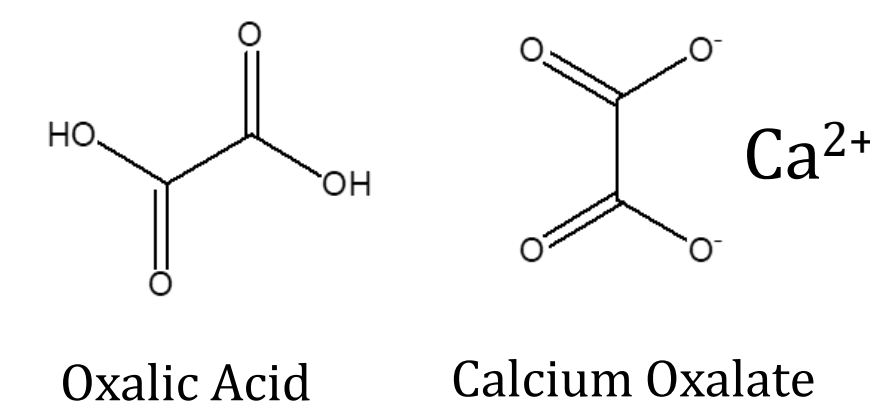


## Introduction

### Oxalate

- Vegetables and green leaves are main components of balanced diet which are eaten raw or cooked.
- Oxalate exists in those as a mixture of soluble and insoluble salts which has a higher affinity for minerals such as calcium.



- Oxalate is an anti-nutrient which is not used in human body and get excreted through kidneys.
- Patients susceptible for kidney stone should limit their dietary oxalate consumption to 40-50mg/day according to American Diabetes Association.
- Kidney stones are mainly due to calcium oxalate precipitation inside the body.

### Calcium and Calcium ion

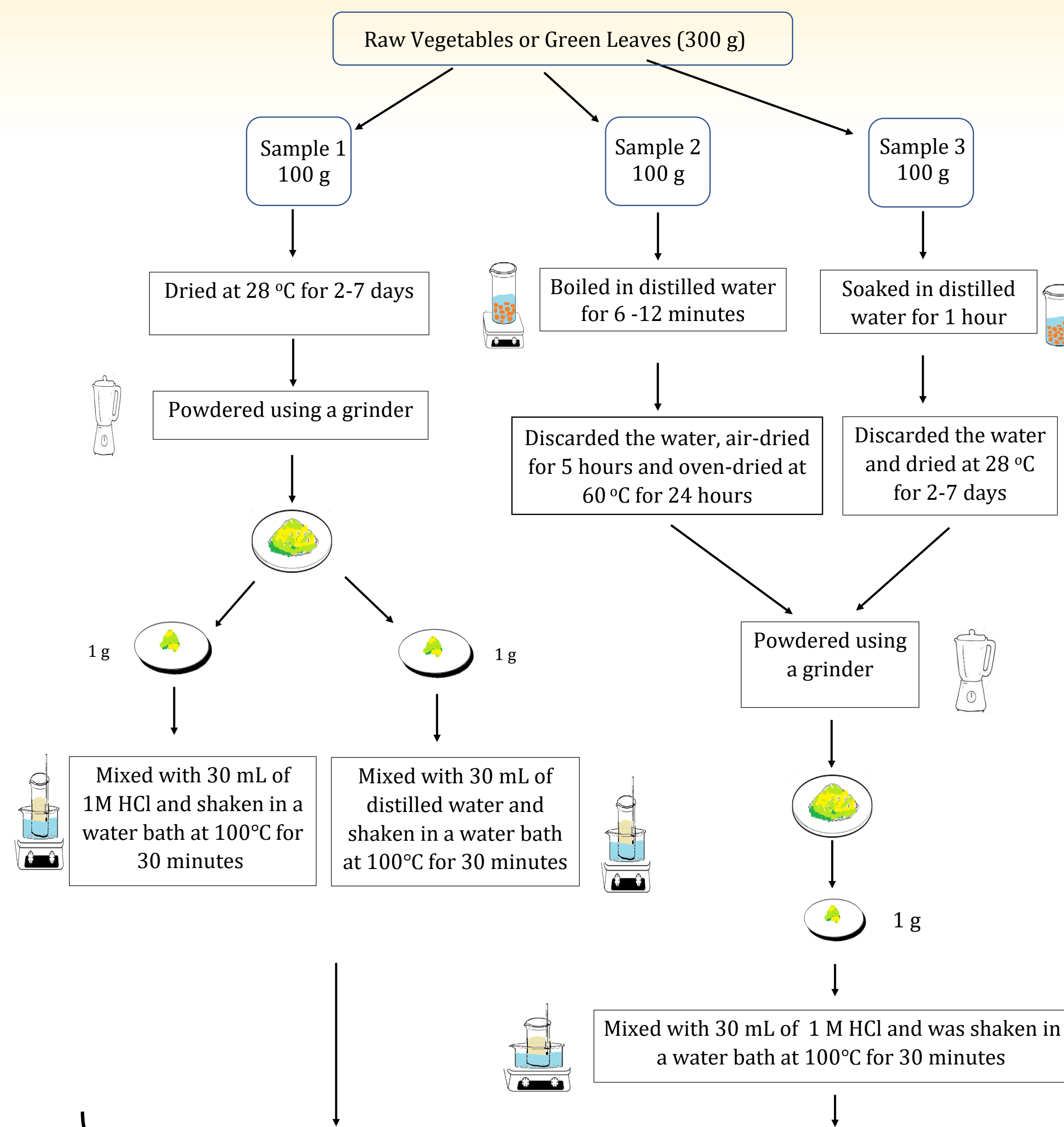
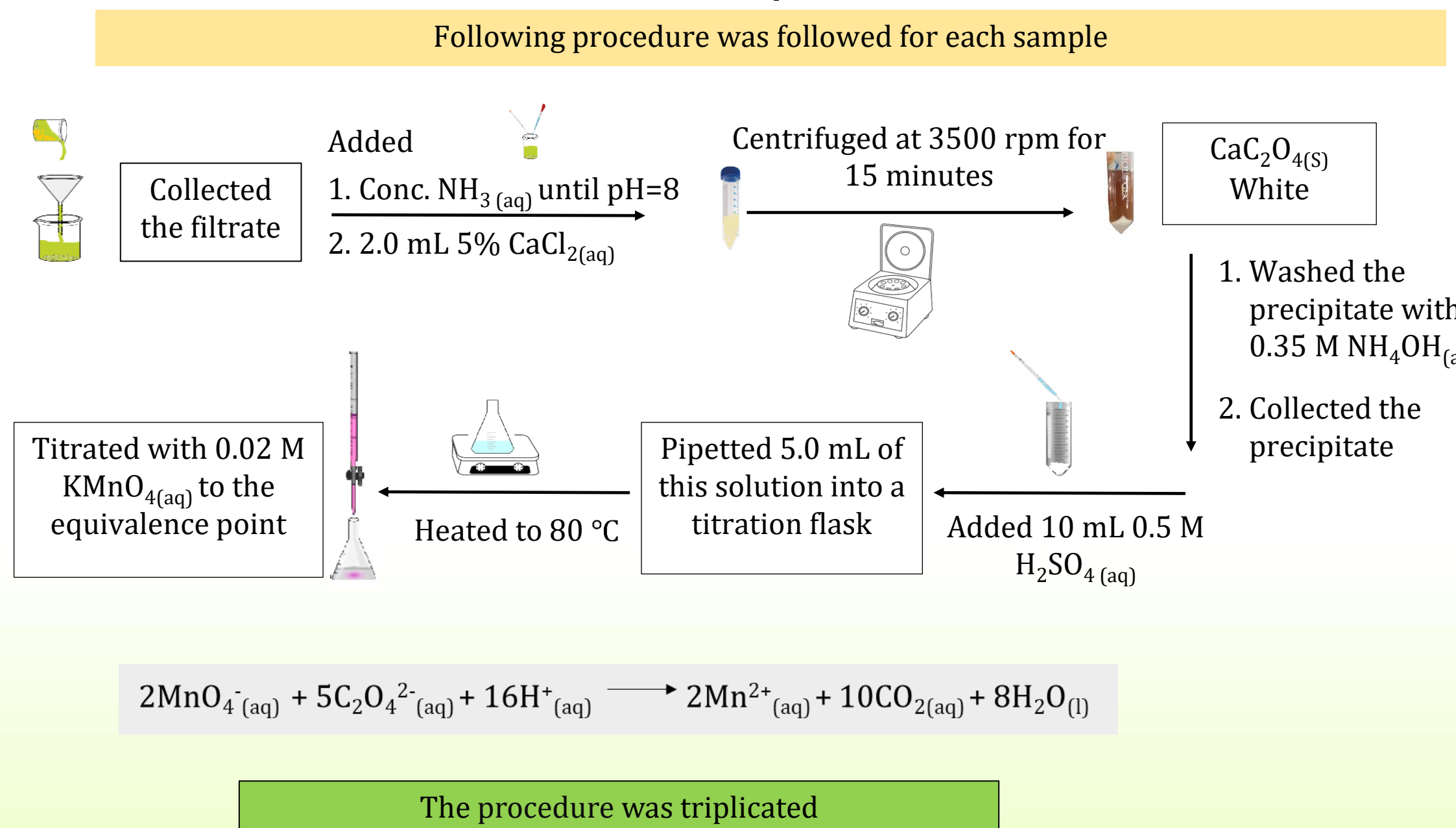
- Human body cannot produce calcium itself, hence it should be provided from external sources such as food supplements.
- Some vegetables and fruits may interfere the calcium sorption to the body due to the presence of inhibitors such as phytates, oxalates and citric acid etc.
- In general, the human digestive system processes vegetables and fruits within one or two hours after consumption.
- If calcium inhibitor foods such as oxalate containing vegetables and fruits are taken within the digestive period, they can have a detrimental effect on the body because oxalate react with calcium from the meal.
- This removal process results calcium deficiency to the human body.

## Research Objectives

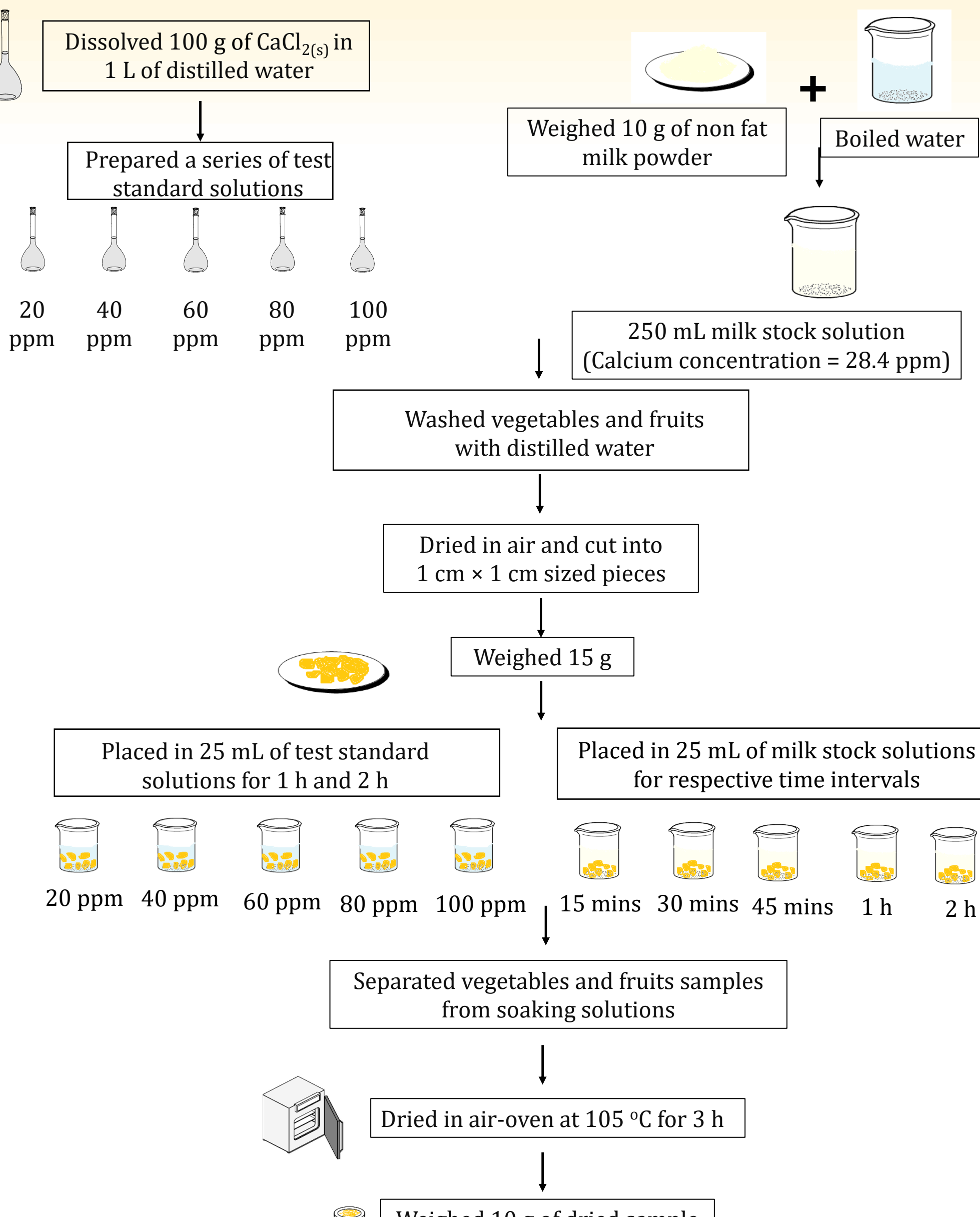
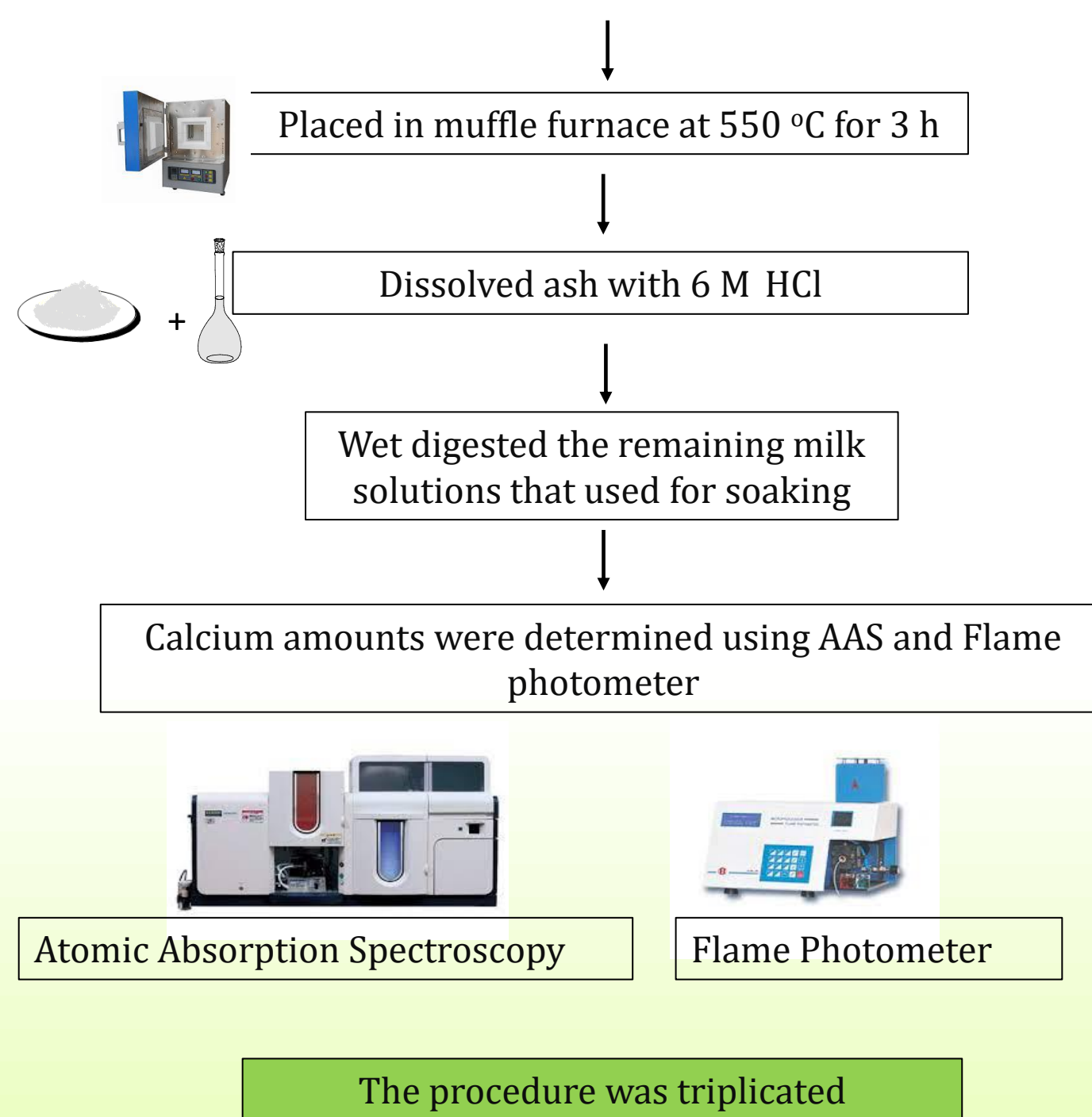
- To determine the oxalate contents in vegetables and green leaves.
- To observe the effect of cooking on oxalate contents in vegetables and green leaves.
- To identify some commercially available vegetables and fruits which could inhibit calcium sorption process.
- To determine the calcium sorption efficiency by vegetables and fruits as a function of time.

## Methodology

### Oxalate Determination



### Calcium Determination

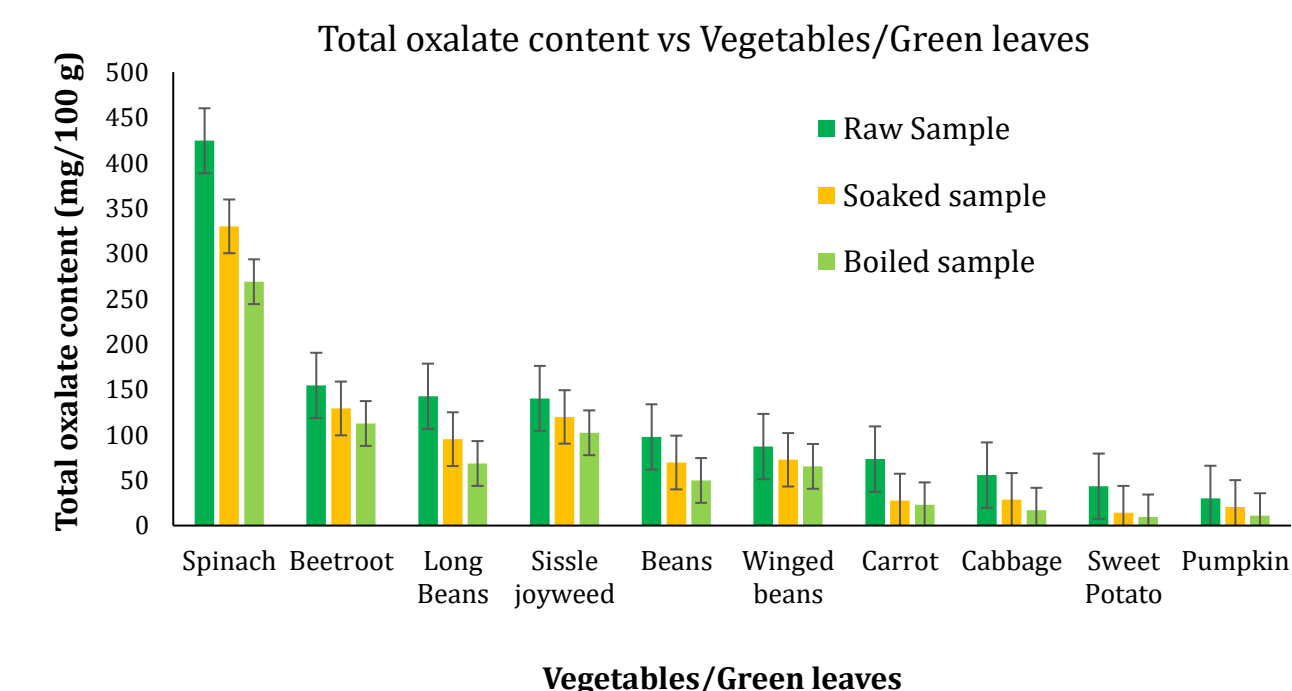


## Results

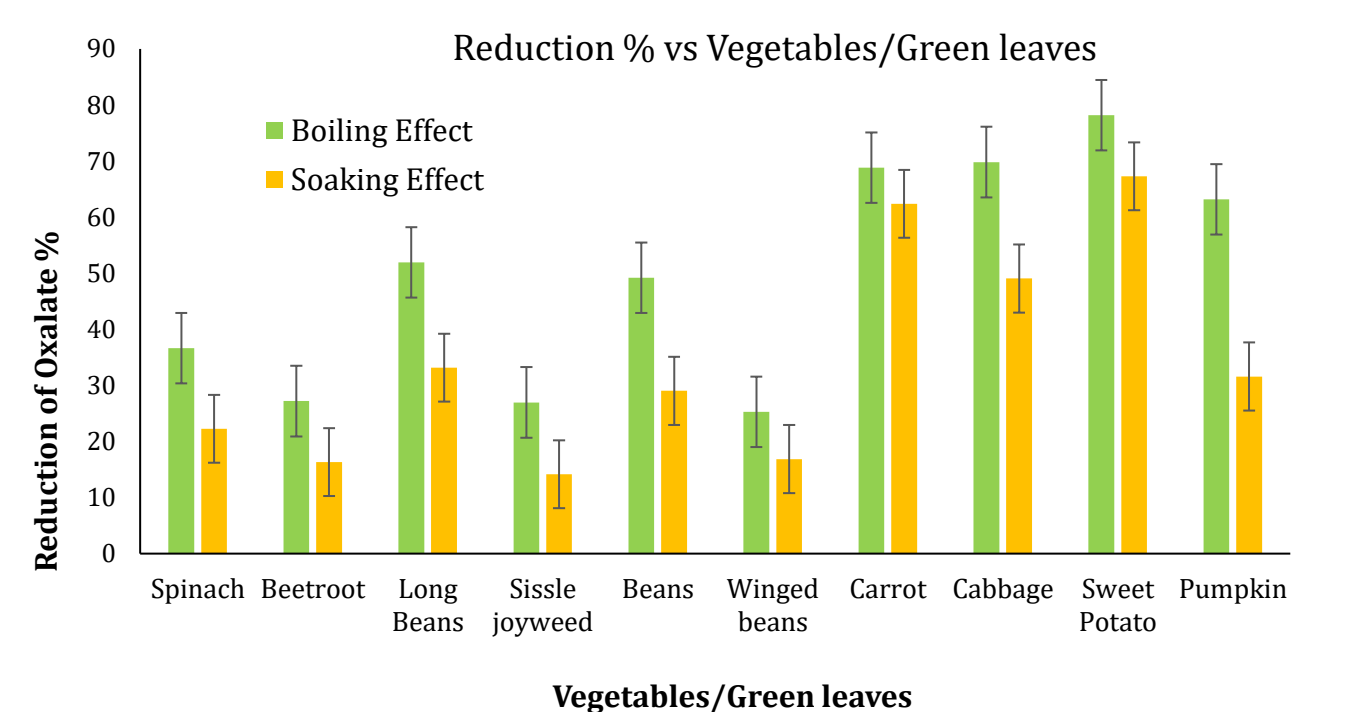
### Oxalate determination and reduction efficiency for vegetables and green leaves

| Vegetables and Green leaves | Raw (mg/100 g)          |                           |                       | Boiled (mg/100 g)     |                       | Soaked (mg/100 g)     |                       |
|-----------------------------|-------------------------|---------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                             | Soluble Oxalate content | Insoluble Oxalate content | Total Oxalate content | Total Oxalate content | Total Oxalate content | Total Oxalate content | Total Oxalate content |
| Spinach                     | 259.49±1.49             | 164.94±3.93               | 424.44±2.97           | 268.95±1.49           | 329.88±2.97           |                       |                       |
| Beetroot                    | 101.91±2.97             | 52.53±7.43                | 154.44±9.28           | 112.41±2.97           | 129.22±11.79          |                       |                       |
| Long Beans                  | 118.98±4.09             | 23.63±5.23                | 142.62±1.36           | 68.55±1.36            | 95.34±1.36            |                       |                       |
| Sessile joyweed             | 69.34±3.15              | 70.91±4.73                | 140.25±1.58           | 102.43±1.58           | 119.77±3.15           |                       |                       |
| Beans                       | 90.61±2.61              | 7.09±2.61                 | 97.70±2.23            | 49.64±2.61            | 69.34±2.23            |                       |                       |
| Winged beans                | 25.21±2.57              | 61.98±3.93                | 87.20±1.49            | 65.14±2.97            | 72.49±2.57            |                       |                       |
| Carrot                      | 42.55±3.52              | 30.73±6.82                | 73.28±3.43            | 22.85±1.36            | 27.58±1.36            |                       |                       |
| Cabbage                     | 39.92±1.49              | 15.76±2.57                | 55.68±1.49            | 16.81±1.49            | 28.37±2.57            |                       |                       |
| Sweet Potato                | 26.79±1.58              | 16.55±4.66                | 43.34±4.09            | 9.46±2.23             | 14.18±1.58            |                       |                       |
| Pumpkin                     | 15.76±3.15              | 14.18±1.58                | 29.94±1.58            | 11.03±1.58            | 20.49±1.58            |                       |                       |

### Comparison of total oxalate contents of raw, soaked and boiled samples



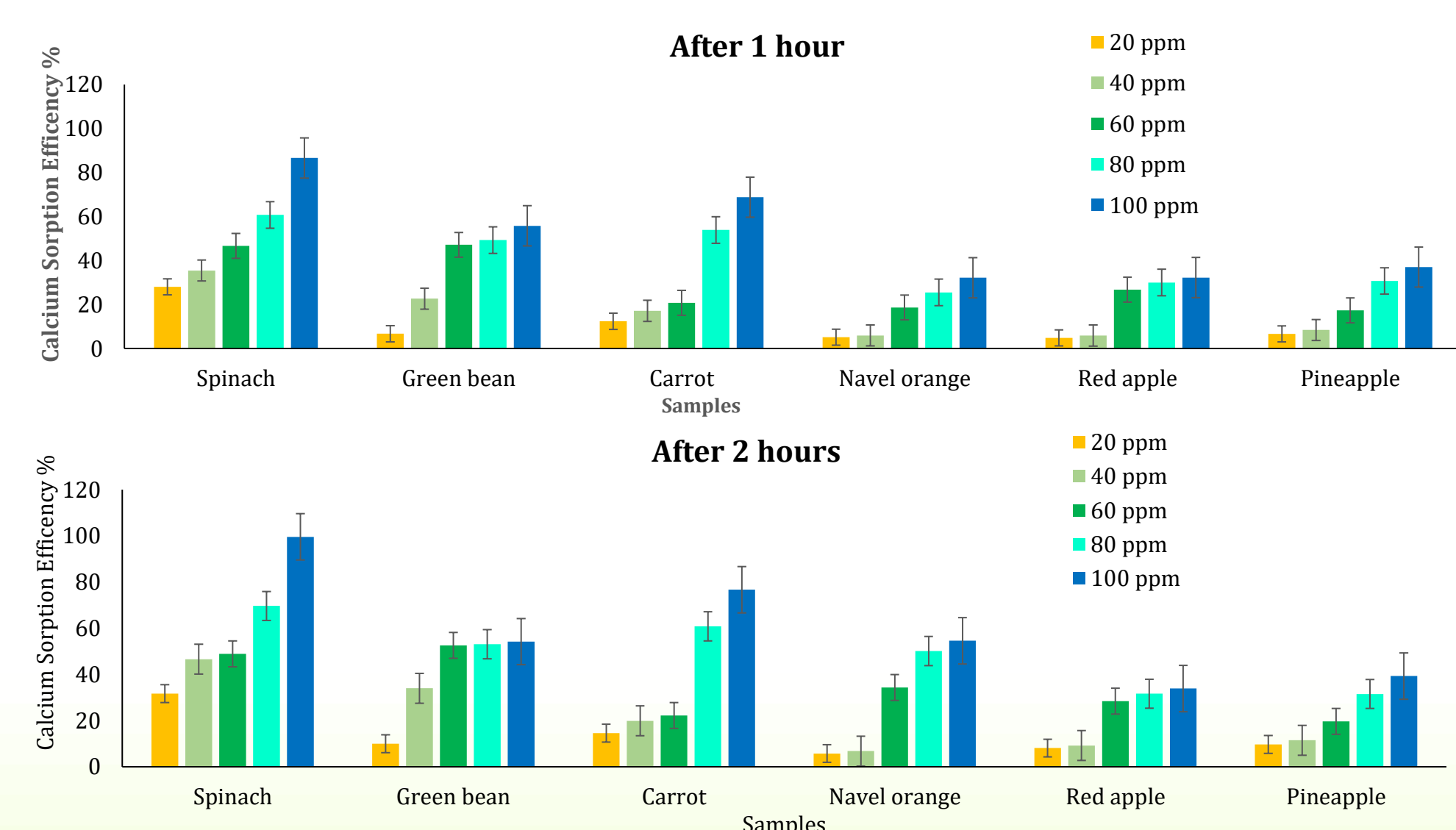
### Comparison of total oxalate reduction % of boiling and soaking



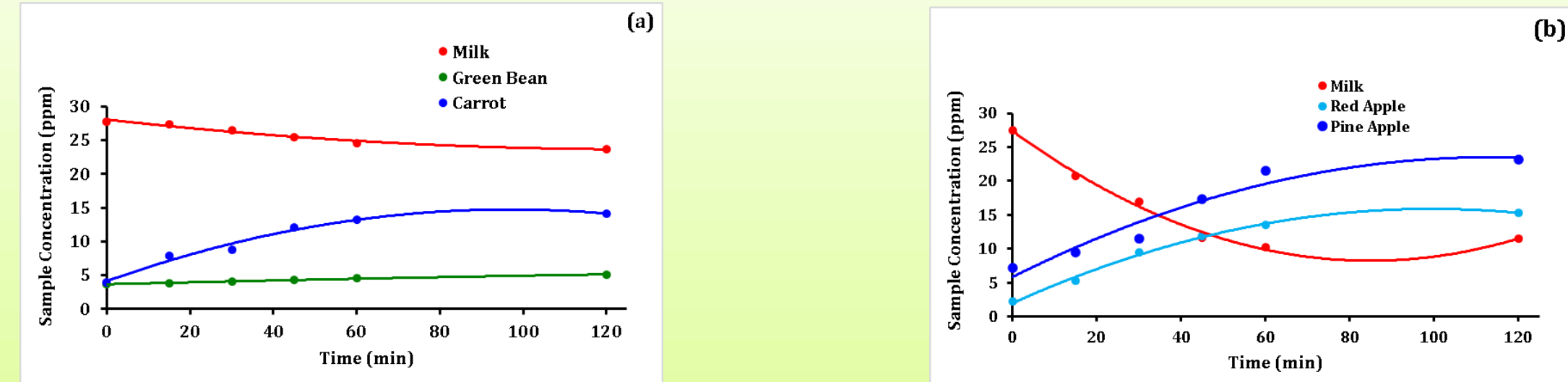
### Calcium sorption efficiency for fruit and vegetable samples soaked in test standard solutions

| Sample       | Without soaking (mg/10g) | Soaked in 20 ppm (mg/10 g) |           | Soaked in 40 ppm (mg/10 g) |           | Soaked in 60 ppm (mg/10 g) |           | Soaked in 80 ppm (mg/10 g) |           | Soaked in 100 ppm (mg/10 g) |           |
|--------------|--------------------------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|----------------------------|-----------|-----------------------------|-----------|
|              |                          | 1 hour                     | 2 hours   | 1 hour                     | 2 hours   | 1 hour                     | 2 hours   | 1 hour                     | 2 hours   | 1 hour                      | 2 hours   |
| Spinach      | 10.0±0.02                | 12.8±0.12                  | 13.1±0.22 | 13.5±0.11                  | 19.9±0.17 | 14.6±0.35                  | 14.9±0.38 | 16.0±0.49                  | 16.9±0.47 | 18.6±0.46                   | 19.9±0.17 |
| Green bean   | 3.71±0.02                | 3.96±0.02                  | 4.08±0.15 | 4.56±0.13                  | 5.72±0.16 | 5.47±0.56                  | 5.55±0.38 | 5.69±0.76                  | 5.78±0.14 | 5.72±0.16                   |           |
| Carrot       | 2.30±0.03                | 2.71±0.13                  | 2.78±0.12 | 2.89±0.22                  | 3.82±0.16 | 4.01±0.30                  | 4.06±0.31 | 5.11±0.59                  | 5.34±0.56 | 5.57±0.02                   | 5.83±0.16 |
| Navel orange | 3.85±1.09                | 4.05±0.43                  | 4.05±0.04 | 4.08±0.72                  | 5.95±0.75 | 4.51±0.48                  | 5.17±0.47 | 4.83±0.57                  | 5.78±0.54 | 5.09±0.32                   | 5.95±0.72 |
| Red apple    | 0.62±0.59                | 0.65±0.25                  | 0.67±0.11 | 0.66±0.38                  | 0.66±0.35 | 0.79±0.40                  | 0.80±0.37 | 0.82±0.48                  | 0.82±0.49 | 0.82±0.68                   | 0.83±0.35 |
| Pineapple    | 1.35±0.42                | 1.44±1.48                  | 1.48±1.46 | 1.46±1.88                  | 1.88±1.76 | 1.58±0.42                  | 1.61±0.46 | 1.77±0.59                  | 1.77±0.53 | 1.85±0.76                   | 1.88±0.76 |

### Calcium sorption efficiency for 20 ppm to 100 ppm soaking



### Calcium concentration variation of milk with selected (a) vegetables and (b) fruits



## Discussion

- Green leaves and vegetables contain oxalates and cooking methods like boiling and soaking in water reduces oxalate content significantly as they get leached into water.
- According to the study, vegetables and green leaves can be classified into 4 types as high (>200 mg/100 g), intermediate (199 mg - 100 mg/100 g), low (99 mg - 40 mg/100 g) and very low (> 40 mg/100 g) based on the oxalate content.
- From all the vegetables studied, for 100 g of spinach, the total oxalate content was 424.44±2.97 mg and was reduced to 268.95±1.49 mg (~37%) for boiled samples while 329.88±2.97 mg (22%) for soaked samples which showed the highest content of oxalate.
- This study demonstrated that the oxalate content can be reduced from 25% to 78% by boiling and from 14% to 67% by soaking.
- The results demonstrated that boiling and soaking of vegetables can effectively reduce the dietary oxalate content significantly which would prevent the formation of kidney stones with the sorption of calcium sources.
- However, the impact to other nutrients should be further investigated to obtain the optimum conditions.
- Calcium sorption process vegetables and fruits was studied in a range of test standard solutions from 20 - 100 ppm.
- Samples soaked in 100 ppm test standard solution showed the highest sorption efficiency for all vegetables and fruits while 20 ppm showed the lowest sorption efficiency.
- Results revealed that spinach (10.01 ± 0.02) mg to (18.68 ± 0.46) mg and navel orange (3.85 ± 1.09) mg to (5.09 ± 0.32) mg have high calcium sorption efficiencies per 10 g sample for 1-hour sorption in 100 ppm calcium standard test solution.
- Further, all vegetables and fruits showed significant calcium sorption rates in the first hour of study and reached equilibria within two hours.
- Increase of calcium sorption could be due to the presence of oxalate in which could bind with calcium effectively.
- Study further demonstrated that calcium sorption from milk by vegetables and fruits increases as a function of time.

## Conclusion

- Study revealed that commonly consumed green leaves and vegetables contain different oxalate levels and they can be categorized into four types as high, intermediate, low and very low.
- However, oxalate ingestion should be controlled by consuming the correct type.
- Soluble oxalates are more bioavailable than insoluble oxalates.
- Simple cooking methods could significantly reduce oxalate.
- Boiling is more effective in reducing oxalate compared with soaking in water.
- Vegetables and fruits could absorb/adsorb calcium nutrients from food supplements such as milk.
- It is highly recommended not to consume calcium rich foods within an hour of a main meal due to health effect.

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