Brix Food Quality Testing in Wales

Exploring how to measure food quality using Brix to encourage the development of a food quality standard that relates to healthy planet and people

By

Matthew Adams
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Report commissioned by Social Farms & Gardens,
Sustainable Food Procurement for Local Prosperity Project

This project has received funding through the Welsh Government Rural Communities - Rural Development Programme 2014-2020, which is funded by the European Agricultural Fund for Rural Development and the Welsh Government to pilot two new procurement food hubs in Carmarthenshire and North Powys.

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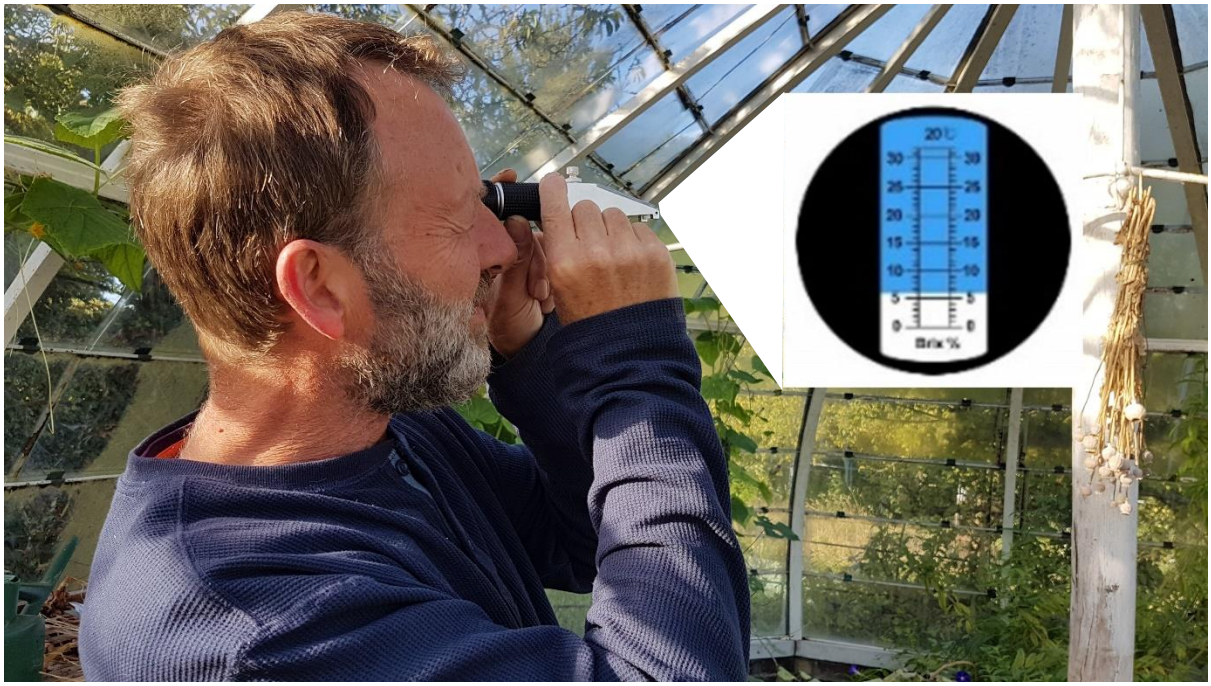
Cover picture: Food Quality testing at Ash & Elm Horticulture. From left to right Maddy, Emma & Dave



About the Author

Matthew Adams is Co-founder and Director of Growing Real Food for Nutrition CIC (Grffn). Matthew studied Environmental Quality and Resource Management B.Sc. (1992-1996) and is inspired by Deep Ecology. Matthew was Director of The Good Gardeners Association (2000-2011) and Author of 'Beyond Organic, a Vision of the Future', published in the Soil Association's journal Mother Earth (Vol 5, Autumn 2011). Matthew contends that food quality can be defined by its nutrient content which relates directly to ecosystem health – the aim of regenerative practices.

About Growing Real Food for Nutrition CIC

Growing Real Food for Nutrition CIC (Grffn) is a new social enterprise (July 2020) exploring nutrient dense food as an indicator of food quality and its relationships to soil health, plant health, human health, and planetary health. Grffn seeks to create partnerships and conduct citizen science projects for mutual benefit and is developing the use of handheld affordable tools and exploring sensory testing e.g., taste and observation to identify and learn about nutrient dense food.

Grffn has worked with growers across four continents including the Natural Farming Community in Andrah Pradesh, India[1] – home to the world's largest experiment in Agroecology with some 630,000 farmers seeing improvements to income, health and wellbeing compared to conventional growers.[2] Grffn is a partner of the Bionutrient Institute (USA) and ran a UK pilot project in 2022/3 following their methodology which aims to investigate causes of nutrient variation, develop a handheld scanner to measure nutrient density and increase food quality in the global food supply.[3]

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Report Summary

Grffn was invited by Social Farms & Gardens (SF&G) to sit on the steering group of their project, Sustainable Food Procurement for Local Prosperity. This report offers an insight in understanding food quality issues by using a comparative test to explore potential differences in food quality using an optical Brix refractometer. 350 samples of different fruits and vegetables, sourced from twenty local growers and retail outlets in Cardiff, Carmarthenshire and Powys, were tested.

Dr Carey Reams, 'Brix Tables' (see appendices p.16) of suggested food quality were used to assess results. On a crop-by-crop basis brix values are rated as 'poor', 'average', 'good', or 'excellent'.

Many useful observations have been made from the results including the potential for developing food quality standards. This could incorporate the potential health value to humans with increased nutritional benefits. In addition, a measure of food quality can also relate to increased carbon sequestration as well as increases in biodiversity. A further benefit would be realised with creating a level playing field that prevents greenwashing encouraging growers to learn from each other to increase quality. This would fulfil the aims of agroecological principles and encourage local growers to produce higher quality food for its community and in so doing improve the flow of nutrition in food ecosystems to create multiple benefits for health, employment and the planet.

Introduction

Grffn were invited by Social Farms & Gardens (SF&G) to sit on the steering group of their project, Sustainable Food Procurement for Local Prosperity. This received funding from the European Agricultural Fund for Rural Development and Welsh Government. The steering group ran between July 2021 and October 2023 and the project was delivered between June 2022 and July 2023. This involved two procurement hubs in Carmarthenshire and Powys to source, pack and distribute locally grown food to schools, care homes, council offices, etc. Grffn's remit was to explore food quality issues based on the concept of measuring nutrient density.

About Brix

Professor Adolf Ferdinand Wenceslaus Brix, a 19th Century German chemist (1798-1890), is credited with the invention of an optical Brix Refractometer which measures the ratio of 'Total Dissolved Solids' in water. When light is passed through a sample, e.g., a few drops of plant juice, the angle of light is refracted at an angle based on the quantity of dissolvable solids the juice contains. Dissolvable solids in plant juice include nutrients such as carbohydrate, some fats, vitamins and thousands of phytonutrients as well as nutrients required by the plant to feed itself and its symbiotic partners, soil microbes.

Using a Brix refractometer to measure food quality was developed in America by Soil Scientist Dr Carey Reams in the 1970's. Reams was an agronomist and owner of a large soil and plant testing laboratory. Upon his retirement he produced the 'Brix Tables' as a suggested guide for measuring food quality in plants. From a lifetime's observation, research and development he catalogued a range of Brix values into 'poor', 'average', 'good' or 'excellent' for a list of fruits, vegetables and grasses (see appendices for copy of the Brix tables). Reams claimed that when 'excellent' Brix values were achieved that the food will correlate to the following metrics:[4],[5]

1) total resistance to pests and diseases
2) increased yields of more uniform growth
3) better taste and
4) longer shelf-life.

Farmers, growers and agronomists today, adopting a regenerative approach to growing food are anecdotally reporting one or more of these food quality metrics.[6] Indeed, the authors own related activities of Brix testing over the past three years, coupled with observation and taste testing experiences, suggest these metrics correlate to higher Brix values.

What we did

Grffn supplied Brix testing kits and ran two workshops with each of the procurement hubs to transfer skills and knowledge to the growers and staff. The intention was to get the staff at the hubs to carry out regular testing and recording of results and where possible engage the growers to do likewise. Whilst all attendees benefited from the workshops the novelty of testing food quality is still in its infancy and for many perhaps, the additional workload of collecting data was not seen to be adding value. Also, the testing is more reliable for assessing freshly harvested produce and the timing of the project was such that much of the produce such as carrots and potatoes were stored.

Between June and August 2023, the author visited many of the growers who supply Carmarthen and Newtown procurement hubs to harvest and test any fresh produce they had available. In total 15 sites were visited and over 300 freshly harvested vegetables, comprising 16 different crops, were tested. The sites included 12 local growers, one fruit and vegetable shop (Martin Rutter's, who also runs Powys Produce, the current supplier of public food procurement in North Wales), Glangwili Hospital, Carmarthen and an aeroponic facility at Cultivate.

As an integral part of Grffn's work to explore how to measure and promote the benefits of well grown food, additional results have been included for this report. These were collected by the author in 2021 from five retail outlets in Cardiff for a report commissioned by MS Jenny Rathbone (Member of the Senedd, Cardiff Central, Labour). The report was required for a debate led by Rathbone on "Nutrient Density of Local Fruit and Vegetables" at the Senedd, 22 September 2021. A range of fruits and vegetables were bought from Paul's Organic Veg (a local grower at Roath Farmers Market), a wholesaler, Waitrose, Tesco and Lidl. Paul's Organic Veg had the highest Brix scores in almost every category. After the debate Jenny Rathbone commented that she "*was very pleased by the Deputy Health Minister's response. There is clearly much more appetite in this Government for bearing down on the obesogenic environment that is shortening people's lives*."[7]

Methodology

Grffn's Methodology and recording sheets were followed and completed for all the samples. In summary this meant that all the produce was tested on the same day of harvesting / purchase using an optical Brix refractometer. Three Brix tests were taken for each crop to create an average score as well as a lowest and highest score. The results were then compared to Dr Carey Reams' Brix Tables of suggested food quality for each specific fruit or vegetable. This allows comparisons to be made between the values obtained from this study and how they relate to one of the four categories of suggested food quality 'poor', 'average', 'good' and 'excellent'.

See appendices for Grffn's Brix methodology and Brix tables

Results

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RESULTS

Where is it from and how was it grown?				Brix test						Quality				
Study Reference	Name of farm, grower or shop	Location	Growing Practice used (if known)	Species	Variety	Date tested	Brix 1	Brix 2	Brix 3		poor	average	good	excellent
										Apples	6	10	14	18
J Rathbone	Tesco	Cardiff	Unknown	Apples	Royal Gala	04/09/2021	13.0	13.0	13.5			13.2		
J Rathbone	Pauls Organic Veg	Cardiff	Organic	Apples	Robins	04/09/2021	13.0	13.0	12.0			12.7		
SF&G	Glangwili Hospital	Carmarthen	Unknown	Apples	green	25/06/2023	12.0					12.0		
SF&G	Richard Edwards	Newtown	No dig	Apples	Discovery?	10/08/2023	11.0	13.0	12.0			12.0		
J Rathbone	Waitrose	Cardiff	Unknown	Apples	Royal Gala	04/09/2021	12.0	12.0	12.0			12.0		
J Rathbone	Lidl	Cardiff	Unknown	Apples	Gala	04/09/2021	10.5	12.0	12.5			11.7		
J Rathbone	Wellfield Road Barrow	Cardiff	Unknown	Apples	Royal Gala	04/09/2021	10.0	11.0	11.0			10.7		
										Broad Beans	No scale suggested			
SF&G	Nevern Valley Veg	Carmarthenshire	No dig	Bean, Broad	The bean only	22/06/2023	15.0	16.0	20.0					
SF&G	Nevern Valley Veg	Carmarthenshire	No dig	Bean, Broad	Pod + bean	22/06/2023	10.0	15.0	12.0					
SF&G	Humma Ho	Carmarthenshire	No dig	Bean, Broad	Pod + bean	21/06/2023	10.0	11.5	11.5					
										Green Beans	4	6	8	10
SF&G	Richard Edwards	Newtown	No dig	Bean, Runner	Yellow	10/08/2023	7.2	7.5	7.0			7.2		
SF&G	John Philips	Newtown	No dig	Bean, Runner	scarlet emperor	11/08/2023	7.0	7.0	7.0			7.0		
SF&G	Richard Edwards	Newtown	No dig	Bean, Runner	Purple	10/08/2023	6.5	7.0	7.0			6.8		
SF&G	Richard Edwards	Newtown	No dig	Bean, Runner	Green	10/08/2023	6.0	6.0	6.0			6.0		
SF&G	Helen's Veg	Tenby		Bean, Runner	Prize Winer	23/06/2023	6.0	6.0	5.0		5.7			
SF&G	M. Rutter (Powys Produce)	Newtown	Conventional	Bean, Green		11/08/2023	5.0	6.0	4.5		5.2			
SF&G	M. Rutter (Powys Produce)	Newtown	Conventional	Bean, Runner		11/08/2023	5.0	5.0	5.3		5.1			
										Beets	6	8	10	12
SF&G	Ash & Elm Horticulture	Newtown	Agroecological	Beets	red	10/08/2023	17.0	16.0	16.0					16.3
SF&G	John Philips	Newtown	No dig	Beets	bolthardy	11/08/2023	14.5	13.0	14.0					13.8
SF&G	Richard Edwards	Newtown	No dig	Beets	round	10/08/2023	12.5	13.0	11.5					12.3
SF&G	Richard Edwards	Newtown	No dig	Beets	Cylindra	10/08/2023	11.0	14.0	11.0					12.0
SF&G	C&M Organics	Carmarthenshire	Min till	Beets	Boro	22/06/2023	9.0	10.0	9.5			9.5		
SF&G	Nevern Valley Veg	Carmarthenshire	No dig	Beets		22/06/2023	9.5	9.0	9.5			9.3		
										Carrots	4	6	12	18
SF&G	Richard Edwards	Carmarthenshire	No dig	Carrots		10/08/2023	9.0	9.0	11.5			9.8		
J Rathbone	Wellfield Road Barrow	Cardiff	Unknown	Carrots	?, with tops	04/09/2021	9.5	10.0	10.0			9.8		
SF&G	Humma Ho	Carmarthenshire	No dig	Carrots	rainbow	21/06/2023	9.0	8.0	9.0			8.7		
SF&G	M. Rutter (Powys Produce)	Newtown	Conventional	Carrots		11/08/2023	8.5	8.0	8.0			8.2		
SF&G	John Philips	Newtown	No dig	Carrots	Autumn King	11/08/2023	8.0					8.0		
J Rathbone	Pauls Organic Veg	Cardiff	Organic	Carrots	Nantes 2, with tops	04/09/2021	8.0	8.0	8.0			8.0		
J Rathbone	Waitrose	Cardiff	Organic	Carrots		04/09/2021	8.0	8.0	8.0			8.0		
J Rathbone	Wellfield Road Barrow	Cardiff	Unknown	Carrots	?	04/09/2021	8.0	8.0	8.0			8.0		
SF&G	Helen's Veg	Tenby		Carrots		23/06/2023	8.0	8.0	7.5			7.8		
SF&G	John Philips	Newtown	No dig	Carrots	Nantes	11/08/2023	7.0	8.0	8.5			7.8		
J Rathbone	Lidl	Cardiff	Organic	Carrots	?	04/09/2021	7.0	8.0	8.0			7.7		
J Rathbone	Tesco	Cardiff	Unknown	Carrots	?	04/09/2021	8.0	7.0	7.0			7.3		
J Rathbone	Waitrose	Cardiff	Unknown	Carrots	British Sweet Kingdc	04/09/2021	6.5	8.0	7.0			7.2		

RESULTS

Where is it from and how was it grown?				Brix test						Quality				
Study Reference	Name of farm, grower or shop	Location	Growing Practice used (if known)	Species	Variety	Date tested	Brix 1	Brix 2	Brix 3		poor	average	good	excellent
										Courgette (MA	4	6	8	10
J Rathbone	Tesco	Cardiff	Unknown	Courgette	?	04/09/2021	6.0	5.0	6.5		5.8			
SF&G	John Philips	Newtown	No dig	Courgette	zuchini	11/08/2023	5.0	5.5	5.5		5.3			
J Rathbone	Wellfield Road Barrow	Cardiff	Unknown	Courgette	?	04/09/2021	5.5	5.5	5.0		5.3			
SF&G	Richard Edwards	Newtown	No dig	Courgette	Soil based	10/08/2023	5.0	5.5			5.3			
J Rathbone	Lidl	Cardiff	Unknown	Courgette	?	04/09/2021	5.0	5.5	5.0		5.2			
J Rathbone	Waitrose	Cardiff	Organic	Courgette	?	04/09/2021	4.5	5.5	5.0		5.0			
SF&G	Nevern Valley Veg	Carmarthenshire	No dig	Courgette		22/06/2023	4.5	5.0	5.0		4.8			
SF&G	M. Rutter (Powys Produce)	Newtown	Conventional	Courgette		11/08/2023	6.0	4.0	4.5		4.8			
SF&G	Nevern Valley Veg	Carmarthenshire	No dig	Courgette		22/06/2023	4.0	4.0	4.5		4.2			
SF&G	C&M Organics	Carmarthenshire	Min till	Courgette	Dunja	22/06/2023	4.0				4.0			
SF&G	Richard Edwards	Newtown	No dig	Courgette	Compost pile	10/08/2023	4.0				4.0			
SF&G	Richard Edwards	Newtown	No dig	Courgette	Soil, diff variety	10/08/2023	4.0	3.0			3.5			
										Cucumbers	4	6	8	12
SF&G	C&M Organics	Carmarthenshire	Min till	Cucumbers	Akito F1	22/06/2023	3.5	3.5	3.5		3.5			
SF&G	Awen Organics	Carmarthenshire	No dig	Cucumbers	Passandra	22/06/2023	4.0	3.0	3.5		3.5			
SF&G	Ash & Elm Horticulture	Newtown	Agroecological	Cucumbers	small	10/08/2023	4.0	3.0	3.5		3.5			
SF&G	John Philips	Newtown	No dig	Cucumbers		11/08/2023	3.0	3.8			3.4			
SF&G	M. Rutter (Powys Produce)	Newtown	Conventional	Cucumbers		11/08/2023	3.0	3.0	4.0		3.3			
SF&G	Richard Edwards	Newtown	No dig	Cucumbers		10/08/2023	3.0				3.0			
SF&G	Ash & Elm Horticulture	Newtown	Agroecological	Herbs	Corriander	10/08/2023	9.0							
SF&G	Nevern Valley Veg	Carmarthenshire	No dig	Herbs	Basil	22/06/2023	5.0							
										Kale (MA)	6	8	10	12
SF&G	Humma Ho	Carmarthenshire	No dig	Kale	purple	21/06/2023	10.0	12.0	9.0				10.3	
SF&G	Richard Edwards	Newtown	No dig	Kale	Red, Curly	10/08/2023	10.0	9.5	10.5				10.0	
SF&G	Humma Ho	Carmarthenshire	No dig	Kale	curly	21/06/2023	9.5	9.5	10.0			9.7		
J Rathbone	Pauls Organic Veg	Cardiff	Organic	Kale	Green	04/09/2021	9.0	10.0	9.0			9.3		
SF&G	Richard Edwards	Newtown	No dig	Kale	Green, curly	10/08/2023	9.0	7.0	9.0			8.3		
J Rathbone	Waitrose	Cardiff	Unknown	Kale	Pentland brig	04/09/2021	8.0	7.5	8.0			7.8		
J Rathbone	Pauls Organic Veg	Cardiff	Organic	Kale	Red Russian	04/09/2021	8.0	7.0	8.0			7.7		
SF&G	Ash & Elm Horticulture	Newtown	Agroecological	Kale	Curly	10/08/2023	7.0	7.0	7.0			7.0		
SF&G	Nevern Valley Veg	Carmarthenshire	No dig	Kale	curly	22/06/2023	7.0	7.0	6.5			6.8		
J Rathbone	Waitrose	Cardiff	Unknown	Kale	Cavolo Nero	04/09/2021	7.5	6.0	7.0			6.8		
SF&G	C&M Organics	Carmarthenshire	Min till	Kale	West Winter	22/06/2023	6.5	6.5	6.5			6.5		
SF&G	Richard Edwards	Newtown	No dig	Kale	Cavelero Nero	10/08/2023	6.0	6.5	7.0			6.5		
J Rathbone	Lidl	Cardiff	Other	Kale	curly, shreded	04/09/2021	7.0	5.0	5.0		5.7			
J Rathbone	Tesco	Cardiff	Unknown	Kale	curly, shreded	04/09/2021	5.0	4.0	6.0		5.0			
Quality tables in red are suggestions by the author because no values for these crops have been listed														

RESULTS

Where is it from and how was it grown?				Brix test						Quality				
Study Reference	**Name of farm, grower or shop**	**Location**	**Growing Practice used (if known)**	**Species**	**Variety**	**Date tested**	**Brix 1**	**Brix 2**	**Brix 3**		**poor**	**average**	**good**	**excellent**
										Lettuce	4	6	8	10
SF&G	Blas Gwent	Cardiff	Agroecological	Lettuce	Celinet	21/06/2023	4.5	4.5	5.5		4.8			
SF&G	Ash & Elm Horticulture	Newtown	Agroecological	Lettuce	green	10/08/2023	3.5	4.0	4.0		3.8			
SF&G	Ash & Elm Horticulture	Newtown	Agroecological	Lettuce	red	10/08/2023	4.0	3.0	4.0		3.7			
SF&G	Cultivate	Newtown	No dig	Lettuce	green	11/08/2023	3.5	4.0	3.5		3.7			
J Rathbone	Pauls Organic Veg	Cardiff	Organic	Lettuce	?	04/09/2021	3.0	4.0	4.0		3.7			
SF&G	Awen Organics	Carmarthenshire	No dig	Lettuce	Seurat (red)	22/06/2023	3.5	3.0	3.5		3.3			
J Rathbone	Waitrose	Cardiff	Organic	Lettuce	Little Gem	04/09/2021	4.0	3.0	3.0		3.3			
SF&G	Monmouth Wildlife Trust	Newtown	No dig	Lettuce		11/08/2023	3.0	3.0	3.5		3.2			
SF&G	Helen's Veg	Tenby		Lettuce	Little Gem	23/06/2023	3.5	2.5	3.0		3.0			
SF&G	Awen Organics	Carmarthenshire	No dig	Lettuce	Maureen (green)	22/06/2023	3.0	2.5	3.0		2.8			
SF&G	Nevern Valley Veg	Carmarthenshire	No dig	Lettuce		22/06/2023	3.0	3.0	2.5		2.8			
SF&G	Helen's Veg	Tenby		Lettuce	Lollow Roso	23/06/2023	3.0	2.5	2.5		2.7			
J Rathbone	Tesco	Cardiff	Unknown	Lettuce	Little Gem	04/09/2021	2.5	3.0	2.5		2.7			
SF&G	Richard Edwards	Newtown	No dig	Lettuce		10/08/2023	3.0	2.5	2.0		2.5			
SF&G	Richard Edwards	Newtown	No dig	Lettuce		10/08/2023	3.0	2.0	2.0		2.3			
SF&G	M. Rutter (Powys Produce)	Newtown	Conventional	Lettuce		11/08/2023	2.0	3.0	2.0		2.3			
J Rathbone	Lidl	Cardiff	Other	Lettuce	Little gem	04/09/2021	2.0	3.0	2.0		2.3			
J Rathbone	Waitrose	Cardiff	Unknown	Lettuce	Sweet Cos	04/09/2021	2.0	2.0	3.0		2.3			
J Rathbone	Wellfield Road Barrow	Cardiff	Unknown	Lettuce	Little gem	04/09/2021	2.0	2.5	2.5		2.3			
J Rathbone	Lidl	Cardiff	Unknown	Lettuce	Trio (L. Rosso, L. Bio	04/09/2021	2.0	1.0	2.0		1.7			
										Potatoes	3	5	7	8
SF&G	Helen's Veg	Tenby		Potatoes	Malody	23/06/2023	7.0	7.5	7.5				7.3	
J Rathbone	Pauls Organic Veg	Cardiff	Organic	Potatoes	Maris Piper	04/09/2021	7.0	7.0	7.0				7.0	
J Rathbone	Wellfield Road Barrow	Cardiff	Unknown	Potatoes	Maris Piper	04/09/2021	6.0	6.5	5.5			6.0		
J Rathbone	Waitrose	Cardiff	Unknown	Potatoes	Maris Piper	04/09/2021	5.0	6.0	5.0			5.3		
SF&G	John Philips	Newtown	Min till	Potatoes	Desiere	11/08/2023	5.0	5.5	5.0			5.2		
SF&G	M. Rutter (Powys Produce)	Newtown	Conventional	Potatoes	Shropshire	11/08/2023	5.5	4.5	5.5			5.2		
SF&G	John Philips	Newtown	Min till	Potatoes	Charolotte (white), e	11/08/2023	4.5	5.0	5.5			5.0		
SF&G	Richard Edwards	Newtown	Min till	Potatoes	2nd early	10/08/2023	5.0	4.5	5.0			4.8		
J Rathbone	Lidl	Cardiff	Unknown	Potatoes	Maris Piper	04/09/2021	5.0	4.5	4.5			4.7		
SF&G	John Philips	Newtown	Min till	Potatoes	Cara, late	11/08/2023	4.5	4.0	4.5			4.3		
J Rathbone	Tesco	Cardiff	Unknown	Potatoes	Maris Piper	04/09/2021	4.0	4.0	4.0			4.0		

RESULTS

Where is it from and how was it grown?				Brix test						Quality				
Study Reference	**Name of farm, grower or shop**	**Location**	**Growing Practice used (if known)**	**Species**	**Variety**	**Date tested**	**Brix 1**	**Brix 2**	**Brix 3**		**poor**	**average**	**good**	**excellent**
										Spinach (MA)	6	8	10	12
SF&G	Ash & Elm Horticulture	Llanidloes, Newtowr	Agroecological	Spinach	baby	10/08/2023	4.0	4.5	4.0		4.2			
J Rathbone	Waitrose	Cardiff	Unknown	Spinach	?	04/09/2021	3.0	3.5	3.0		3.2			
J Rathbone	Wellfield Road Barrow	Cardiff	Unknown	Spinach	?	04/09/2021	3.5	3.0	3.0		3.2			
J Rathbone	Lidl	Cardiff	Organic	Spinach	?	04/09/2021	3.0	3.0	2.5		2.8			
J Rathbone	Tesco	Cardiff	Unknown	Spinach	?	04/09/2021	3.5	3.0	2.0		2.8			
										Swiss Chard (M	6	8	10	12
J Rathbone	Pauls Organic Veg	Cardiff	Organic	Swiss chard	?	04/09/2021	6.0	7.5	7.0		6.8			
SF&G	Ash & Elm Horticulture	Newtown	Agroecological	Swiss chard	rainbow	10/08/2023	8.5	5.0	3.5		5.7			
J Rathbone	Waitrose	Cardiff	Unknown	Swiss chard	?	04/09/2021	5.0	5.5	5.5		5.3			
SF&G	Awen Organics	Carmarthenshire	No dig	Swiss chard	rainbow	22/06/2023	5.5	5.0	5.0		5.2			
SF&G	Blas Gwent	Cardiff	Agroecological	Swiss chard	yellow	21/06/2023	5.5	5.5	4.5		5.2			
SF&G	Nevern Valley Veg	Carmarthenshire	No dig	Swiss chard	Rainbow	22/06/2023	7.0	3.5	4.5		5.0			
SF&G	Humma Ho	Carmarthenshire	No dig	Swiss chard	rainbow	21/06/2023	4.5	5.0	5.0		4.8			
SF&G	C&M Organics	Carmarthenshire	Min till	Swiss chard	Rainbow	22/06/2023	3.5	5.0	4.0		4.2			
SF&G	Awen Organics	Carmarthenshire	No dig	Swiss chard	Rainbow	22/06/2023	3.5	4.0	4.0		3.8			
Quality tables in red are suggestions by the author because no values for these crops have been listed														

RESULTS

Where is it from and how was it grown?				Brix test						Quality				
Study Reference	**Name of farm, grower or shop**	**Location**	**Growing Practice used (if known)**	**Species**	**Variety**	**Date tested**	**Brix 1**	**Brix 2**	**Brix 3**		**poor**	**average**	**good**	**excellent**
										Tomatoes	4	6	8	12
J Rathbone	Pauls Organic Veg	Cardiff	Organic	Tomatoes, cherry	Orange	04/09/2021	9.0	9.0	9.0				9.0	
SF&G	Monmouth Wildlife Trust	Newtown	Bio fertilisers	Tomatoes, cherry	red, round	11/08/2023	8.0	9.5	9.0				8.8	
SF&G	Richard Edwards	Newtown	No dig	Tomatoes, cherry	Gardeners ectasy	10/08/2023	8.2	8.0	8.2				8.1	
SF&G	John Philips	Newtown	No dig	Tomatoes, cherry	Sungold	11/08/2023	8.0	8.0	7.5			7.8		
SF&G	John Philips	Newtown	No dig	Tomatoes, cherry	Gardeners delight	11/08/2023	7.0	7.5	8.0			7.5		
SF&G	C&M Organics	Carmarthenshire	Min till	Tomatoes, cherry	Sakura F1	22/06/2023	7.5	7.5	7.0			7.3		
J Rathbone	Waitrose	Cardiff	Organic	Tomatoes, cherry	Angelle (Baby Plum)	04/09/2021	8.0	7.0	7.0			7.3		
J Rathbone	Wellfield Road Barrow	Cardiff	Unknown	Tomatoes, cherry	?	04/09/2021	6.5	7.5	8.0			7.3		
SF&G	Ash & Elm Horticulture	Newtown	Agroecological	Tomatoes, cherry	yellow, plum	10/08/2023	6.5	7.0	7.0			6.8		
SF&G	Richard Edwards	Newtown	No dig	Tomatoes, cherry	Black Cherry	10/08/2023	6.0	7.0	7.0			6.7		
J Rathbone	Pauls Organic Veg	Cardiff	Organic	Tomatoes, cherry	Purple	04/09/2021	7.0	7.0	6.0			6.7		
SF&G	Cultivate	Newtown	No dig	Tomatoes, cherry	round	11/08/2023	6.2	7.0	6.5			6.6		
J Rathbone	Lidl	Cardiff	Other	Tomatoes, cherry	Marvellous	04/09/2021	6.0	6.5	7.0			6.5		
J Rathbone	Tesco	Cardiff	Other	Tomatoes, cherry	Piccalo	04/09/2021	6.5	6.5	6.0			6.3		
SF&G	M. Rutter (Powys Produce)	Newtown	Conventional	Tomatoes, salad	on the vine, red, rou	11/08/2023	6.0	7.0	6.0			6.3		
SF&G	Richard Edwards	Newtown	No dig	Tomatoes, cherry	Gold, Tana	10/08/2023	5.0	7.0	6.5			6.2		
J Rathbone	Tesco	Cardiff	Unknown	Tomatoes, cherry	Genio	04/09/2021	6.5	6.0	6.0			6.2		
SF&G	Ash & Elm Horticulture	Newtown	Agroecological	Tomatoes, cherry	yellow	10/08/2023	6.0	6.0	6.0			6.0		
SF&G	Richard Edwards	Newtown	No dig	Tomatoes, salad	banana	10/08/2023	6.0	6.0	6.0			6.0		
SF&G	Cultivate	Newtown	No dig	Tomatoes, cherry	plum	11/08/2023	5.0	6.0	6.0		5.7			
SF&G	Ash & Elm Horticulture	Newtown	Agroecological	Tomatoes, salad	red	10/08/2023	5.5	5.5	6.0		5.7			
J Rathbone	Tesco	Cardiff	Unknown	Tomatoes, salad	Brioso	04/09/2021	6.0	5.5	5.5		5.7			
SF&G	Richard Edwards	Newtown	No dig	Tomatoes, cherry	Matina	10/08/2023	6.0	5.0	5.0		5.3			
SF&G	Richard Edwards	Newtown	No dig	Tomatoes, cherry	Goch, YDDRA16	10/08/2023	4.5	4.5	6.5		5.2			
J Rathbone	Pauls Organic Veg	Cardiff	Organic	Tomatoes, salad	?	04/09/2021	4.0	5.5	5.5		5.0			
J Rathbone	Wellfield Road Barrow	Cardiff	Unknown	Tomatoes, salad	?	04/09/2021	5.0	4.5	5.0		4.8			
J Rathbone	Waitrose	Cardiff	Unknown	Tomatoes, salad	? (large, vine)	04/09/2021	5.0	4.5	4.5		4.7			
J Rathbone	Lidl	Cardiff	Unknown	Tomatoes, salad	?	04/09/2021	4.0	4.0	4.0		4.0			
J Rathbone	Tesco	Cardiff	Other	Tomatoes, salad	Mediax 47/57	04/09/2021	3.5	4.0	4.0		3.8			
J Rathbone	Lidl	Cardiff	Organic	Tomatoes, salad	Chelino	04/09/2021	3.0	4.0	3.0		3.3			

RESULTS

Where is it from and how was it grown?				Brix test						Quality				
Study Reference	**Name of farm, grower or shop**	**Location**	**Growing Practice used (if known)**	**Species**	**Variety**	**Date tested**	**Brix 1**	**Brix 2**	**Brix 3**		**poor**	**average**	**good**	**excellent**
										Cabbage	6	8	10	12
SF&G	Hook Farm Vegetables	Tenby		Cabbage	Hipsi	23/06/2023	6.0				6.0			
SF&G	Hook Farm Vegetables	Tenby		Cabbage	Savoy	23/06/2023	4.0				4.0			
										Parsnips	No scale suggested			
SF&G	Ash & Elm Horticulture	Newtown	Agroecological	OTHER	Baby parsnips	10/08/2023	10.0	10.0	9.5					
										English Peas	8	10	12	14
SF&G	Richard Edwards	Newtown	No dig	Peas, English		10/08/2023	13.0	13.5	11.0				12.5	
SF&G	Blas Gwent	Cardiff	Agroecological	Peas, English	mangetout, Beijou	21/06/2023	9.5	10.0	9.5		9.7			
										Onions	4	6	8	10
SF&G	Helen's Veg	Tenby		Onions	Sturon	23/06/2023	14.0	11.0	12.5					12.5
SF&G	Glangwili Hospital	Carmarthen	Unknown	Onions	?	23/06/2023	8.0	8.0	8.0				8	
										Micro Greens	No scale suggested			
SF&G	MicroGreens @ Cultivate	Newtown	No dig	OTHER	Green Pea, ?	11/08/2023	7.0	6.5	6.0					
SF&G	MicroGreens @ Cultivate	Newtown	No dig	OTHER	Sunflower, micro	11/08/2023	4.0	4.0	4.2					
SF&G	MicroGreens @ Cultivate	Newtown	No dig	OTHER	Radish, Roji	11/08/2023	2.0	2.0	2.2					
										Weeds	No scale suggested			
SF&G	Humma Ho	Carmarthenshire	No dig	Weed	Fat Hen	21/06/2023	9.0	10.5		Weeds can be useful indicators!				
SF&G	Blas Gwent	Cardiff	Agroecological	Weed	Thistle (mushroom	21/06/2023	12.0			Brix 12 and above for a leaf is considered				
SF&G	Blas Gwent	Cardiff	Agroecological	Weed	Thistle (field)	21/06/2023	8.0	8.5	8.5	excellent and will be free from pest and disease.				

Observations

Lettuce (20 samples) these are all in the poor category however, the values run between 1.7 and 4.8 suggesting a range of qualities exist. The highest value was a variety called Celinet which was grown using agroecological principles. The lowest five values came from supermarkets and wholesalers where their freshness is not known, which mean the results are not as reliable. We know that when crops dehydrate the Brix value will increase because the ratio of water to solid matter is altered. However, to keep foods fresh (prevent dehydration) they must be refrigerated which suggests not only is the lettuce of low quality but it's also consuming excess energy in refrigeration to prop it up.

Tomatoes (31 samples) were identified as either being salad (10) or cherry (21) and its clear to see that most salad tomatoes were found towards the bottom of the table. Of note was the highest Brix value for a cherry tomato in 2023. This was being grown by Monmouthshire Wildlife Trust in a shared polytunnel space at Cultivate, Newtown. What made this stand out was not just its exceptional taste but that the way it was being grown involved making and using biological fertilisers. This creates an example of how this work can identify best practice and how other growers might care to investigate themselves and compare values next year to see what happened.

Kale (14 samples) demonstrated a good range with ratings in the poor, average and good columns but no 'excellent'.

Spinach (5 samples) and **chard** (9 samples), much like lettuce were all in the poor column except Pauls Organic chard. This is encouraging as it suggests more than 'poor' can be achieved.

Potatoes (12 samples) turned up an unexpected high score for Glangwili Hospital, Carmarthen. However, this score is not reliable because its freshness is not known and the potatoes had been delivered ready peeled.

What does this mean?

We clearly see an ordering of Brix values from high to low, suggesting a measurement system could be developed that could rank crop quality from poor to excellent. For some vegetables e.g., spinach, lettuce and chard the Brix values associated with the quality categories require further research to either verify or re-assign the Brix values. To validate the difference between high and low quality exploring sensory data relating to the four quality metrics e.g. taste and resistance to pests can be developed alongside laboratory analysis of high and low Brix samples for nutrient composition.

Higher Brix values suggest the plant is more efficient at photosynthesis. According to J Kempf of Advancing Ecological Agriculture, plant photosynthesis can be increased by a factor of 3 or 4 times when a plant has access to the correct nutrition (chemistry and micro-biology).[8] This means more carbohydrate is produced in efficient plants of which up to 40% is converted into root exudates to feed soil microbes. This provides more basic building blocks for the plant to create a more diverse range of beneficial nutrients to increase health and immunity of itself and the food chain it supports.

Whilst there are many variables to take into account that can affect the Brix score for example, freshness of produce, time of day tested and maturity of plant the results show a trend for locally grown food being of higher quality than supermarket produce. Statistical analysis of these results would help support this idea, including development of a robust scoring system that takes variables such as freshness into account so improved comparisons can be made. This would also give the potential for developing a food quality standard that encourages natural innovation to increase nutrient density.

Discussion

A loss of food quality? A review of historical data indicates a loss of nutrients in fruits and vegetables since the Second World War in the UK and USA[9]. This coincides with the Green Revolution of the 1950's and 1960's and the widespread use of synthetic fertilisers, herbicides, fungicides, pesticides and seed breeding, to increase yield. This had the effect of linking food quality to yield which is related to profitability and food production became dominated by business values. According to research by David Thomas, an average, 40% of mineral content was lost from the UK food supply chain between 1940 and 1991.[10] Anne-Marie Mayer, another researcher found similar results.

> *A comparison of the mineral content of 20 fruits and 20 vegetables grown in the 1930s and the 1980s shows that there are statistically significant reductions in the levels of Ca, Mg, Cu, and Na in vegetables and Mg, Fe, Cu and K in fruit. The only mineral not to decline was P.* ***The water content increased significantly, and dry matter decreased significantly in fruit****. This indicates that a nutritional problem associated with the quality of food has developed over those 50 years.*[11]

If a change in dry matter to water content is related to a decline in mineral content, then recording Brix values during this time might have detected this potential loss of nutrients. If this had been the case, perhaps a different course of action regarding food quality could have been implemented.

Beyond labels (a guarantee of nutritional quality). Many trials and research projects have tried to link increased nutrition to labels such as Organic Certification[12]. However, the official view from Government and the Food standards Authority is repeated[13],[14]

> *there are no important differences in the nutrition content, or any additional health benefits, of organic food when compared with conventionally produced food.* (FSA, 2009)[15]

Whilst Organic Certification has many benefits, it relates more to a production process which cannot guarantee nutritional quality. Whilst the use of chemical inputs is reduced there is no guarantee the nutritional quality of the crops will be of the same quality from an organic field scale monocropping system compared to a small-scale diverse market garden. Indeed, the Brix results highlight this.

Greenwashing. There is currently an explosion of different labels claiming new ways of growing food e.g., Regenerative and Agroecological and many more. Some of these are developing certification standards whilst others e.g., Regenerative is more open to interpretation. Consequently, companies worth USD 3 trillion mention regenerative agriculture initiatives in their disclosures but only 8% have targets to support the farmers adopting these practices.[16,17] As this report alludes to, with more research it could be shown that to grow high quality, nourishing food would achieve the claimed outcomes of Organic and Regenerative practices. This includes increased carbon capture, increased soil health, biodiversity and water quality, reduced chemical inputs and improved farmer incomes. In other words, the quality of food itself, becomes the guarantee.

Food as medicine. A peer reviewed, clinical trial in 2021 studied the effect of heritage varieties of leafy green vegetables compared to modern varieties on people with type two diabetes. After being on the diet for twelve weeks 70% of those eating heritage varieties came off their medication. The lead researcher suggests this may be due to heritage varieties having increased levels of bitter compounds (polyphenols).[18] This example highlights the importance of heritage seed varieties.

Understanding the nutritional qualities of a plant, being able to easily measure it and setting quality standards that encourage all food to be 'excellent' would reverse a loss of nutrition, overcome problems of certification and greenwashing and increase the health of people and planet.

Conclusion

This report offers an insight into understanding food quality issues by generating a table of results for a range of vegetables using a handheld Brix refractometer. The value of this exercise is to generate discussion around food quality issues and support further development of these ideas.

The results show a ranking from high Brix values to low Brix values for each crop tested. When average values are put into the Brix tables it suggests a quality ranking can be created that relates to how well a plant has grown. This is based on a plants ability to photosynthesise efficiently and produce an excess of carbohydrate; the building blocks a plant requires to produce a more diverse range of beneficial nutrients that promote healthy ecosystems.

In the discussion, the benefits of developing a food quality standard are explored, including the potential for food as medicine to tackle degenerative disease. This has become a focus for American policy with the aim of cutting cancer deaths by 50% in 25 years.[19] In 2022 the United States Department of Agriculture (USDA) launched the Agricultural Science Centre of Excellence for Nutrition and Diet for Better Health (ASCEND for Better Health) in support of President Biden's Cancer Moonshot.[20] As Shavonda Jacobs-Young, USDA Chief scientist explains, their renewed aim is to "use food and nutrition to reduce the risk of diet related chronic diseases, including cancer".[21] The environmental benefits coupled with higher 'food quality standards' include an increase in soil health, water quality, biodiversity and carbon capture as its locked into promoting local ecosystems.

Food quality is poorly understood at a National, European and international level. The **Social Partnership and Public Procurement (Wales) Act 2023** has placed a responsibility on Local Authorities in Wales to procure **20% of goods locally**.[22] A focus on understanding the concept of nutrient dense food and developing a food quality standard in Wales could lead the field by showcasing how this can work to support the health of people and planet. Grffn welcomes support and collaboration to develop these ideas by increasing local food production that's focused on supporting the health and well-being of local communities.

Recommendations

The aim is to develop a food standard that sets a benchmark for well grown food plants of 'excellent' quality. This would create a culture of learning how to work with natural principles and create multiple opportunities for scientific studies and validation of all the benefits. Farmers and growers reaching or surpassing such a benchmark would be validated by the food quality standard, which brings transparency and elevates their value in society to the level they deserve. Four key recommendations to help move this forward are:

- Food Quality standards – Support collaborative research and projects that investigates food quality with the aim of developing food quality standards that can be easily measured
- 20% of local goods - Support local employment by encouraging growers to return to the land and increase knowledge on how to grow and process nourishing nutrient dense food
- Food as medicine - Develop clinical trials aimed at reversing degenerative diseases with diets comprising 'excellent' quality food, packed full of high-quality nutrients
- Monitor environmental benefits – Promoting an 'Excellent' food quality standard is related to increasing soil health, carbon sequestration, water quality and biodiversity

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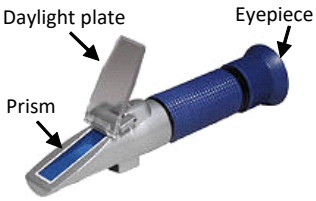
Appendix 1 - Brix Testing Methodology

Introduction

A Brix refractometer measures the Total Dissolved Solids (TDS) in a liquid. When light is passed through a liquid onto a prism, the angle of refraction is altered by the concentration of TDS present in the liquid. This is measured as ^{O}Brix. Pure water has no TDS and will read 'zero' ^{O}Brix. Plant sap consists of water plus the products of photosynthesis that are soluble in water - including sucrose, fructose, many of the vitamins and minerals, amino acids, proteins, hormones, etc. The amount (or density) of these substances in the sap will change the angle of light refraction accordingly, hence the ^{O}Brix value.

Equipment

Handheld Brix refractometer (0-32)
Sap press
Sharp knife
Soft cleaning cloth
Recording sheet



To calibrate a Brix refractometer (check it reads 'zero')

Place 2 or 3 drops of distilled water (or clean tap water) on the prism, close the daylight plate to exclude any air bubbles then point the prism towards a light source and look into the eyepiece (twist to focus) to read the numerical scale. The ^{0}Brix value is taken where the upper blue portion meets the lower white portion on the numerical scale. If this reads 'zero' ^{0}Brix then it is already calibrated, and the test can proceed. If not, please follow the manufacturer's calibration instructions (included in the box).

Obtain a plant sample for Brix testing

Use whichever part of the plant you would eat, if it is ripe e.g. for a carrot obtain a sample by cutting a mid-section or for a lettuce pick a freshly matured leaf and fold to fit the jaws of the sap press. Before pressing do not wash. To avoid false readings, use a soft cloth to remove any dirt or moisture. If testing pasture, take a handful of grasses (without roots) and for grains, use the flag leaf (top-most mature leaf).

Using the sap press

The locking point, when the jaws are fully closed, is adjusted by turning the thumbscrew (see image above). If required, set a wide locking point to make an initial press. Open the press, turn the thumbscrew clockwise and make a second press. Wait a few seconds for the sap to appear.

Using the Brix refractometer

- Place 2 or 3 drops of sap onto the prism and close the daylight plate
- Point towards a light source and focus the eyepiece
- Read the Brix value to the nearest 0.5 ^{0}Brix, e.g. the image opposite shows a Brix value of 14.0 for an English pea
- Clean the lens and sap press between each Brix test with a soft cloth

Note: the bamboo cloth provided in the Brix kit can be washed and reused many times.
Tip: wet one half of the cloth and wring out so it's damp. Clean with the damp half first and then dry.

How does the Brix value relate to food quality?

Match the Brix value of the sample with the corresponding crop in the Brix Tables to determine whether its quality, based on nutrient density is: 'poor', 'average', 'good' or 'excellent'.

Appendix 2 - Brix Tables

Brix Tables – The refractive index of crop juices calibrated in °Brix

	Poor	Average	Good	Excellent			Poor	Average	Good	Excellent
FRUITS						**VEGETABLES**				
Apples	6	10	14	18		Asparagus	2	4	6	8
Avocados	4	6	8	10		Beets	6	8	10	12
Bananas	8	10	12	14		Bell Peppers	4	6	8	12
Blueberries	10	14	16	20		Broccoli	6	8	10	12
Cantaloupe	8	12	14	16		Cabbage	6	8	10	12
Casaba	8	10	12	14		Carrots	4	6	12	18
Cherries	8	10	12	14		Cauliflower	4	6	8	10
Coconut	8	10	12	14		Celery	4	6	10	12
Grapes	8	12	16	20		Corn Stalks	4	8	14	20
Grapefruit	6	10	14	18		Corn (young)	6	10	18	24
Kumquat	4	6	8	10		Cow peas	4	6	10	12
Lemons	4	6	8	12		Cucumbers	4	6	8	12
Limes	4	6	10	12		Endives	4	6	8	10
Mangos	4	6	10	14		English Peas	8	10	12	14
Oranges	6	10	16	20		Field Peas	4	6	10	12
Papayas	6	10	18	22		Green Beans	4	6	8	10
Peaches	6	10	14	18		Hot Peppers	4	6	8	10
Pears	6	10	12	14		Kohlrabi	6	8	10	12
Pineapple	12	14	20	22		Lettuce	4	6	8	10
Raisins	60	70	75	80		Onions	4	6	8	10
Raspberries	6	8	12	14		Parsley	4	6	8	10
Strawberries	6	10	14	16		Peanuts	4	6	8	10
Tomatoes	4	6	8	12		Potatoes	3	5	7	8
Watermelons	8	12	14	16		Potatoes, Sweet	6	8	10	14
						Romaine	4	6	8	10
GRASSES						Swede	4	6	10	12
Alfalfa	4	8	16	22		Squash	6	8	12	14
Grains	6	10	14	18		Sweet Corn	6	10	18	24
Sorghum	6	10	22	30		Turnips	4	6	8	10

The Brix Tables were created in the early 1970's by American soil scientist Dr Carey Reams. Following a successful career running a large Agricultural laboratory service testing soils and plants, combined with observations in the field, Reams suggested that when 'excellent' Brix values are achieved, the plant will:

1. be completely resistant to pests and diseases
2. give higher yields of more uniform growth
3. taste better
4. have a longer shelf life.

Join Grffn's Community of Practice and share your results

Grffn is a not-for-profit exploring how to grow, measure and promote the benefits of nutrient dense food. For more information, download a recording sheet and share results, please visit www.grffn.org