbreviations	

INTRODUCTION

Soluble fiber dietary supplementation is useful for the management of both constipation and fecal incontinence, particularly seen in congenital colorectal anomalies[1], but specific dietary guidelines for this non-pharmacological bowel management adjunct are lacking. Impaired continence in congenital colorectal disorders can be due to an absent or abbreviated anal canal ± loss of rectosigmoid storage capacity and varying degrees of loss of colonic water absorption. Laxatives and/or anti-motility agents and dietary changes are critical in improving quality of life for many of these patients. Soluble fibers “swell and gel”, slowing intestinal transit by absorbing water from the fecal stream, to form gel-like masses that have a laxative effect, with a soft but bulky consistency which enhances detection of the stool bolus entering the rectum and anal canal[2]. Limited studies confirm their effectiveness in improving stool consistency, bowel movement regularity and overall gastrointestinal function[2-4]. There are several varieties of fibers, but none are standard in the South African diet, and many are expensive. Such dietary supplements typically need to be purchased directly by the patient without reimbursement from medical insurance and are not available from government healthcare institutions. Additionally, data on patient tolerance, including taste and texture, is extremely limited, especially in the pediatric population.

Information on what cost-effective soluble fibers are available in South Africa and clear guidelines for their use are lacking. This study seeks to address this gap through laboratory evaluation and affordability analysis of locally available soluble fibers, to inform their application for pediatric bowel management programs.

Aim

High **soluble fiber** food sources on the South African market were identified, and their costs and absorption (swelling & water retention) properties were compared. Fiber textures were also noted.

METHODS

An internet search of grey and scientific literature to identify food sources with a high component of soluble dietary fiber was conducted using Google and PubMed using the term “soluble dietary fiber”. Online and physical grocery retail stores were assessed for local availability of fiber.

A series of 3 bench laboratory experiments were conducted, based on the protocol shown in Figure 1, to assess their absorptive properties. A dry sample (15 mL) of each fiber was soaked in 125 mL of room temperature (23˚ Celsius) water for 10, 60, and 120 minutes. Boiling water was also poured onto similar samples for the same periods and allowed to stand. Swelling and water retention capacities were recorded for each sample and costs per serving were analyzed. The sample size of a tablespoon serving of each fiber type, with addition of a half-cup of water for hydration, was chosen as a practical serving size for fiber consumption that was also easy to measure and compare. The soak times were chosen arbitrarily, based on food recipes from popular literature sources, but reflect feasible meal serving preparation times for practical application.

The fiber hydration properties were assessed using the following defined formulas as described by Robertson[5]:

Swelling: the volume occupied by a known weight fiber under the conditions used, reported as ml/g as indicated in the formula.

The following formula is used: *total volume of water in substrate after addition of water (ml) divided by the mass of substrate before addition of water (g)*.

Water retention capacity: the amount of water retained by a known weight of fiber under the conditions used, reported as g/g (or x100 to be expressed as a percentage).

- The following formula was used: *[(mass of substrate after water in grams)- (mass of substrate before water in grams)] divided by (mass of substrate before water in grams)*.

Additionally, absorptive capacity was calculated by the amount of water retained by each sample.

- The following formula was also used: *volume of water added (ml) – volume of water drained through filter and collected in cylinder (ml)*.

For the formula using volume measurements, the volume of the water remaining in the filter was estimated based on aggregated assessments of wet filters and deducted.

Figure 1. Laboratory protocol

1. Arrange conically folded filter in a prelabelled beaker for each fibre sample, for each time and each water temperature category.
2. Measure (with levelled measuring spoon)15ml dry fibre and add to center of filter.
3. Measure 125ml of [room temperature=23˚Celcius OR just boiled] distilled water and pour over fibre samples, ensuring complete coverage of fibre; where necessary, stir fibre gently to prevent clumping and ensure even penetration of water into fibre mass.
4. Time [10 OR 60 OR 120 minutes] dwell period, with 5-minute intervals between each additional sample preparation.
5. Uplift filter containing soaked fibre and place in funnel suspended over same beaker until no further dripping from the filter is observed for 1 minute (for a maximum 4 minutes) **.
6. Transfer filter containing soaked fibre to dry weighing boat, ensuring scale [Radwag AS 120.R2 PLUS analytical balance] is tared to subtract the weight of the weighing boat. Measure wet weight of fibre.
7. Measure water volume collected within beaker.

**Filters used for all samples for sequential iterations of the study included (1) double layer paper coffee filters, (2) presoaked muslin cloth wrung out before use and (3) presoaked microfiber mesh cloth wrung out before use. As the same filter was used for each sample, the retention from the filter was considered negligible; aggregated wet filter weight was subtracted from the wet weight of each fibre to calculate water retention capacity. **All fibers stopped dripping within this period.*

Fig 1. Laboratory Protocol

RESULTS

Eighteen soluble fiber sources available in South Africa were identified for evaluation. The overall fiber content and soluble fiber content, as well as type of soluble fiber for each is shown in Table 1[6,7], excluding three (Maltodextrin, Pectin-kaolin mixture and Cacao powder) which showed negligible absorption despite commercial descriptions of soluble fiber properties. Six items (marked with an asterisk (*) in Table 1) were not available for purchase in mainstream grocery stores and only sourced through specialty spice or baking supply stores, health shops or online stores.

Fiber Type	Soluble Fiber (g)	Insoluble Fiber (g)	Total Fiber (g)	Soluble Fiber (%)	Insoluble Fiber (%)	Key Soluble Fibers	Key Insoluble Fibers
Wheat Bran	~2-5	~35-40	~40-45	4,4-12,5	87,5-95,6	soluble arabinoxylans, small β-glucans	cellulose, lignin, insoluble arabinoxylans
Chia Seeds	~10-12	~20-24	~34	29-35	65-71	mucilage, pectins	lignin, cellulose
Black Beans	~6-8	~17-19	~25	24-32	68-76	pectins, gums, oligosaccharides	cellulose, hemicellulose, resistant starch
Quinoa	~1,3-1,5	~5,5-5,7	~7	18,6-21,4	78,6-81,4	pectins, hemicellulose	cellulose, lignin
Oat Bran	~5-7	~10-12	~15-19	26-37	63-74	β-glucans, soluble arabinoxylans	cellulose, lignin, insoluble arabinoxylans
Psyllium (Ispaghula) Husk	~70-75	~5-10	~80	88-94	6-12	arabinoxylans, mucilage	cellulose, hemicellulose
Agar Agar*	~75	Negligible	~75	~100	~0	agarose, agaropectin	-
Xanthan Gum*	~78	Negligible	~78	~100	~0	exopolysaccharide (glucuronic acid, mannose)	-
Flaxseeds (Linseed) (Whole)	~7-10	~17-20	~27	26-37	63-74	mucilage, pectins	cellulose, lignin
Flaxseeds (Flour)*	~6-8	~20-22	~28-30	20-27	73-80	mucilage, pectins	cellulose, lignin
Guar Gum*	~75-80	Negligible	~75-80	~100	~0	galactomannans	-
Baobab Powder*	~25-30	~15-20	~44-50	~55-66	~34-45	pectins, mucilage	hemicellulose, cellulose, lignin
Pectin*	~85-90	Negligible	~85-90	~100	~0	pectin (α-1,4-galacturonic acid)	-
Red Sorghum	~1-3	~5-9	~6-12	~8-25	~75-92	arabinoxylans, β-glucans, gums, pectins	cellulose, lignin insoluble arabinoxylans, hemicellulose
Falooda Seeds (Sweet basil/ Sabje seeds)*	~25-30	~10-15	~37-45	~67-70	~30-33	mucilage, pectin, arabinoxylans	Cellulose, hemicellulose, lignin

Table 1. Soluble and Insoluble Fiber Composition of Selected Fibers (per 100g)

Swelling (Figure 2 and Supplemental Table 3 to Table 3.3) and water retention (Figure 3 and Supplemental Table 3 to 3.3) properties are shown for all 3 time periods after both room temperature and boiling water application.

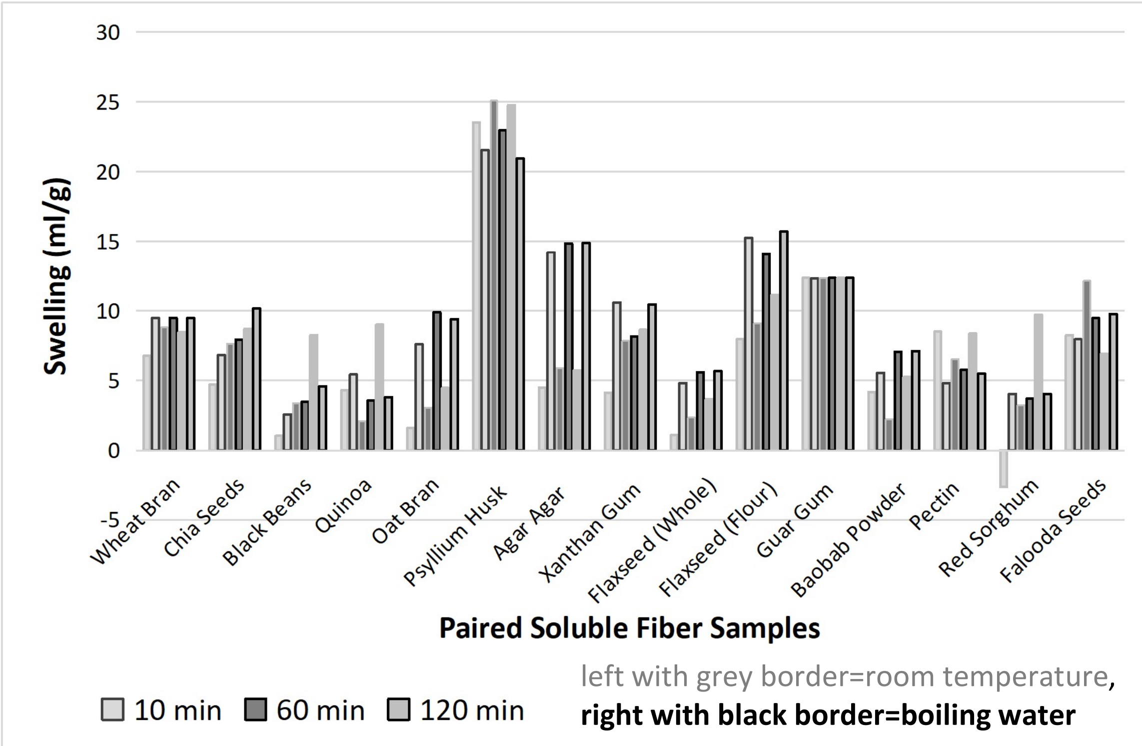

Fig 2. Swelling (ml/g) of Soluble Fibers Over Time

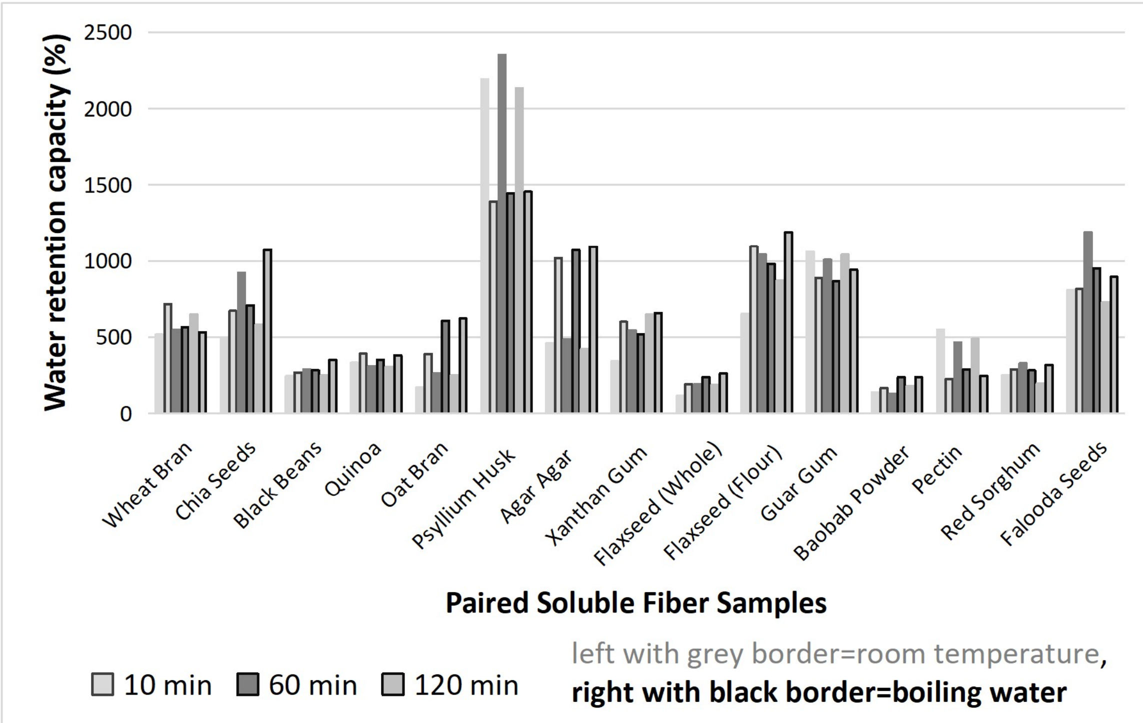

Fig 3. Water retention capacity (%) of Soluble Fibers Over Time

Psyllium husk consistently demonstrated the highest water retention and swelling across all conditions, particularly at room temperature for 60 minutes. Flaxseed flour (boiling, 120 minutes) and Agar Agar (boiling, 120 minutes) also performed strongly. Guar gum, falooda seeds and chia seeds, showed good absorption. Pectin, xantham gum, wheat bran and oat bran had moderate effectiveness. Whole flaxseeds, cacao powder, and baobab powder showed poor absorption. Maltodextrin, Pectin-kaolin mixture, Cacao powder showed negligible absorption and were not included in the figures.

Water temperature and soaking time

Most fibers performed better after prolonged soaking and at elevated temperatures, except for psyllium husks, pectin and falooda seeds which performed much better at room temperature. Chia seeds in boiling water showed the biggest interval improvement. Agar Agar performed much better in boiling water. Quinoa, bean and sorghum initially performed poorly but improved greatly with prolonged soaking.

Dry weights of the different fibers are shown in supplementary Table 4, which was used to inform both swelling calculations and cost-based assessments. Costs are summarized in supplementary Table 5 and 5.1, with cost: solubility compared in Figure 4. Flaxseed flour followed by psyllium husks were the most effective affordable fibers. Wheat and oat bran were also cheap and widely available in common mainstream grocery stores. Other highly effective sources such as Agar Agar, xantham gum and guar gum were very expensive and difficult to find, restricted to online shops and specialist baking or health shops. Pectin and baobab powder were the most expensive and difficult to source.

Fiber textures are summarized in Table 2. Softer fibers included xantham gum, flaxseed flour, chia and falooda seeds. Grainier fibrous textures were noted for wheat and oat bran, quinoa and sorghum. Agar Agar had a very firm jelly-like texture.

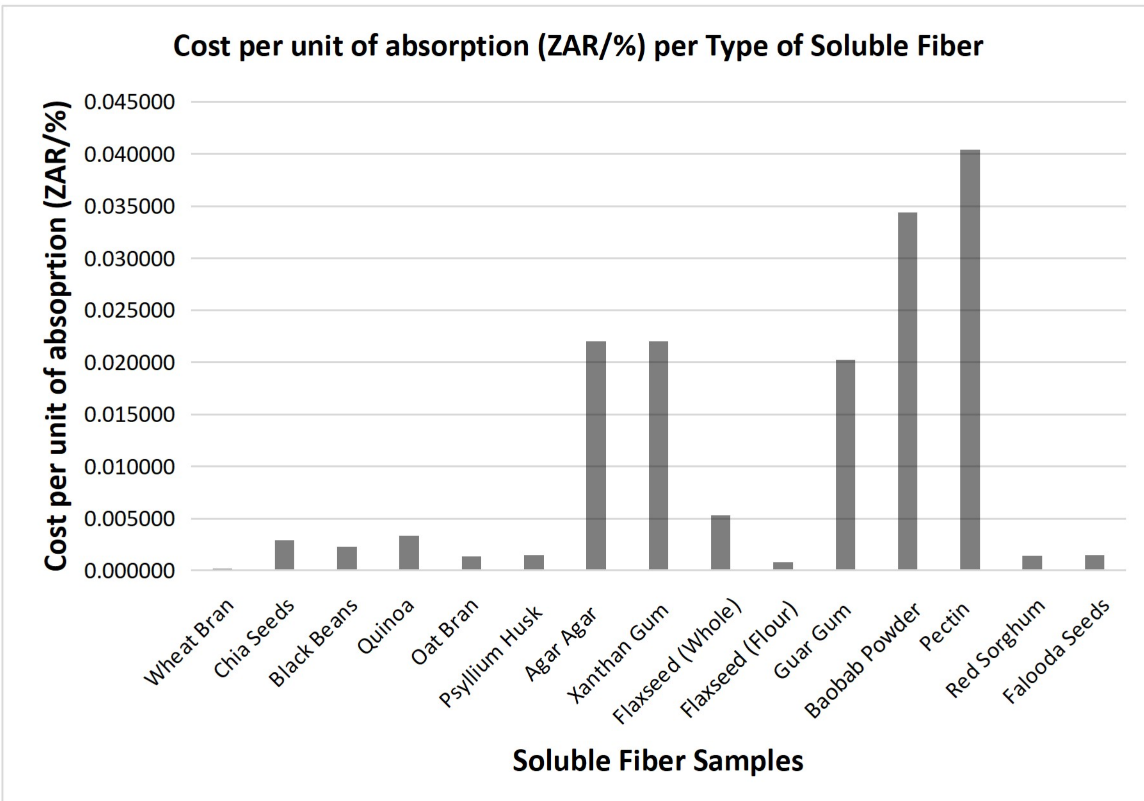

Fig 4. Cost of Fibers

Fiber Type	Observed Texture
Wheat Bran	soft, fibrous
Chia Seeds	gel-like, mucilaginous, slippery
Black Beans	soft outer skin, creamy interior
Quinoa	soft, slightly chewy, fluffy grains
Oat Bran	grainy, semi-cohesive
Psyllium Husk	thick, gel-like, uniform
Agar Agar	firm, jelly-like clumps
Xanthan Gum	sticky, mucilaginous, glossy
Flaxseed (Whole)	coarse with minimal cohesion
Flaxseed (Flour)	smooth paste, cohesive
Guar Gum	highly viscous, slimy
Baobab Powder	loose, sandy paste
Pectin	soft gel, slightly grainy
Red Sorghum	large soft granules (once cooked)
Falooda Seeds	gel-like, slippery, mucilaginous

Table 2. Texture Observations of Soluble Fiber Types After Hydration

DISCUSSION

Bowel management for constipation and/or fecal incontinence is required for most patients with congenital colorectal disorders despite successful surgical correction of their anomalies, notably for anorectal malformations (ARMs), Hirschsprung's disease and neurogenic bowel dysmotility associated with spinal defects[1]. Although individually rare with a broad range of outcomes in terms of bowel function, these conditions collectively carry a high healthcare burden, characterized by a high incidence of constipation and fecal incontinence. Easily accessible, low-cost, simple ways to improve stool consistency and frequency improve ability of children to attend school, allowing parents to seek employment opportunities, and improving family social interactions and acceptability. Identifying soluble fiber options that are available, affordable, effective and palatable to children with these conditions is especially important in low-to-middle income countries where the socioeconomic burden of these conditions is high.

Psyllium husk is the most effective soluble fiber for stool bulking and water retention, in line with international literature[2-4]. Flaxseed flour emerged as a strong, affordable alternative, but has a much higher insoluble fiber component, which may affect outcomes for continence[6]. Less grainy, soft-gelling chia and falooda seeds are affordable and -effective compared to the similarly soft-textured guar gum, which is pricey, and excellent sources of predominantly soluble fiber. While sorghum and black beans did not perform as well as several other high fiber foods, they may be more available in rural areas and further assessment after including a full cooking process is required. Highly functional fibers like Guar gum, baobab powder and pectin offer poor cost-efficiency and low availability despite their hydration properties.

Suitability of the cheapest options, wheat and oat bran, depends on indications for use, as the high insoluble fiber constituents may have a prokinetic effect, useful in constipation but detrimental to patients with incontinence.

While heat improved swelling in most fibers, some such as psyllium and pectin absorbed better at room temperature. This is useful in considering food preparation requirements.

Texture, taste and gastrointestinal side effects remain important tolerance considerations[9] in pediatric use, and our local clinical experience supports good acceptance of chia seeds, while the grainier texture of psyllium husks and other fibers may be trickier to introduce into foods without altering their palatability. Some children may accept stiffer textures better than others and this information can be useful to parents to guide their individual food choices. More clinical research is needed in this regard.

The findings support their application in pediatric bowel management but highlight the need for further clinical trials to establish optimal dosing and assess patient compliance and gastrointestinal tolerance. For example, it is important for clinical trials to see whether the marked increase in swelling over time seen with chia seeds increases or decreases fecal transit time compared to other choices.

Study limitations

Three sets of bench tests were conducted, each by different groups of medical students as part of an elective research project. Slight inter-test differences might have arisen as a result. Measuring errors may have been incurred due to use of volumetric based sampling of the irregularly shaped fiber. The accuracy could be further affected by water evaporation from the samples that soaked in boiling water. The volume of the water retained in the filters should be minor with each sample affected similarly but may have affected exact measurements.

Further evidence-based dietary recommendations require clinical studies tailored to affordability and efficacy, especially in public sector healthcare settings.

CONCLUSION

This study provides useful effectiveness and economic ranking information to guide clinical prescribing of soluble fiber in colorectal care. Psyllium husk, flaxseed flour, chia and falooda seeds represent the most practical and effective soluble fiber options for pediatric bowel management in South Africa, with the first 3 being fairly widely available in general supermarkets and health stores in main cities. The study supports expansion into clinical trials to explore the clinical effectiveness, tolerability and compliance in pediatric patients of various soluble fiber as regular dietary supplements.

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7. Appendix: Supplementary Tables and Observational Data

Table 3.1. Swelling and Water Retention Capacities of Soluble Fibers (10 min)

Fiber Type	Swelling (ml/g): room temperature	Swelling (ml/g): boiling water	Capacity (%): room temperature	Capacity (%): boiling water
Wheat Bran	6,78	9,49	516,61	716,27
Chia Seeds	4,71	6,82	491,94	671,59
Black Beans	1,03	2,58	244,23	267,79
Quinoa	4,29	5,44	332,43	391,84
Oat Bran	1,60	7,80	169,31	389,26
Psyllium Husk	23,53	21,54	2191,41	1391,82
Agar Agar	4,5	14,19	458,88	1018,24
Xanthan Gum	4,15	10,61	340,93	600,22
Flaxseeds (Whole)	1,09	4,84	114,23	192,65
Flaxseeds (Flour)	7,97	15,26	651,66	1095,14
Guar Gum	12,36	12,32	1061,23	888,03
Baobab Powder	4,18	5,57	138,78	166,28
Pectin	8,51	4,83	549,13	223,94
Red Sorghum	-2,63*	4,05	169,3	289,67
Falooda Seeds	8,26	7,96	808,14	814,34

**Measuring error*

Table 3.2. Swelling and Water Retention Capacities of Soluble Fibers (60 min)

Fiber Type	Swelling (ml/g): room temperature	Swelling (ml/g): boiling water	Capacity (%): room temperature	Capacity (%): boiling water
Wheat Bran	8,81	9,49	547,80	566,10
Chia Seeds	7,63	7,94	922,70	708,19
Black Beans	3,38	3,47	289,39	282,25
Quinoa	2,09	3,56	308,68	350,73
Oat Bran	3,07	9,90	262,89	608,28
Psyllium Husk	25,08	22,96	2350,31	1445,60
Agar Agar	5,91	14,87	485,22	1071,99
Xanthan Gum	7,85	8,18	544,92	518,47
Flaxseeds (Whole)	2,34	5,61	190,74	237,44
Flaxseeds (Flour)	9,11	14,08	1042,33	981,59
Guar Gum	12,36	12,36	1007,32	865,28
Baobab Powder	2,23	7,07	127,79	237,05
Pectin	6,53	5,77	465,71	288,90
Red Sorghum	3,24	3,70	328,37	281,86
Falooda Seeds	12,15	9,48	1189,55	951,52

Table 3.3. Swelling and Water Retention Capacities of Soluble Fibers (120 min)

Fiber Type	Swelling (ml/g): room temperature	Swelling (ml/g): boiling water	Capacity (%): room temperature	Capacity (%): boiling water
Wheat Bran	8,47	9,49	649,49	532,54
Chia Seeds	8,71	10,17	579,65	1072,58
Black Beans	8,25	4,60	248,64	349,77
Quinoa	9,02	3,82	305,86	380,54
Oat Bran	4,47	9,42	249,12	621,94
Psyllium Husk	24,75	20,94	2132,52	1455,42
Agar Agar	5,75	14,90	422,17	1093,80
Xanthan Gum	8,64	10,47	648,81	658,42
Flaxseeds (Whole)	3,67	5,69	186,53	261,80
Flaxseeds (Flour)	11,15	15,71	869,57	1190,54
Guar Gum	12,36	12,36	1041,05	941,15
Baobab Powder	5,25	7,13	178,00	237,19
Pectin	8,38	5,51	487,16	246,51
Red Sorghum	9,71	4,05	195,04	318,03
Falooda Seeds	6,91	9,78	727,83	894,05

Table 4. Dry weight of Fiber Types per 15ml serving

Fiber Type	Dry weight (g)
Wheat Bran	2,95
Chia Seeds	8,06
Black Beans	10,65
Quinoa	9,65
Oat Bran	8,57
Psyllium Husk	4,89
Agar Agar	8,39
Xanthan Gum	9,26
Flaxseeds (Whole)	10,47
Flaxseeds (Flour)	7,82
Guar Gum	10,11
Baobab Powder	6,91
Pectin	8,02
Red Sorghum	9,87
Falooda Seeds	8,23

Table 5. Cost Comparison of Soluble Fiber Types per 15ml Serving (2024 Prices)

Fiber Type	**Approx, Price per Gram (ZAR)**	**Estimated Cost per 15ml Serving (ZAR)**
Wheat Bran	0,04	0,12
Chia Seeds	0,27	2,18
Black Beans (uncooked)	0,06	0,64
Quinoa (uncooked)	0,12	1,16
Oat Bran	0,06	0,51
Psyllium Husk	0,56	2,74
Agar Agar	1,99	16,70
Xanthan Gum	0,73	6,76
Flaxseed (Whole)	0,10	1,05
Flaxseed (Flour)	0,10	0,78
Guar Gum	1,94	19,61
Baobab Powder	0,90	6,22
Pectin	1,90	15,24
Red Sorghum	0,04	0,39
Falooda Seeds	0,16	1,32

***** The average cost per serving was calculated by using the price per gram of each fiber and multiplying that by dry weight of that fiber (as seen in Table 4).

Table 5.1. Cost Comparison of Average Water Retention Capacity (%) of Soluble Fiber Types per 15ml Serving

Fiber Type	Cost per 15ml Serving (ZAR)	Average Water Retention Capacity (%)	Cost per Unit Absorption (ZAR/%)
Wheat Bran	0,12	588,14	0,000204
Chia Seeds	2,18	741,11	0,002942
Black Beans	0,64	280,34	0,002283
Quinoa	1,16	345,01	0,003362
Oat Bran	0,51	383,47	0,001330
Psyllium Husk	2,74	1827,85	0,001499
Agar Agar	16,70	758,38	0,022021
Xanthan Gum	6,76	551,96	0,022021
Flaxseeds (Whole)	1,05	197,23	0,005324
Flaxseeds (Flour)	0,78	971,80	0,000803
Guar Gum	19,61	967,34	0,020272
Baobab Powder	6,22	180,85	0,034393
Pectin	15,24	376,89	0,040436
Red Sorghum	0,39	277,17	0,001407
Falooda Seeds	1,32	897,57	0,001471

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