SUSTENIR agriculture

Step 1: Calculate the daily volume of leafy greens imported to Singapore

The total value of leafy greens imported per year to Singapore is **USD $39,110,000**.
The price per kilogram is **USD$1.193**.

Leafy green import volume per year:
Annual value / price per kilogram = $39,110,000 / $1.193 = 32,796,646 kg
Total volume of leafy greens imported to Singapore in a year**: 32,796,646 kg.**

The daily volume of leafy greens imported to Singapore.
Annual volume / 365 Days = 32,796,646 kg / 365 = 89,854kg
The daily volume of leafy greens imported to Singapore is **89,854kg.**

Step 2: Calculate the average (weighted) distance from key markets

The top 4 markets from where leafy greens are imported to Singapore are **China (60%), Malaysia (12%), Indonesia (6%) and Australia (6%).**

We then calculated the distances from the nearest international airports in leafy greens producing cities in each of the markets to Singapore.

Guangzhou Baiyun International Airport, China	Changi Airport, Singapore	2,567 km
KL International Airport, Malaysia	Changi Airport, Singapore	300 km
Tanjung Balai Airport, Riau, Indonesia	Changi Airport, Singapore	259 km
Brisbane Airport, Australia	Changi Airport, Singapore	6142 km

Using the volume contribution and distances we calculated a weighted average distance:
Average distance (weighted) = (60% x 2,567) + (12% x 300) + (6% x 259) + (6% x 6,142) = 1,953 km

The average distance between key markets importing leafy greens and Singapore is **1,953 km.**

Step 3: Calculate the daily carbon cost of importing leafy greens

From an internal study, we have learned that the $kgCO_2e$ of transporting 1kg of leafy greens from Brisbane, Australia to Singapore is **6.878 $kgCO_2e$**.

We then indexed the weighted average distance calculated in Step 2 against the distance between Brisbane, Australia and Singapore to calculate the carbon footprint of importing 1 kg leafy greens to Singapore

Import Distance Index: Average Weighted Distance / Distance between Brisbane, Australia and Singapore = 1,953 / 6,142 = 0.318

Carbon Cost of transporting 1 kg of Leafy Greens to Singapore:
Carbon cost of transporting from Brisbane, Australia * Import Distance Index
= 6.878 x 0.318 = 2.19$kgCO_2e$

Carbon cost of importing 1 kg of leafy greens to Singapore is equal to **2.19 $kgCO_2e$**

Daily Carbon Cost = Daily Import Volume x Carbon Cost of Importing 1 kg
= 89,854 kg per day x 2.19 = 196,527.49 $kgCO_2e$
Carbon cost of the 89,854 kg of strawberries imported daily is **196,528 $kgCO_2e$**

Step 4: Calculate the carbon cost of leaving a car engine running

Next, we looked at the $kgCO_2e$ cost of an idling car. **10 min of idling releases 0.5$kgCO_2e$**
This means that in 1 hour, an engine left running has a carbon emission of **3$kgCO_2e$** and in 24 hours, **72$kgCO_2e$.**

Step 5: Compare the carbon cost of daily leafy green imports to a car engine running

Looking at our total daily carbon cost of importing leafy greens and dividing by the carbon cost of keeping an engine running, we were able to calculate how many days it would take an idling car to each the same figure.
Daily carbon cost of importing leafy greens to Singapore / Carbon cost of engine running all day
= 196,527.49 / 72 = 2,730 days =7.48 years **Or about 7 years.**

Sources:
https://www.tridge.com/intelligences/kale/import
https://www.edf.org/attention-drivers-turn-your-idling-engines

2019

Transport Emissions from Fresh Produce Transported to Singapore

Study commissioned by Iris Worldwide

AUTHORS

Report author: Xana Villa García, 3Keel LLP.

USAGE

This report is intended to inform Iris Worldwide on the emissions from transportation. If figures or excerpts are to be used, the full report must be made available to interested parties.

ACRONYMS

CO_2e	Carbon Dioxide Equivalents
GHG	Greenhouse Gas
GWP	Global warming potential
IPCC	Intergovernmental Panel on Climate Change
n/a	Not Applicable

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FIGURES & TABLES

FIGURES

TABLES

1 EXECUTIVE SUMMARY

As part of the drive to understand the impacts of transporting produce over large distances, including using aircraft, Iris Worldwide commissioned 3Keel LLP to conduct a transport carbon footprint analysis for five types of produce from different international locations.

The brief study has been conducted in line with good practice carbon footprint requirements, but it has not been subjected to independent, third party critical review which is recommended for statements and claims made as public disclosures.

The study focussed on the transportation of 1 kilogram of cooled, fresh produce from farm gate to distribution centres in Singapore. Farms are located in Australia, USA, and Singapore. Kale, lettuce and strawberries were the produce items nominated for analysis.

Data were received from Iris on kale grown in Australia and strawberries in the USA, along with data of importers of these products to Singapore. Data were also received on the location of the urban farm in Singapore where kale and strawberries are grown.

Results show that transporting produce by aircraft is very carbon intensive, and produce arriving form the USA has the highest carbon footprint of the fruits and vegetables analysed.

Figure 1: Final results for transporting 1 kilogram of fresh produce to destination point in Singapore.

	Road $kgCO_2e$		Air $kgCO_2e$	TOTAL $kgCO_2e$
Country/Produce	**Outside Singapore**	**Inside Singapore**	**Air**	
Australian kale	0.015	0.002	6.861	6.878
Australian lettuce	0.015	0.002	6.861	6.878
US strawberry	0.059	0.002	16.345	16.407
Singapore kale		0.003		0.003
Singapore strawberries		0.003		0.003

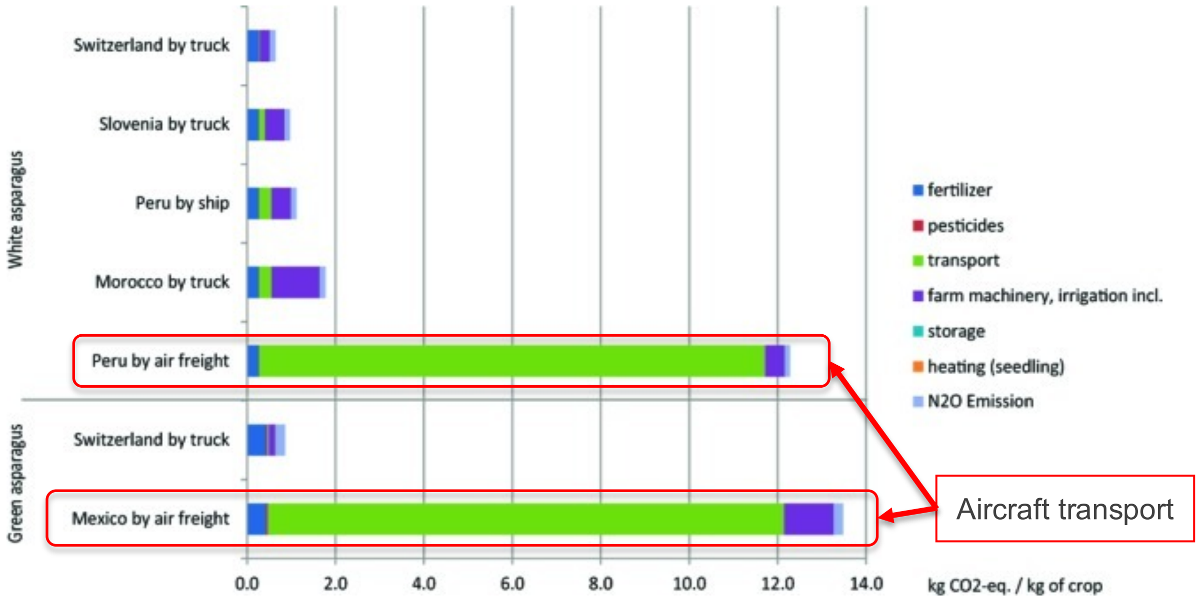
2 Introduction

2.1 Project background

As part of the drive to understand the impacts of transporting produce over large distances by aircraft, Iris Worldwide commissioned 3Keel LLP to conduct a transport carbon footprint analysis for five types of produce.

Published literature consistently shows that transporting fresh produce by aircraft is the most significant contributor to the total carbon footprint of fruits and vegetables, including pre-farm processes, such as impacts from irrigation infrastructure; on-farm activities, like fertiliser application; and post-farm components, such as packaging.

Figure 2: Example of GWP associated with asparagus imported to Switzerland from different countries of origin, (Stoesselet al., 2012).



Furthermore, the ecoinvent dataset representing transport of reefer (refrigerated container) on a freight plane, states: “Transport of food by plane is by far the most expensive type of transport with the highest environmental impact.”

2.2 Goal of the study

The goal of this study is to provide a bespoke farm gate-to-distribution centre carbon footprint comparing five fresh fruit and vegetables grown in different countries and transported to specific distribution centres in Singapore. This study covers only the transport footprint.

Table 1: Fruits and vegetable examined in the transport carbon footprint, Iris Worldwide, 2019.

Country of cultivation	Fruit/Vegetable types	Transport mode
Australia	Lettuce	Lorry; Aircraft
Australia	Kale	Lorry; Aircraft
USA	Strawberry	Lorry; Aircraft
Singapore	Kale	Lorry
Singapore	Strawberry	Lorry

3 SCOPE OF THE CARBON FOOTPRINT

3.1 FUNCTIONAL UNIT AND REFERENCE FLOW

The functional unit is 1 kilogram of cooled, fresh produce from farms in Australia, USA, and Singapore to storage in distribution centre in Singapore.

The reference flow is the transport of the fresh produce from farm gate to distribution centre.

3.2 SYSTEM BOUNDARIES

System boundaries delimit the extent of the study and determine which life cycle stages are included in the analysis. This farm gate-to-distribution carbon footprint covers only transport.

3.2.1 Excluded processes

The following components have been excluded from the carbon footprint:

- Pre-farm processes (production and transport of agrichemicals; etc)
- On-farm processes (energy and water use; application of fertilisers; etc)
- Production and disposal of packaging
- Warehousing
- Distribution to consumers
- Retail
- Consumer use
- Produce waste
- Capital goods

3.3 GLOBAL WARMING POTENTIAL

The carbon footprint is a measure of the total amount of greenhouse gases (GHG) emitted by a product or process measured in carbon dioxide equivalents as determined by a range of different Global Warming Potential (GWP) methodologies. The most common methodology, and the one used for company and national reporting under international protocols is developed by the International Panel on Climate Change (IPCC). For this study, IPCC 2013 GWP factors, 100-year horizon, as calculated by the Ecoinvent Database (version 3.5) are used.

4 METHOD

4.1 DATA

Data were received from Iris Worldwide on the location of farm and cold storage in Singapore, and on the producers and importers of fruits and vegetables from Australia and USA to Singapore. For Australia and USA, several farms were identified as locations for crop production.

4.1.1 Singapore

Location data were provided for the urban farm in Singapore and the main distribution centre. The farm cultivates fruits and vegetables hydroponically and delivers packaged produce to three distribution/retail centres in Singapore. Only transport to the main distribution centre is calculated here.

Table 2: Singapore Location and distance data, Iris Worldwide, 2019.

Origin	Destination	Distance (km)	Mode	Distance source
Sustenir Farm	Cold Storage Great	28	road	Googlemaps

4.1.2 Australia

Data on the crop producer were provided. The crop producer has two packing sheds in two different regions of Queensland, near Brisbane. It was assumed produce is transported 10 km from field to packing shed. As it was unclear what proportion of produce is derived from each region an average was used to calculate road distances in Australia. It was assumed produce is flown from Brisbane airport to Singapore airport. Data were also received on the importer of Australian produce and a location was determined for the importer’s distribution centre.

Table 3: Australia Location and distance data, Iris Worldwide, 2019.

Origin	Destination	Distance (km)	Mode	Distance source
Australian farm	Australian packing	10	road	Assumption
Peak Crossing, packing	Airport Brisbane	70	road	Googlemaps
Wyreema, packing	Airport Brisbane	150	road	Googlemaps
Airport Brisbane	Airport Singapore	6142	air	Great Circle Mapper
Airport Singapore	FairPrice	20	road	Googlemaps

4.1.3 USA

Data on the crop producer were provided. Because produce is soft fruit, the crop producer packs produce at farm. The crop is grown in various regions of California, and seasonally in Mexico and Florida. It was assumed that growing season is proportional to the amount of crop produced, so that regions with short growing seasons will contribute less to the total crop produced throughout the year. It was assumed produce is flown to Singapore airport from San Diego airport for crop grown in California, from Tijuana airport for crop grown in Mexico and from Tampa Airport for crop grown in Florida. Data were also received on the importer of USA produce and a location was determined for the importer’s distribution centre.

Table 4: USA Location and distance data, Iris Worldwide, 2019.

Origin	Destination	Distance (km)	Mode	Distance source	Growing (months)
Oxnard, CA	Airport San Diego	290	road	Googlemaps	10
Santa Maria, CA	Airport San Diego	480	road	Googlemaps	9
Watsonville, CA	Airport San Diego	720	road	Googlemaps	7
Baja California; MX	Airport Tijuana	280	road	Googlemaps	10
Central Mexico, MX	Airport Tijuana	366	road	assumption	8

Plant City, FL	Airport Tampa City	50	road	Googlemaps	6
Airport San Diego	Airport Singapore	14282	air	Great Circle Mapper	-
Airport Tijuana	Airport Singapore	14310	air	Great Circle Mapper	-
Airport Tampa	Airport Singapore	16685	air	Great Circle Mapper	-
Airport Singapore	Lazada	20	road	Googlemaps	-

4.2 Calculated Transport Distances

The final transport distances used for the analysis are shown in the table below:

Table 5: Calculated transport distances, Iris Worldwide, 2019.

Country/Produce	Farm to Packer	Packer to Airport	Airport/Farm to Cold Storage	Airport to Airport
Australian kale	10	110	20	6142
Australian lettuce	10	110	20	6142
US strawberry	0	479	20	14632
Singapore kale	0	n/a	28	n/a
Singapore strawberries	0	n/a	28	n/a

4.3 Emissions factors

A review of different emission factor databases was undertaken to enable the selection of appropriate factors for this analysis. USEPA, Defra, Ecoinvent 3.5 (2018) and Ecoinvent 3.6 (2019) were assessed.

The USEPA reports emissions for refrigerated transport in medium and heavy-duty trucks, but is lacking data on international air freight transport.

Defra reports aircraft freight emissions but does not include refrigeration. Defra calculates air freight emission including and excluding radiative forcing. Radiative forcing is used to better model airplane emissions, which have specific effects at high altitude, contributing more to climate change than similar emissions at ground level.

Ecoinvent 3.6 reports emissions arising from both road and air refrigerated transport. However, for refrigerated air transport, ecoinvent 3.6 has removed emissions from amongst others, two GHG: nitrous oxide and methane because no reliable source could be found to model them.

Ecoinvent 3.5 reports emissions arising from both road and air refrigerated transport, and includes emissions from all GHG associated with air freight. This dataset was chosen for this analysis, although it does not include calculations on radiative forcing. According to Jungbluth and Meili (2018), a radiative forcing index factor of 2 should be used on total aircraft carbon dioxide emissions modelled in ecoinvent.

Table 6: Emission factors considered and chosen for this analysis.

Transport type	Factor name	source	kgCO2e/ tkm	comments	Chosen?
Australian road	lorry with refrigeration machine, 7.5-16 ton, EURO5, carbon dioxide, liquid refrigerant, cooling, global	Ecoinvent 3.5	0.255	Current Australian emissions standards comparable to EURO5, Australia ratified Kigali Amendment to Montreal Protocol (phase-out of HFCs)	no
Australian road	transport, truck, 28t, fleet average/AU U	Iris Worldwide	0.107	Method and data source unclear	no
USA road	Medium and Heavy-duty Truck, refrigerated transport	USEPA, 2014	0.204	Factor available is from 2012 data	no
Singapore road	lorry with refrigeration machine, 3.5-7.5 ton, EURO5, R134a refrigerant, cooling, global	Ecoinvent 3.5	0.637	Assume smaller lorries are used in Singapore than in mainland USA and Australia, Singapore has not ratified Kigali Amendment	no
All road	HGVs refrigerated (all diesel), All HGVs, average laden	Defra, 2019	0.129	UK geography	no
All road	lorry with reefer, cooling, global	Ecoinvent 3.6	0.126	Version consistency	no
All road	lorry with reefer, cooling, global	Ecoinvent 3.5	0.123	Global factor	yes
Australia air	air freight, international/AU U	Iris Worldwide	1.734	Method and data source unclear	no
Australia air	air freight domestic/AU U	Iris Worldwide	1.938	Method and data source unclear	no
All air	Freight flights, Long-haul, to/from UK with RF	Defra, 2019	1.132	UK geography	no
All air	Freight flights, Long-haul, to/from UK without RF	Defra, 2019	0.598	UK geography	no
All air	aircraft with reefer, cooling, global	Ecoinvent 3.6	0.436	Version consistency (change in methodology)	no
Australia, USA and Singapore air	aircraft with reefer, cooling, global	Ecoinvent 3.5	1.117	Global factor	yes

5 Results

Total distances produce is transported (Section 4.2) were used to determine tonne-kilometres and kg CO_2e for road transport outside Singapore, road transport inside Singapore, and air transport from producing countries to Singapore.

Table 7: Tonne-kilometres required to transport 1 kg of produce, as calculated for this analysis

	Road tkm		Air tkm
Country/Produce	**Outside Singapore**	**Inside Singapore**	**Air**
Australian kale	0.120	0.020	6.142
Australian lettuce	0.120	0.020	6.142
US strawberry	0.479	0.020	14.632
Singapore kale		0.028	
Singapore strawberries		0.028	

Figure 3: Tonne-kilometres required to transport 1 kg of produce, as calculated for this analysis

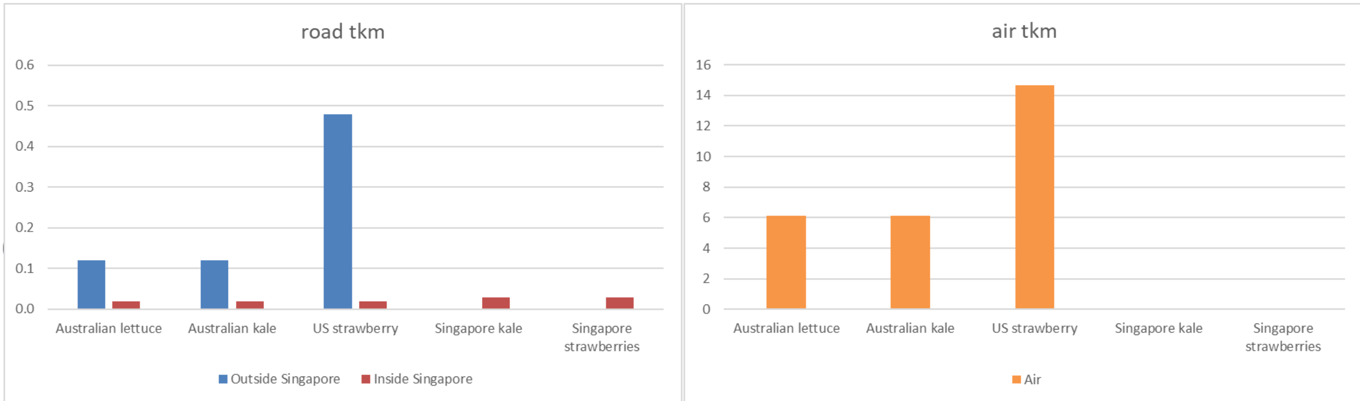
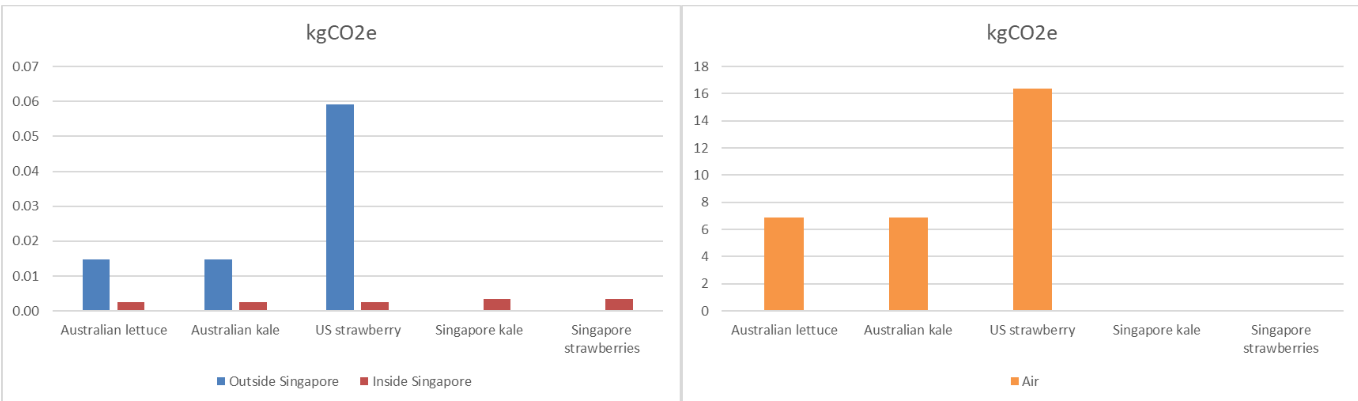


Table 8: $KgCO_2e$ emitted from transporting 1 kg of produce, as calculated for this analysis

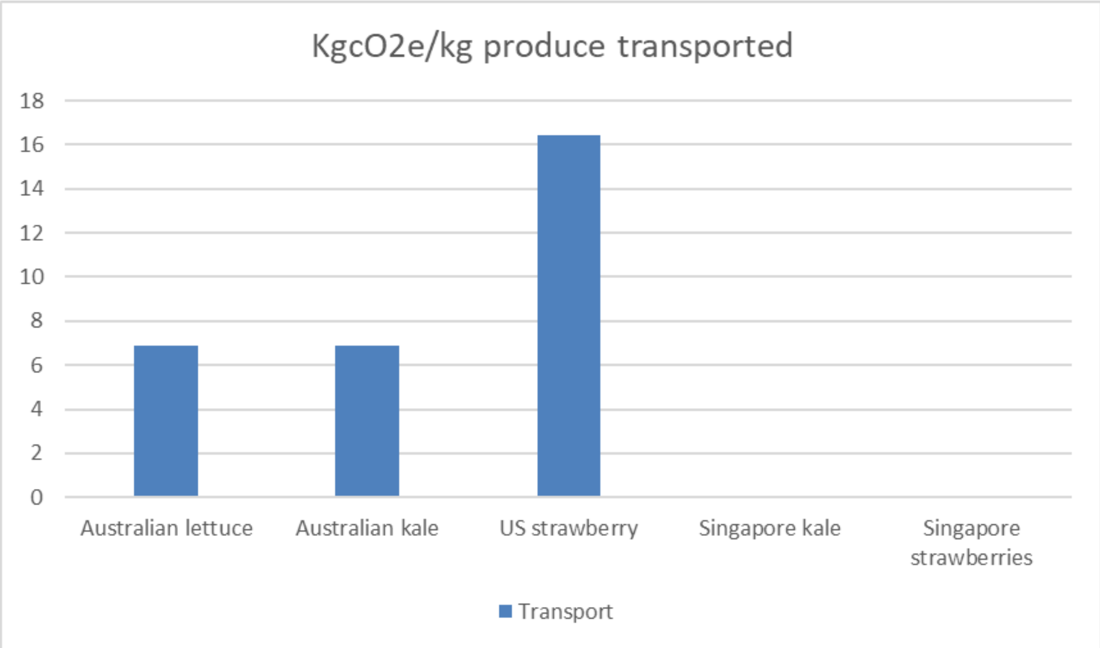
	Road $kgCO_2e$		Air $kgCO_2e$	TOTAL $kgCO_2e$
Country/Produce	**Outside Singapore**	**Inside Singapore**	**Air**	
Australian kale	0.015	0.002	6.861	6.878
Australian lettuce	0.015	0.002	6.861	6.878
US strawberry	0.059	0.002	16.345	16.407
Singapore kale		0.003		0.003
Singapore strawberries		0.003		0.003

Figure 4: $KgCO_2e$ emitted from transporting 1 kg of produce by road and by air, as calculated for this analysis



Total results are shown in Figure 4, below:

Figure 5: Total $KgCO_2e$ emitted from transporting 1 kg of produce, as calculated for this analysis



Note: Singapore transport emissions do not show in graphical representation because of scale (i.e. they are too small to register).

7 CONCLUSIONS

It is clear from this analysis that transporting fresh produce by air contributes significantly to the carbon footprint, and is likely to be the most important climate change impact derived from the production, distribution and consumption of fresh fruits and vegetables. Strawberries from the USA have the highest transport footprint, while kale and strawberries from Singapore have the lowest.

8 References

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