CHEMISTRY EXTENDED ESSAY

"Determining the percentage of sulfur dioxide (SO_2), used as a preservative in the process of drying in dried fruits such as apricots and figs."

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Diploma number: D1129-072

Session: May 2012

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Word Count: 3903

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ABSTRACT

Sulfur dioxide (SO_2) is used as a preservative in the dried fruit industry to keep fruits from losing their original colour and taste however it is a poisonous chemical and can be lethal if exposed to in high levels.

I wondered the amount of sulfur dioxide we ingest by dried fruits unaware thus my research question for my experiment was "What is the percentage of sulfur dioxide (SO_2), used as a preservative in the process of drying, in dried fruits such as apricots and figs, where the percentage of sulfur dioxide will be found with calculating the mass of barium sulfate precipitate ($BaSO_4$) per fruit by first oxidizing the sulfur in sulfite ions (SO_3^{2-}) to sulfate ions (SO_4^{2-}) by adding 30 mL of 3% hydrogen peroxide (H_2O_2) and then precipitating the sulfate ions by adding barium chloride ($BaCl_2$) drop by drop?"

I experimented on naturally dried figs, artificially dried figs, naturally dried apricots, artificially dried yellow apricots, artificially dried brown apricots to compare the percentages of SO_2 in both naturally and artificially dried fruits. Although higher levels of SO_2 was expected in artificially dried fruits (yellow apricots, the highest as more SO_2 would be used to keep the light colour) and close to none expected in naturally dried ones, the lowest percentage was observed in artificially dried yellow apricots. The highest amount was found in artificially dried figs, followed by naturally dried apricots, naturally dried figs and then artificially dried brown apricots.

The data did not give the results I had expected but my research showed that there is still enough SO_2 in all dried fruit groups experimented on to possibly cause sulfite-sensitive individuals problems. The research should be expanded to many more food groups for the sake of general human health.

Keywords: Dried fruit, sulfur dioxide, sulfite-sensitive

Word Count: 298

1. INTRODUCTION

Dried fruits are prepared by removing the majority of the original water content of the fruit naturally, by sun drying, or using specialized dryers or dehydrators. They are prized because of their nutritive value, sweet taste, and long shelf life. Today, dried fruit consumption is widespread. Raisins, dates, prunes (dried plums), figs, apricots, peaches, apples and pears make up nearly half of the dried fruits sold.[1]

Dried fruits are viewed worldwide as healthy snacks, however the general populace does not know much about the process of drying the fruits and the chemicals used in the meantime before they come to our tables. Thus, I wondered if dried fruits pose any danger to humans who may be sensitive to the chemicals that are used in these procedures when they are not even aware of the risks. My investigation was focused on sulfur dioxide (SO_2) a heavy, colourless and poisonous gas[2] that is commonly used as preservatives in dried fruits.[3]

So, how much sulfur residue actually remains in the after product? And is the percentage of the sulfur remaining in the dried fruits above the health regulations? I chose to use dried figs and dried apricots in the experiment as my home country; Turkey is the leading fig producer[4] as well as the leading apricot producer[5] in the world. There will be both naturally and artificially dried fig and apricot groups experimented on as to see how the percentage of sulfur dioxide differs with the differentiating drying procedures as well.

To find the sulfur dioxide present in the fruits redox and precipitation reactions will be used. Oxidation and reduction are mostly defined in terms of the loss and gain of electrons. Oxidation is the loss of electrons. Conversely, reduction is the gain of electrons.[6] After the SO_3^{2-} ions are free after the sulfur dioxide reacts with water when immersing the dried fruits in water, they will be oxidized with H_2O_2 to SO_4^{2-} ions. Following the redox reactions, SO_4^{2-} will be precipitated in the form of $BaSO_4$ using $BaCl_2$. Precipitation reaction is a reaction of two water soluble salts in which cation and anion partners are "traded" also called a metathesis or double displacement reaction where a solid precipitate forms as product.[7]

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[1] http://en.wikipedia.org/wiki/Dried_fruit
[2] http://www.britannica.com/EBchecked/topic/572748/sulfur-dioxide
[3] Green, John & Damji, Sadru: International Baccalaureate, Chemistry 3rd Edition, IBID Press,2008 (pg.479-480)
[4] http://en.wikipedia.org/wiki/Common_fig
[5] http://en.wikipedia.org/wiki/Apricot
[6] Green, John & Damji, Sadru: International Baccalaureate, Chemistry 3rd Edition, IBID Press,2008 (pg.232)
[7] http://www.wpi.edu/Academics/Depts/Chemistry/Courses/General/pptnacidbaseredox.html

2. RESEARCH QUESTION

What is the percentage of sulfur dioxide (SO_2), used as a preservative in the process of drying, in dried fruits such as apricots and figs, where the percentage of sulfur dioxide will be found with calculating the mass of barium sulfate precipitate ($BaSO_4$) per fruit by first oxidizing the sulfur in sulfite ions (SO_3^{2-}) to sulfate ions (SO_4^{2-}) by adding 30 mL of 3% hydrogen peroxide (H_2O_2) and then precipitating the sulfate ions by adding barium chloride ($BaCl_2$) drop by drop?

3. BACKGROUND INFORMATION

3.1. Sulfur Dioxide in Fruit Drying

Sulfur dioxide works as an antioxidant in drying fruits to protect their colour and flavour. For example in apples and apricots sulfur dioxide is used to prevent losing their light colour by stopping browning reactions that darkens fruit and alter the flavour. Sulfur dioxide was first employed as a food additive in 1664, and was later approved for such use in the United States as far back as the 1800s.[8]

To tell how much difference usage of sulfur dioxide makes on the end product, both naturally dried apricots and figs dried in the sun and artificially dried ones where the fruits are pre-treated then dried are examined.

Pre-treatments prevent fruits from darkening. Light-coloured fruits like apples darken quickly when cut and exposed to air. If not pre-treated, fruits will continue to darken after drying. For long-term storage dried fruits are pre-treated by sulfuring or using a sulfite dip. However, sulfites found in the food after these treatments, can cause asthmatic reactions.

Sulfuring is an old method of pre-treating fruits. Sublimed sulfur is ignited and burned in an enclosed box with the fruit. The sulfur fumes penetrate the fruit and act as a pre-treatment by retarding spoilage and darkening of the fruit.

Sulfite dips can achieve the same long-term anti-darkening effect as sulfuring, but more quickly and easily. Sodium bisulfite, sodium sulfite or sodium meta-bisulfite can be used.[9]

[8] http://en.wikipedia.org/wiki/Dried_fruit
[9] http://nchfp.uga.edu/publications/uga/uga_dry_fruit.pdf

3.2. Effect of Sulfur Dioxide on Human Health

Sulfur dioxide is pretty harmless to healthy individuals. However, it can induce asthma when inhaled or ingested by sensitive people. The Food and Drug Administration (FDA) estimates that one out of a hundred people is sulfite-sensitive (allergic), and about 5%-8% of asthmatics are prone to react adversely. About 10% of the world population suffers from asthma, so there are approximately 500.000-720.000 people with potential for sulfite-sensitivity.[10] [11]

On the recommendation of the WHO, food regulators have been working slowly to reduce the use of large amounts of sulphite preservatives in our foods. However, this reduction can be offset by increasing promotion of dried fruit as a healthy snack.[12]

People who might be affiliated with sulfite-sensitivity have to be very careful about their diets, especially where dried fruits are concerned as it is less likely to suspect products as nutritious as dried fruits harmful.

In my opinion it is vital that the amount of Sulfur Dioxide we unknowingly ingest by consuming dried fruits is investigated.

4. METHOD

According to the regulations require if sulfites are at concentrations above 10 PPM (Parts per Million) in foods it has to be declared on the label. The sulfites however cannot be detected with human eye.

The official method for analysing sulfites is the Monier-Williams procedure. Several hours are needed to complete one analysis in the Monier-Williams procedure and it does not distinguish between sulfites and other volatile sulfur-containing compounds. Another technique is ion chromatographic analysis that offers rapid detection and selecting of anions. Sulfite can be determined using anion exchange ion chromatography with conductivity detection in minutes rather than hours.[13]

[10] http://en.wikipedia.org/wiki/Dried_fruit
[11] http://www.fmi.org/media/bg/?fuseaction=sulfites
[12] http://www.fedupwithfoodadditives.info/factsheets/Factsulphites.htm
[13] http://www.accessdata.fda.gov/ScienceForums/forum06/A-77.htm

However as my resources allowed neither the Monier-Williams procedure nor Ion chromatography, I used a much simpler way to detect the sulfur dioxide in the dried fruits. Although the method stretches over a week it shares the same ion exchange principle with Ion chromatography, using basic redox and precipitation reactions.

4.1. Variables

- **Independent Variable:** Type of dried fruit (naturally dried fig, artificially dried fig, naturally dried apricot, artificially dried yellow apricot, artificially dried brown apricot)

- **Dependent Variable:** Percentage of sulfur dioxide (SO_2) per fruit

- **Controlled Variables:**

1. Temperature of the laboratory
2. Air pressure in the laboratory
3. Amount of dried fruit (2 pieces per trial)
4. Volume of water fruits are immersed in (100.0 ± 0.1 mL)
5. Temperature of water (23.0 ± 0.1 °C)
6. Period of time fruits are immersed in water (1 day)
7. Volume of 3% H_2O_2 (30 ± 0.1 mL)
8. Volume of $BaCl_2$ (3-4 drops per trial)
9. Filter papers (x50 -25 for filtering fruits from water, 25 for filtering $BaSO_4$ from the mixtures prepared with H_2O_2 and $BaCl_2$)
10. Period of time filter papers -used for $BaSO_4$- are left to dry (1 week)

4.2. Materials

1. 250 mL Beakers (x25-to immerse the fruits in 100 ± 0.1 mL water)
2. 100 ± 0.1 mL Pure water (x25)
3. 250 mL Erlenmeyer flasks (x50- 25 to prepare the mixtures with H_2O_2 and $BaCl_2$, 25 to filter the solutions and pour the left over solution into)
4. Funnel with stand (x25)
5. 30 ± 0.1 mL of 3% H_2O_2 (x25)

6. 50 mL Graduated cylinder
7. 3M $BaCl_2$ solution (50 ± 0.1 mL)
8. Dropper
9. Filter papers (x50)
10. Stirring rod
11. Sensitive electronic scale (± 0.001 g)

4.3. Procedure

1. The windows and doors of the laboratory were kept closed at all times during the experiment to keep the temperature and air pressure stable.
2. The dried fruits were grouped (as naturally dried fig, artificially dried fig, naturally dried apricot, artificially dried yellow apricot, artificially dried brown apricot) and weighted.
3. The dried fruits were then immersed in 100 ± 0.1 mL pure water so that any sulfur dioxide (SO_2) residue that rested on the skin of the fruit was transferred into the water. When the sulfur dioxide dissolves in water, it reacts to form SO_3^{2-};[14]

$$SO_{2\,(g)} + H_2O_{\,(l)} \rightarrow SO_3^{2-}{}_{(aq)} + 2H^+{}_{(aq)}$$

4. The trials were left to rest for a day. The following day the fruit compotes were filtered so that no fruit pieces remained in the water. The fruits were scrubbed as to extract as much sulfur as possible from the skin.
5. 30 ± 0.1 mL of 3% hydrogen peroxide (H_2O_2) was added to the mixture produced by immersing the dried fruits in water in each trial to oxidize the sulfite (SO_3^{2-}) ions. The sulfite ions react with hydrogen peroxide (H_2O_2) to form sulfate (SO_4^{2-}) ions; [14]

$$SO_3^{2-}{}_{(aq)} + H_2O_{2\,(aq)} \rightarrow SO_4^{2-}{}_{(aq)} + H_2O_{\,(l)}$$

6. Barium chloride ($BaCl_2$) solution was added drop by drop to each trial (about 3-4 drops) until a white precipitate was produced. The sulfate ions react with the barium ions in the $BaCl_2$ solution, to produce the precipitate, barium sulfate ($BaSO_4$); [14]

$$Ba^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} + \rightarrow BaSO_{4\,(s)}$$

White precipitate

[14] Borgford, Christie L & Summerlin, Lee R.:Chemical Activities, Teacher's Addition, American Chemical Society, Washington DC, 1998

7. Filter papers were weighted before filtration.
8. The solutions prepared with H_2O_2 and $BaCl_2$ were filtered and the filter papers were left to dry for a week.
9. The weights of the papers with the $BaSO_4$ precipitate on them were measured then the weights of the filter paper found earlier were subtracted to find the amount of $BaSO_4$ precipitate in each trial.
10. The percentage of sulfur dioxide per fruit was calculated; with stoichiometry to find the mol of SO_2 using the mol (measured weight/molar mass) of $BaSO_4$ and then calculating the percentage per fruit with the weights of the fruits measured in the beginning.

4.4. Safety Information & Precautions

$BaCl_2$; Barium chloride is highly toxic. Sodium sulfate and magnesium sulfate can be antidotes as they form $BaSO_4$ which is nontoxic.[15]

H_2O_2; Low concentrations, like 3%, are widely available and legal to use. In high concentrations, hydrogen peroxide is an aggressive oxidizer and will corrode many materials, including human skin. In the presence of a reducing agent, high concentrations of H_2O_2 will react violently.[16]

Use of surgical gloves and goggles are advised.

[15] http://en.wikipedia.org/wiki/Barium_chloride#Safety
[16] http://en.wikipedia.org/wiki/Hydrogen_peroxide#Safety

5. DATA COLLECTION

Naturally Dried Figs/g (±0.001g)	Artificially Dried Figs/g (±0.001g)	Naturally Dried Apricots/g (±0.001g)	Artificially Dried Yellow Apricots/g (±0.001g)	Artificially Dried Brown Apricots/g (±0.001g)
26.131	15.058	4.481	11.323	9.895
26.157	15.287	4.634	10.268	10.245
27.415	17.215	4.576	8.614	10.806
25.454	17.421	4.863	8.336	9.519
26.906	16.898	4.717	7.943	10.680

Table 1. Weight (g) of the dried fruits used for each trial

Qualitative Data:

There were colour changes observed in the water after the dried fruits were immersed in it, in every trial. The water blurred and darkened. After the fruits were left in the water overnight, in the next observation the following day the colour of the water was immensely different. It had turned a much darker orange-brownish (depending on the type of fruit) colour from what I hoped was the sulfur residue that was left on the skin of the dried fruits and other particles. Also, the fruits had absorbed some of the water and turned to their original forms prior to the dehydration. The compositions of the mixtures in the beakers were very similar to fruit compote.

Naturally Dried Figs/g (±0.001g)	Artificially Dried Figs/g (±0.001g)	Naturally Dried Apricots/g (±0.001g)	Artificially Dried Yellow Apricots/g (±0.001g)	Artificially Dried Brown Apricots/g (±0.001g)
0.777	0.775	0.783	0.764	0.766
0.767	0.761	0.778	0.771	0.774
0.771	0.764	0.778	0.776	0.776
0.782	0.759	0.781	0.777	0.785
0.772	0.770	0.772	0.773	0.781

Table 2. Weight (g) of the filter paper used in each trial[17]

[17] The filter papers' weights were measured so that when the dried barium sulfate (BaSO4) precipitate was weighted together with the paper, weight of the filter paper can be subtracted to find how much barium sulfate is present.

Qualitative Data: In trials with artificially dried yellow apricots there was fast and visible whit precipitation. This was also observed in trials where artificially dried figs were used. However no visible change occurred in the solutions made from naturally dried figs.

In trials with artificially dried yellow apricots white precipitate was stuck to the bottom of the Erlenmeyer flask the solutions were prepared in, so not all of the barium sulfate that precipitated in those trials could be measured because the precipitate could not be transferred on to the filter papers that were weighted. The same was –although not as much- observed in trials with artificially dried brown apricots.

Naturally Dried Figs/g (±0.001g)	Artificially Dried Figs/g (±0.001g)	Naturally Dried Apricots/g (±0.001g)	Artificially Dried Yellow Apricots/g (±0.001g)	Artificially Dried Brown Apricots/g (±0.001g)
1.581	1.678	0.992	0.901	1.417
1.775	2.405	0.876	0.904	0.955
1.532	2.270	1.050	0.889	0.949
1.379	2.578	1.046	0.907	0.930
1.640	1.430	0.963	0.907	0.941

Table 3. Weight (g) of the barium sulfate ($BaSO_4$) precipitate combined with the weight of the filter paper

6. DATA PROCESSING

6.1. Calculations

1. Weight of the barium sulfate ($BaSO_4$) precipitate is found by subtracting the weight of the filter paper (Table 2) from that of the barium sulfate precipitate combined with the filter paper (Table 3).

(Calculations are shown on trials with naturally dried figs as an example, the complete calculations can be found in Appendix I)

Trial 1; (1.581±0.001) - (0.777±0.001) = 0.804±0.002 g

Trial 2; (1.775±0.001) - (0.767±0.001) = 1.008±0.002 g

Trial 3; (1.532±0.001) - (0.771±0.001) = 0.761±0.002 g

Trial 4; (1.379±0.001) - (0.782±0.001) = 0.579±0.002 g

Trial 5; (1.640±0.001) - (0.772±0.001) = 0.868±0.002 g

Naturally Dried Figs/g (±0.002g)	Artificially Dried Figs/g (±0.002g)	Naturally Dried Apricots/g (±0.002g)	Artificially Dried Yellow Apricots/g (±0.002g)	Artificially Dried Brown Apricots/g (±0.002g)
0.804	0.903	0.209	0.137	0.651
1.008	1.644	0.098	0.133	0.181
0.761	1.506	0.272	0.113	0.173
0.597	1.819	0.265	0.130	0.145
0.868	0.660	0.188	0.134	0.160

Table 4. Weight (g) of the barium sulfate ($BaSO_4$) precipitate

2. Percentage of sulfur dioxide (SO_2) per fruit is found from the barium sulfate ($BaSO_4$) precipitate.

(Calculations are shown on Trial 1 of natural dried figs as an example, the complete calculations can be found in Appendix I, percentage uncertainty calculations are shown in Appendix I also.)

$SO_{2\,(g)} + H_2O_{\,(l)} \rightarrow SO_3^{2-}{}_{(aq)} + 2H^+{}_{(aq)}$

1mol 1mol

$SO_3^{2-}{}_{(aq)} + H_2O_{2\,(aq)} \rightarrow SO_4^{2-}{}_{(aq)} + H_2O_{\,(l)}$

1mol 1mol

$SO_4^{2-}{}_{(aq)} + Ba^{2+}{}_{(aq)} \rightarrow BaSO_{4\,(s)}$

1mol 1mol

Weight of $BaSO_4$; 0.804±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol[18]

$n_{BaSO4} = \frac{0.804 \pm 0.249\%}{233.43} = 3.444 \times 10^{-3} \pm 0.249\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g[19]

3. 444x10^{-3} ± 0.249% mol SO_2 ? g

?= (3. 444x10^{-3} ± 0.249%) x (64.066) ≈ 0.221 ± 0.249% g

26.131±0.004% g naturally dried fig 0.221 ± 0.249% g SO_2

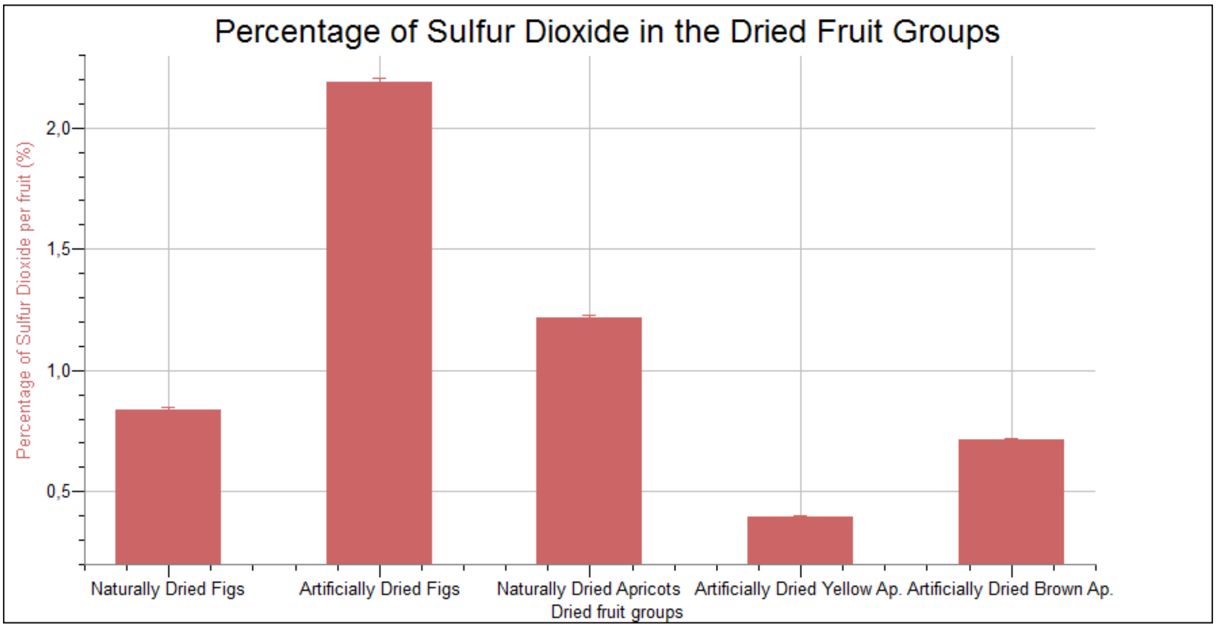
100 ?

$?= \frac{(0.221 \pm 0.249\%) x\ 100}{26.131 \pm 0.004\%} \approx 0.846\ (\pm 0.253\%)$ % Sulfur Dioxide

[18] http://en.wikipedia.org/wiki/Barium_sulfate
[19] http://en.wikipedia.org/wiki/Sulfur_dioxide

Trial	Naturally Dried Figs/%	Artificially Dried Figs/%	Naturally Dried Apricots/%	Artificially Dried Yellow Apricots/%	Artificially Dried Brown Apricots/%
1	0.846(±0.253%)	1.647(±0.229%)	1.272(±0.979%)	0.336(±1.469%)	1.809(±0.317%)
2	1.059(±0.202%)	2.950(±0.128%)	0.583 (±3%)	0.351(±1.514%)	0.488(±1.115%)
3	0.762(±0.267%)	2.400(±0.139%)	1.639 (±0.757%)	0.418(±1.782%)	0.444 (±1.165%)
4	0.644(±0.339%)	2.870(±0.116%)	1.501(±0.775%)	0.432(±1.550%)	0.420(±1.389%)
5	0.885(±0.234%)	1.071(±0.309%)	1.102(±1.085 %)	0.453(±1.505%)	0.412(±1.259%)
mean	***0.839(±0.259%)***	***2.188(±0.184%)***	***1.219(±1.319%)***	***0.398(±1.564%)***	***0.715(±1.049%)***

Table 5. Percentage of Sulfur Dioxide per fruit(%)



Graph 1. Percentage of Sulfur Dioxide (SO_2) in all the dried fruit groups experimented on(%)

The percentage error value for the graph was taken as the mean of the percentage uncertainties of the mean values shown in Table 5.

$$\frac{\mathbf{0.259+0.184+1.319+1.564+1.049}}{5} = \frac{4.375}{5} = 0.875\%$$

3. Percentage error is calculated.

%Er = $\frac{|Observed-Expected|}{Expected}x100$

As there is no literary (expected) value concerning our research, the average of the values per group shown in Table 5 were used instead.

Average percentage of sulfur dioxide for naturally dried figs = 0.839

Trial 1; Er = $\frac{|0.846-0.839|}{0.839}x100 = \frac{0.007}{0.839}x100 \approx$ 0.834%

Trail 2, Er = $\frac{|1.059-0.839|}{0.839}x100 = \frac{0.220}{0.839}x100 \approx$ 27%

Trial 3; Er = $\frac{|0.762-0.839|}{0.839}x100 = \frac{0.077}{0.839}x100 \approx$ 10%

Trial 4; Er = $\frac{|0.644-0.839|}{0.839}x100 = \frac{0.195}{0.839}x100 \approx$ 24%

Trial 5; Er = $\frac{|0.885-0.839|}{0.839}x100 = \frac{0.046}{0.839}x100 \approx$ 6%

Average percentage of sulfur dioxide for artificially dried figs = 2.188

Trial 1; Er = $\frac{|1.647-2.188|}{2.188}x100 = \frac{0.541}{2.188}x100 \approx$ 25%

Trail 2, Er = $\frac{|2.950-2.188|}{2.188}x100 = \frac{0.762}{2.188}x100 \approx$ 35%

Trial 3; Er = $\frac{|2.400-2.188|}{2.188}x100 = \frac{0.212}{2.188}x100 \approx$ 10%

Trial 4; Er = $\frac{|2.870-2.188|}{2.188}x100 = \frac{0.682}{2.188}x100 \approx$ 32%

Trial 5; Er = $\frac{|1.071-2.188|}{2.188}x100 = \frac{1.117}{2.188}x100 \approx$ 52%

Average percentage of sulfur dioxide for naturally dried apricots = 1.219

Trial 1; Er = $\frac{|1.272-1.219|}{1.219}x100 = \frac{0.053}{1.219}x100 \approx 5\%$

Trail 2, Er = $\frac{|0.583-1.219|}{1.219}x100 = \frac{0.636}{1.219}x100 \approx 53\%$

Trial 3; Er = $\frac{|1.639-1.219|}{1.219}x100 = \frac{0.420}{1.219}x100 \approx 35\%$

Trial 4; Er = $\frac{|1.501-1.219|}{1.219}x100 = \frac{0.282}{1.219}x100 \approx 24\%$

Trial 5; Er = $\frac{|1.102-1.219|}{1.219}x100 = \frac{0.117}{1.219}x100 \approx 10\%$

Average percentage of sulfur dioxide for artificially dried yellow apricots = 0.398

Trial 1; Er = $\frac{|0.336-0.398|}{0.398}x100 = \frac{0.062}{0.398}x100 \approx 16\%$

Trail 2, Er = $\frac{|0.351-0.398|}{0.398}x100 = \frac{0.047}{0.398}x100 \approx 12\%$

Trial 3; Er = $\frac{|0.418-0.398|}{0.398}x100 = \frac{0.020}{0.398}x100 \approx 6\%$

Trial 4; Er = $\frac{|0.432-0.398|}{0.398}x100 = \frac{0.034}{0.398}x100 \approx 9\%$

Trial 5; Er = $\frac{|0.453-0.398|}{0.398}x100 = \frac{0.055}{0.398}x100 \approx 14\%$

Average percentage of sulfur dioxide for artificially dried brown apricots = 0.715

Trial 1; Er = $\frac{|1.809-0.715|}{0.715}x100 = \frac{1.094}{0.715}x100 \approx 153\%$

Trail 2, Er = $\frac{|0.488-0.715|}{0.715}x100 = \frac{0.227}{0.715}x100 \approx 32\%$

Trial 3; Er = $\frac{|0.444-0.715|}{0.715}x100 = \frac{0.271}{0.715}x100 \approx 38\%$

Trial 4; Er = $\frac{|0.420-0.715|}{0.715}x100 = \frac{0.295}{0.715}x100 \approx 42\%$

Trial 5; Er = $\frac{|0.412-0.715|}{0.715}x100 = \frac{0.303}{0.715}x100 \approx 43\%$

6.2. Interpretation of Results

The amount of sulfur dioxide (SO_2) I detected in the dried fruits experimented on was much different than expected. Whereas the highest percentage would be in artificially dried fruits I hoped there would be close to none in naturally dried ones. Although similar was observed in the trials with naturally and artificially dried figs, the amount being higher in the artificially dried ones, the opposite occurred in dried apricots. The percentage of sulfur dioxide in artificially dried yellow apricots should have been the highest (as more sulfur dioxide would have been used to preserve its light yellow colouring) the percentage of sulfur dioxide was the lowest in this particular group at an average of 0.398(±1.564%) %. This was mostly due to the fact that most of the barium sulfate precipitate in the trials with artificially dried yellow apricots was stuck to the bottom of the Erlenmeyer flask the mixtures were prepared in and couldn't be included into the measurements. The percentage of sulfur dioxide found within one group of dried fruit fluctuated as well. For example in artificially dried figs the amount is 1.647(±0.229%) in the first trial, rising to the amount 2.950(±0.128%) in the second, but then declining to 1.071(±0.309%) in the last trial. The fluctuations in the processed data was observed in almost all groups as also seen in the high percentage error results, the highest being the first trial of artificially dried brown apricots at 153% error. In addition, the reason for the higher amounts of sulfur in naturally dried apricots 1.219(±1.319%) % and the unexpected amount in naturally dried figs 0.839(±0.259%) % might be that naturally occurring sulfites exist in a few foods. The weights of the dried fruits could not be kept constant for all trials for all dried fruit groups as they were taken by pieces for the experimentation; thus the high amount of sulfur in naturally dried figs was because the weight was larger, the more sulfur was found in the fruit. Also even in natural habitat, prior to picking and drying, the trees of these fruits are expose to many chemicals like pesticides and even when dried naturally the fruit had already absorbed sulfur and many other chemicals from the surroundings, thus the high amount of sulfur dioxide although none was used in the drying process. Which again raises the question; what toxins are we getting into our bodies, believing that we are consuming natural products?

7. CONCLUSION

My research has shown that sulfur dioxide exist in dried fruits whether dried naturally or artificially. The highest percentage was observed in artificially dried figs at 2.188(±0.184%) % followed by naturally dried apricots at 1.219(±1.319%) % and naturally dried figs at 0.839(±0.259%) %. The percentage was surprisingly low in artificially dried brown apricots at 0.715(±1.049%) % and artificially dried yellow apricots at 0.398(±1.564%) % which I had expected to contain the highest amount.

Sulfites, or sulfiting agents, are sulfur-based substances that are primarily used as preservatives. Sulfur dioxide, sodium sulfite, sodium bisulfite, sodium metabisulfite, potassium bisulfite, and potassium metabisulfite are commonly used in the food industry. They prevent spoilage and browning during the preparation, storage and distribution of foods. Sulfites also stop the deterioration of nutrients like vitamin C.[20] However; sulfites destroy thiamine (Vitamin B_1), essential for metabolism of carbohydrates and alcohol[21] and are also thought to destroy folic acid.[22]

Sulfites may cause breathing difficulty within minutes after eating a food containing it; so asthmatics are at a higher risk. Sulfite sensitivity seem to occur almost exclusively in severe asthmatics but people should be careful as there are still a number of cases of non-asthmatic individuals reacting to sulfur. Sulphites can cause food intolerance symptoms including headaches, irritable bowel symptoms, nausea, diarrhoea, skin rashes, behaviour disturbance, hives however the most reported reaction is asthma attack. Breathing high levels of sulfur dioxide can constrict airways, causing wheezing, and chest tightness, coughing, and breathing problems. This can aggravate existing respiratory diseases, like bronchitis, asthma, emphysema. Chronic exposure may cause bronchitis. It may also impair the respiratory system's defences against foreign particles and bacteria. Exposure to extremely high concentrations of SO_2 can cause severe shortness of breath and pulmonary enema.[23] The amount sulfur dioxide found in dried fruits is very low and should not cause any of these problems but they can still be dangerous to sensitive-people.[24]

[20] http://www.fmi.org/media/bg/?fuseaction=sulfites
[21] http://en.wikipedia.org/wiki/Sulfite
[22] http://www.fedupwithfoodadditives.info/factsheets/Factsulphites.htm
[23] http://healthychild.org/issues/chemical-pop/sulfur_dioxide/
[24] http://www.ehow.com/about_5514704_health-sulfur-dioxide-dried-fruits.html

Prior to January 9, 1987, only sulfites involved in the processing of the final product, used for preservation, had to be listed on a product label but today FDA and FSIS requires food manufactures and processors to disclose the presence of sulfiting agents on the label if the concentration is higher than 10 parts per million. According to regulations; any standardized food that contains a sulfiting agent or combination of sulfiting agents that is functional and provided for in the applicable standard or that is present in the finished food at a detectable level is misbranded unless the presence of the sulfiting agent or agents is declared on the label of the food.[25] Manufacturers do not list sulfites on product labels risk removing products from the marketplace. In 1986, FDA requested hundreds of recalls for products with labels that failed to disclose the presence of sulfites. Many of these were dried fruit.

In the U.S., labelling regulations do not require products to indicate the presence of sulfites in foods unless it is added specifically as a preservative. In Australia and New Zealand, sulfites must be declared in the ingredients when present in packaged foods in concentrations of 10 mg/kg or more.[26] Consumers should check food labels for any presence of sulfur dioxide, sodium sulfite, sodium bisulfite, sodium metabisulfite, potassium bisulfite, potassium metabisulfite or any other sulfiting agents.

From my results, it is seen that dried fruits (figs and apricots used) contain a considerable amount of sulfur dioxide. The most surprising result was observed in apricots where the percentage of the sulfur dioxide in naturally dried ones (with no sulfuring process) exceeded the ones artificially dried. This shows that even before putting them out the dry, the fruits were subjected to sulfur dioxide in their growth, most likely from pesticides, air pollutants and the chemicals alike used on the fruit tree itself or the surroundings.

I do not believe, after my research, that dried fruits are lethal, however the issue of sulfites in dried fruits is worth looking into considering the sulfur-sensitive people along with everyone who might have an undesirable reaction to them and the large scale consumption of dried fruits as nutritious, healthy food even if they might pose a danger to our health if not monitored closely. The experiment should be repeated with more food groups and the research on sulfite containing products that might endanger human health should be expanded.

[25] http://edocket.access.gpo.gov/cfr_2001/aprqtr/pdf/21cfr130.9.pdf
[26] http://en.wikipedia.org/wiki/Sulfite

8. LIMITATIONS and EVALUATION

The percentage uncertainties are little enough (at an average of 0.875%) they point to the presence of random errors. Also the undesired high rates of percentage error found by using the average percentage of sulfur dioxide per fruit group (for example; 153% in the first trial for artificially dried brown apricots) show that there are systematic errors in the experiment as well.

First of all, mass of the different specimen of fruits taken for the experiment were not equal as fruits were taken into count by piece. Thus, it would be expected that the more mass and volume the fruit had more it would contain sulfur dioxide. Trials with naturally dried figs could be shown example to this (with the highest weights) as there were traces of sulfur dioxide found even though none was expected to found. To prevent data from fluctuating as it did in the experiment fruits can be taken at equal weights instead of by pieces.

The laboratory dried fruits were immersed in pure water, left to rest and then where the solutions were filtered and the filter papers left to dry was not a stable environment for the experiment. The doors and windows of the laboratory was kept shut at all times to keep the temperature and the air pressure constant however the temperature changes between night and day as well as the pressure of the room could not be controlled even though the doors and windows were kept closed at all times to avoid changes in the air. These environmental properties affected the drying process.

The filter papers could not be oven-dried; so they could have absorbed the moisture in the air and the weights increased. This affected the weight measurements concerning the amount of barium sulfate precipitate calculated. In a repeat of this experiment filter paper should be properly dried.

In trials with artificially dried yellow apricots (which I expected to find the most amount of sulfur dioxide but the calculations have shown the least amount) and artificially dried brown apricots (which also contained a lesser amount of sulfur dioxide than expected) the barium sulfate precipitate was stuck to the Erlenmeyer flasks the solutions with hydrogen peroxide and barium chloride were prepared in so not all of the precipitate could be weighted and included in the calculations. This was the primary reason as to why the amount of sulfur dioxide was low in those trials. The bottom of the Erlenmeyer flasks should be scrubbed to get the most amount of barium sulfate precipitate present in the trials.

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APPENDIX I

1. Calculating the uncertainty for weight of Barium Sulfite ($BaSO_4$) precipitate

(a±0.001) - (b±0.001) = a-b (±0.002)

2. Calculating the values of Barium Sulfite ($BaSO_4$) precipitate

Naturally Dried Figs:

Trial 1; (1.581±0.001) - (0.777±0.001) = 0.804±0.002 g

Trial 2; (1.775±0.001) - (0.767±0.001) = 1.008±0.002 g

Trial 3; (1.532±0.001) - (0.771±0.001) = 0.761±0.002 g

Trial 4; (1.379±0.001) - (0.782±0.001) = 0.579±0.002 g

Trial 5; (1.640±0.001) - (0.772±0.001) = 0.868±0.002 g

Artificially Dried Figs:

Trial 1; (1.678±0.001) - (0.775±0.001) = 0.903±0.002 g

Trial 2; (2.405±0.001) - (0.761±0.001) = 1.644±0.002 g

Trial 3; (2.270±0.001) - (0.764±0.001) = 1.506±0.002 g

Trial 4; (2.578±0.001) - (0.759±0.001) = 1.819±0.002 g

Trial 5; (1.430±0.001) - (0.770±0.001) = 0.660±0.002 g

Naturally Dried Apricots:

Trial 1; (0.992±0.001) - (0.783±0.001) = 0.209±0.002 g

Trial 2; (0.876±0.001) - (0.778±0.001) = 0.098±0.002 g

Trial 3; (1.050±0.001) - (0.778±0.001) = 0.272±0.002 g

Trial 4; (1.046±0.001) - (0.781±0.001) = 0.265±0.002 g

Trial 5; (0.963±0.001) - (0.772±0.001) = 0.188±0.002 g

Artificially Dried Yellow Apricots:

Trial 1; (0.901±0.001) - (0.764±0.001) = 0.137±0.002 g

Trial 2; (0.904±0.001) - (0.771±0.001) = 0.133±0.002 g

Trial 3; (0.889±0.001) - (0.776±0.001) = 0.113±0.002 g

Trial 4; (0.907±0.001) - (0.777±0.001) = 0.130±0.002 g

Trial 5; (0.907±0.001) - (0.773±0.001) = 0.134±0.002 g

Artificially Dried Brown Apricots:

Trial 1; (1.417±0.001) - (0.766±0.001) = 0.651±0.002 g

Trial 2; (0.955±0.001) - (0.774±0.001) = 0.181±0.002 g

Trial 3; (0.949±0.001) - (0.776±0.001) = 0.173±0.002 g

Trial 4; (0.930±0.001) - (0.785±0.001) = 0.145±0.002 g

Trial 5; (0.941±0.001) - (0.781±0.001) = 0.160±0.002 g

3. Calculating the uncertainty when finding the percentage of Sulfur Dioxide (SO_2)

The uncertainty values are found in percentage;

A 0.002 g

100 ?

?= 0.2/A%

The percentage uncertainty values are added in all steps of the calculation if they are present;

$$\frac{(a \pm b\%)x\ 100}{c \pm d\%} \approx a/c \text{ x}100 \pm (b+d)\%$$

4. **Calculations of the percentage of Sulfur Dioxide (SO_2) per fruit with stoichiometry to find the mol of SO_2 using the mol (measured weight/molar mass) of $BaSO_4$ and then calculating the percentage per fruit with the weights of the fruits measured in the beginning.**

$SO_{2\,(g)} + H_2O_{\,(l)} \rightarrow SO_3^{2-}{}_{(aq)} + 2H^+{}_{(aq)}$

1mol 1mol

$SO_3^{2-}{}_{(aq)} + H_2O_{2\,(aq)} \rightarrow SO_4^{2-}{}_{(aq)} + H_2O_{\,(l)}$

1mol 1mol

$SO_4^{2-}{}_{(aq)} + Ba^{2+}{}_{(aq)} \rightarrow BaSO_{4\,(s)}$

1mol 1mol

Naturally Dried Figs:

Trial 1:

Weight of $BaSO_4$; 0.804±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.804 \pm 0.249\%}{233.43} = 3.444x10^{-3} \pm 0.249\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

3.444x10^{-3} ± 0.249% mol SO_2 ? g

?= (3.444x10^{-3} ± 0.249%) x (64.066) ≈ 0.221 ± 0.249% g

26.131±0.004% g naturally dried fig 0.221 ± 0.249% g SO_2

100 ?

$?= \frac{(0.221 \pm 0.249\%) x\ 100}{26.131 \pm 0.004\%} \approx 0.846\ (\pm 0.253\%)$ % Sulfur Dioxide

Trial 2:

Weight of $BaSO_4$; 1.008±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{1.008 \pm 0.198\%}{233.43} = 4.318x10^{-3} \pm 0.198\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

$4.318x10^{-3} \pm 0.198\%$ mol SO_2 ? g

?= $(4.318x10^{-3} \pm 0.198\%)$ x (64.066) ≈ 0.277 ± 0.198% g

26.157±0.004% g naturally dried fig 0.277 ± 0.198% g SO_2

100 ?

?= $\frac{(0.277 \pm 0.198\%)x\ 100}{26.157 \pm 0.004\%}$ ≈ 1.059 (±0.202%) % Sulfur Dioxide

Trial 3:

Weight of $BaSO_4$; 0.761±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.761 \pm 0.263\%}{233.43} = 3.260x10^{-3} \pm 0.263\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

$3.260x10^{-3} \pm 0.263\%$ mol SO_2 ? g

?= $(3.260x10^{-3} \pm 0.263\%)$ x (64.066) ≈ 0.209 ± 0.263% g

27.415±0.004% g naturally dried fig 0.209 ± 0.263% g SO_2

100 ?

?= $\frac{(0.209 \pm 0.263\%\ )x\ 100}{27.415 \pm 0.004\%}$ ≈ 0.762 (±0.267%) % Sulfur Dioxide

Trial 4:

Weight of $BaSO_4$; 0.597±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.597 \pm 0.335\%}{233.43} = 2.588x10^{-3} \pm 0.335\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

2.588x10^{-3} ± 0.335% mol SO_2 ? g

?= (2.588x10^{-3} ± 0.335%) x (64.066) ≈ 0.164 ± 0.335% g

25.454±0.004% g naturally dried fig 0.164 ± 0.335% g SO_2

100 ?

$?= \frac{(0.164 \pm 0.335\%)x\ 100}{25.454 \pm 0.004\%} \approx 0.644\ (\pm 0.339\%)$ % Sulfur Dioxide

Trial 5:

Weight of $BaSO_4$; 0.868±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.868 \pm 0.230\%}{233.43} = 3.718x10^{-3} \pm 0.230\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

3.718x10^{-3} ± 0.230% mol SO_2 ? g

?= (3.718x10^{-3} ± 0.230%) x (64.066) ≈ 0.238 ± 0.230% g

26.906±0.004% g naturally dried fig 0.238 ± 0.230% g SO_2

100 ?

$?= \frac{(0.238 \pm 0.230\%)x\ 100}{26.906 \pm 0.004\%} \approx 0.885\ (\pm 0.234\%)$ % Sulfur Dioxide

Artificially Dried Figs:

Trial 1:

Weight of $BaSO_4$; 0.903±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.903 \pm 0.222\%}{233.43} = 3.868x10^{-3} \pm 0.222\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

3.868x10^{-3} ± 0.222% mol SO_2 ? g

?= (3.868x10^{-3} ± 0.222%) x (64.066) ≈ 0.248 ± 0.222% g

15.058±0.007% g artificially dried fig 0.248 ± 0.222% g SO_2

100 ?

$?= \frac{(0.248 \pm 0.222\%)x\ 100}{15.058 \pm 0.007\%}$ ≈ 1.647 (±0.229%) % Sulfur Dioxide

Trial 2:

Weight of $BaSO_4$; 1.644±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{1.644 \pm 0.122\%}{233.43} = 7.043x10^{-3} \pm 0.122\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

7.043x10^{-3} ± 0.122% mol SO_2 ? g

?= (7.043x10^{-3} ± 0.122%) x (64.066) ≈ 0.451 ± 0.122% g

15.287±0.006% g artificially dried fig 0.451 ± 0.122% g SO_2

100 ?

$?= \frac{(0.451 \pm 0.122\%)x\ 100}{15.287 \pm 0.006\%}$ ≈ 2.950 (±0.128%) % Sulfur Dioxide

Trial 3:

Weight of $BaSO_4$; 1.506±0.002 g   Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{1.506 \pm 0.133\%}{233.43} = 6.452x10^{-3} \pm 0.133\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

$6.452x10^{-3} \pm 0.133\%$ mol SO_2 ? g

?= $(6.452x10^{-3} \pm 0.133\%)$ x (64.066) ≈ 0.413 ± 0.133% g

17.215±0.006% g artificially dried fig   0.413 ± 0.133% g SO_2

100   ?

$?= \frac{(0.413 \pm 0.133\%)x\ 100}{17.215 \pm 0.006\%} \approx 2.400\ (\pm 0.139\%)$ % Sulfur Dioxide

Trial 4:

Weight of $BaSO_4$; 1.819±0.002 g   Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{1.819 \pm 0.110\%}{233.43} = 7.792x10^{-3} \pm 0.110\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

$7.792x10^{-3} \pm 0.110\%$ mol SO_2 ? g

?= $(7.792x10^{-3} \pm 0.110\%)$ x (64.066) ≈ 0.500 ± 0.110% g

17.421±0.006% g artificially dried fig   0.500 ± 0.110% g SO_2

100   ?

$?= \frac{(0.500 \pm 0.110\%)x\ 100}{17.421 \pm 0.006\%} \approx 2.870\ (\pm 0.116\%)$ % Sulfur Dioxide

Trial 5:

Weight of $BaSO_4$; 0.660±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.660 \pm 0.303\%}{233.43} = 2.827x10^{-3} \pm 0.303\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

2.827x10^{-3} ± 0.303% mol SO_2 ? g

?= (2.827x10^{-3} ± 0.303%) x (64.066) ≈ 0.181 ± 0.303% g

16.898±0.006% g artificially dried fig 0.181 ± 0.303% g SO_2

100 ?

$?= \frac{(0.181 \pm 0.303\%) x\ 100}{16.898 \pm 0.006\%} \approx 1.071\ (\pm 0.309\%)$ % Sulfur Dioxide

Naturally Dried Apricots:

Trial 1:

Weight of $BaSO_4$; 0.209±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.209 \pm 0.957\%}{233.43} = 0.895x10^{-3} \pm 0.957\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.895x10^{-3} ± 0.957% mol SO_2 ? g

?= (0.895x10^{-3} ± 0.957%) x (64.066) ≈ 0.057 ± 0.957% g

4.481±0.022% g naturally dried apricot 0.057 ± 0.957% g SO_2

100 ?

$?= \frac{(0.057 \pm 0.957\%) x\ 100}{4.481 \pm 0.022\%} \approx 1.272\ (\pm 0.979\%)$ % Sulfur Dioxide

Trial 2:

Weight of $BaSO_4$; 0.098±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.098 \pm 3\%}{233.43} = 0.420x10^{-3} \pm 3\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.420x10^{-3} ± 3% mol SO_2 ? g

?= (0.420x10^{-3} ± 3%) x (64.066) ≈ 0.027 ± 3% g

4.634±0.022% g naturally dried apricot 0.027 ± 3% g SO_2

100 ?

$?= \frac{(0.027 \pm 3\%) x\ 100}{4.634 \pm 0.022\%}$ ≈ 0.583 (±3%) % Sulfur Dioxide

Trial 3:

Weight of $BaSO_4$; 0.272±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.272 \pm 0.735\%}{233.43} = 1.165\ x10^{-3} \pm 0.735\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

1.165 x10^{-3} ± 0.735% mol SO_2 ? g

?= (1.165 x10^{-3} ± 0.735%) x (64.066) ≈ 0.075 ± 0.735% g

4.576±0.022% g naturally dried apricot 0.075 ± 0.735% g SO_2

100 ?

$?= \frac{(0.075 \pm 0.735\%) x\ 100}{4.576 \pm 0.022\%}$ ≈ 1.639 (±0.757%) % Sulfur Dioxide

Trial 4:

Weight of $BaSO_4$; 0.265±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.265 \pm 0.755\%}{233.43} = 1.135 \times 10^{-3} \pm 0.755\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

1.135 x10^{-3} ± 0.755% mol SO_2 ? g

?= (1.135 x10^{-3} ± 0.755%) x (64.066) ≈ 0.073 ± 0.755% g

4.863±0.020% g naturally dried apricot 0.073 ± 0.755% g SO_2

100 ?

$?= \frac{(0.073 \pm 0.755\%)x\ 100}{4.863 \pm 0.020\%}$ ≈ 1.501 (±0.775%) % Sulfur Dioxide

Trial 5:

Weight of $BaSO_4$; 0.188±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.188 \pm 1.064\%}{233.43} = 0.805 \times 10^{-3} \pm 1.064\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.805 x10^{-3} ± 1.064% mol SO_2 ? g

?= (0.805 x10^{-3} ± 1.064%) x (64.066) ≈ 0.052 ± 1.064% g

4.717±0.021% g naturally dried apricot 0.052 ± 1.064% g SO_2

100 ?

$?= \frac{(0.052 \pm 1.064\%)x\ 100}{4.717 \pm 0.021\%}$ ≈ 1.102 (±1.085%) % Sulfur Dioxide

Artificially Dried Yellow Apricots:

Trial 1:

Weight of $BaSO_4$; 0.137±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.137 \pm 1.460\%}{233.43} = 0.587x10^{-3} \pm 1.460\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.587x10^{-3} ± 1.460% mol SO_2 ? g

?= (0.587x10^{-3} ± 1.460%) x (64.066) ≈ 0.038 ± 1.460% g

11.323±0.009% g artificially dried yellow apricot 0.038 ± 1.460% g SO_2

100 ?

$?= \frac{(0.038 \pm 1.460\%)x\ 100}{11.323 \pm 0.009\%} \approx 0.336\ (\pm 1.469\%)$ % Sulfur Dioxide

Trial 2:

Weight of $BaSO_4$; 0.133±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.133 \pm 1.504\%}{233.43} = 0.570x10^{-3} \pm 1.504\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.570x10^{-3} ± 1.504% mol SO_2 ? g

?= (0.570x10^{-3} ± 1.504%) x (64.066) ≈ 0.036 ± 1.504% g

10.268±0.010% g artificially dried yellow apricot 0.036 ± 1.504% g SO_2

100 ?

$?= \frac{(0.036 \pm 1.504\%)x\ 100}{10.268 \pm 0.010\%} \approx 0.351\ (\pm 1.514\%)$ % Sulfur Dioxide

Trial 3:

Weight of $BaSO_4$; 0.113±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.113 \pm 1.770\%}{233.43} = 0.570x10^{-3} \pm 1.770\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.570x10^{-3} ± 1.770% mol SO_2 ? g

?= (0.570x10^{-3} ± 1.770%) x (64.066) ≈ 0.036 ± 1.770% g

8.614±0.012% g artificially dried yellow apricot 0.036 ± 1.770% g SO_2

100 ?

$?= \frac{(0.036 \pm 1.770\%)x\ 100}{8.614 \pm 0.012\%}$ ≈ 0.418 (±1.782%) % Sulfur Dioxide

Trial 4:

Weight of $BaSO_4$; 0.130±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.130 \pm 1.538\%}{233.43} = 0.557x10^{-3} \pm 1.538\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.557x10^{-3} ± 1.538% mol SO_2 ? g

?= (0.557x10^{-3} ± 1.538%) x (64.066) ≈ 0.036 ± 1.538% g

8.336±0.012% g artificially dried yellow apricot 0.036 ± 1.538% g SO_2

100 ?

$?= \frac{(0.036 \pm 1.538\%)x\ 100}{8.336 \pm 0.012\%}$ ≈ 0.432 (±1.550%) % Sulfur Dioxide

Trial 5:

Weight of $BaSO_4$; 0.134±0.002 g   Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.134 \pm 1.492\%}{233.43} = 0.557 x 10^{-3} \pm 1.492\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.557x10^{-3} ± 1.492% mol SO_2 ? g

?= (0.557x10^{-3} ± 1.492%) x (64.066) ≈ 0.036 ± 1.492% g

7.943±0.013% g artificially dried yellow apricot   0.036 ± 1.492% g SO_2

100   ?

$?= \frac{(0.036 \pm 1.492\%)x\ 100}{7.943 \pm 0.013\%}$ ≈ 0.453 (±1.505%) % Sulfur Dioxide

Artificially Dried Brown Apricots:

Trial 1:

Weight of $BaSO_4$; 0.651±0.002 g   Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.651 \pm 0.307\%}{233.43} = 2.789 x 10^{-3} \pm 0.307\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

2.789x10^{-3} ± 0.307% mol SO_2 ? g

?= (2.789x10^{-3} ± 0.307%) x (64.066) ≈ 0.179 ± 0.307% g

9.895±0.010% g artificially dried brown apricot   0.179 ± 0.307% g SO_2

100   ?

$?= \frac{(0.179 \pm 0.307\%)x\ 100}{9.895 \pm 0.010\%}$ ≈ 1.809 (±0.317%) % Sulfur Dioxide

Trial 2:

Weight of $BaSO_4$; 0.181±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.181 \pm 1.105\%}{233.43} = 0.775x10^{-3} \pm 1.105\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.775x10^{-3} ± 1.105% mol SO_2 ? g

?= (0.775x10^{-3} ± 1.105%) x (64.066) ≈ 0.050 ± 1.105% g

10.245±0.010% g artificially dried brown apricot 0.050 ± 1.105% g SO_2

100 ?

$?= \frac{(0.050 \pm 1.105\%) x\ 100}{10.245 \pm 0.010\%}$ ≈ 0.448 (±1.115%) % Sulfur Dioxide

Trial 3:

Weight of $BaSO_4$; 0.173±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.173 \pm 1.156\%}{233.43} = 0.741x10^{-3} \pm 1.156\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.741x10^{-3} ± 1.156% mol SO_2 ? g

?= (0.741x10^{-3} ± 1.156%) x (64.066) ≈ 0.048 ± 1.156% g

10.806±0.009% g artificially dried brown apricot 0.048 ± 1.156% g SO_2

100 ?

$?= \frac{(0.048 \pm 1.156\%) x\ 100}{10.806 \pm 0.009\%}$ ≈ 0.444 (±1.165%) % Sulfur Dioxide

Trial 4:

Weight of $BaSO_4$; 0.145±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.145 \pm 1.379\%}{233.43} = 0.621x10^{-3} \pm 1.379\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.621x10^{-3} ± 1.379% mol SO_2 ? g

?= (0.621x10^{-3} ± 1.379%) x (64.066) ≈ 0.040 ± 1.379% g

9.519±0.010% g artificially dried brown apricot 0.040 ± 1.379% g SO_2

100 ?

$?= \frac{(0.040 \pm 1.379\%)x\ 100}{9.519 \pm 0.010\%} \approx 0.420\ (\pm 1.389\%)$ % Sulfur Dioxide

Trial 5:

Weight of $BaSO_4$; 0.160±0.002 g Molar mass of $BaSO_4$; 233.43 g/mol

$n_{BaSO4} = \frac{0.106 \pm 1.250\%}{233.43} = 0.685x10^{-3} \pm 1.250\%$ mol

$n_{BaSO4} = n_{SO2}$

1mol SO_2 64.066g

0.685x10^{-3} ± 1.250% mol SO_2 ? g

?= (0.685x10^{-3} ± 1.250%) x (64.066) ≈ 0.044 ± 1.250% g

10.680±0.009% g artificially dried brown apricot 0.044 ± 1.250% g SO_2

100 ?

$?= \frac{(0.044 \pm 1.250\%\ )x\ 100}{10.680 \pm 0.009\%} \approx 0.412\ (\pm 1.259\%)$ % Sulfur Dioxide

5. Calculations of means of the percentage of sulfur dioxide (SO_2) values per fruit groups

Naturally Dried Figs:

$$\frac{(0.846 \pm 0.253\%)+(1.059 \pm 0.202\%)+(0.762 \pm 0.267\%)+(0.644 \pm 0.339\%)+(0.885 \pm 0.234\%)}{5} =$$

$\frac{(4.196 \pm 1.295\%)}{5}$ = 0.839 (± 0.259%) % sulfur dioxide

Artificially Dried Figs:

$$\frac{(1.647 \pm 0.229\%)+(2.950 \pm 0.128\%)+(2.400 \pm 0.139\%)+(2.870 \pm 0.116\%)+(1.071 \pm 0.309\%)}{5} =$$

$\frac{(10.938 \pm 0.921\%)}{5}$ = 2.188 (± 0.184%) % sulfur dioxide

Naturally Dried Apricots:

$$\frac{(1.272 \pm 0.979\%)+(0.583 \pm 3\%)+(1.639 \pm 0.757\%)+(1.501 \pm 0.775\%)+(1.102 \pm 1.085\%)}{5} =$$

$\frac{(6.097 \pm 6.596\%)}{5}$ = 1.219 (± 1.319%) % sulfur dioxide

Artificially Dried Yellow Apricots:

$$\frac{(0.336 \pm 1.469\%)+(0.351 \pm 1.514\%)+(0.418 \pm 1.782\%)+(0.432 \pm 1.550\%)+(0.453 \pm 1.505\%)}{5} =$$

$\frac{(1.990 \pm 7.820\%)}{5}$ = 0.398 (± 1.564%) % sulfur dioxide

Artificially Dried Brown Apricots:

$$\frac{(1.809 \pm 0.317\%)+(0.488 \pm 1.115\%)+(0.444 \pm 1.165\%)+(0.420 \pm 1.389\%)+(0.412 \pm 1.259\%)}{5} =$$

$\frac{(3.575 \pm 5.245\%)}{5}$ = 0.715 (± 1.049%) % sulfur dioxide

APPENDIX II

1. Information on Chemical Compounds in the Experiment

3M Barium Chloride ($BaCl_2$):[27] Most common water soluble salt of barium

Toxic

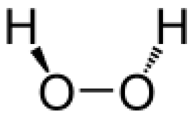
Molar mass: 244.26 g/mol

%3 Hydrogen Peroxide (H_2O_2):[28] Clear liquid, slightly more viscous than water

Colourless in dilute solution

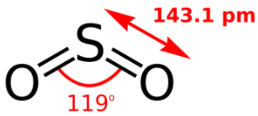
Strong oxidizer

Molar mass: 34.0147 g/mol

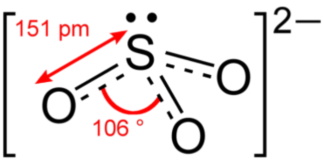


Sulfur Dioxide (SO_2):[29] Poisonous gas

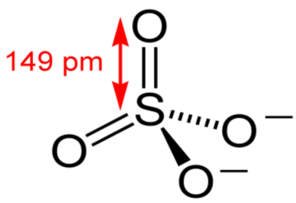
Molar mass: 64.066 g/mol



Sulfite (SO_3^{2-}):[30]



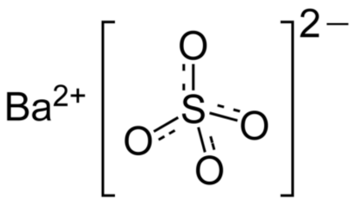
Sulfate (SO_4^{2-}):[31]



Barium Sulfate ($BaSO_4$):[32] Odourless white crystalline solid

Insoluble in water

Molar mass: 233.43 g/mol



[27] http://en.wikipedia.org/wiki/Barium_chloride
[28] http://en.wikipedia.org/wiki/Hydrogen_peroxide
[29] http://en.wikipedia.org/wiki/Sulfur_dioxide
[30] http://en.wikipedia.org/wiki/Sulfite
[31] http://en.wikipedia.org/wiki/Sulfate
[32] http://en.wikipedia.org/wiki/Barium_sulfate

2. During the Experimentation Process

Figure 1. Five dried fruit groups used in the experiment (Naturally dried figs-bottom left-, artificially dried figs-top left-, naturally dried apricots-bottom right-, artificially dried yellow apricots-top middle-, artificially dried brown apricots-top right-)

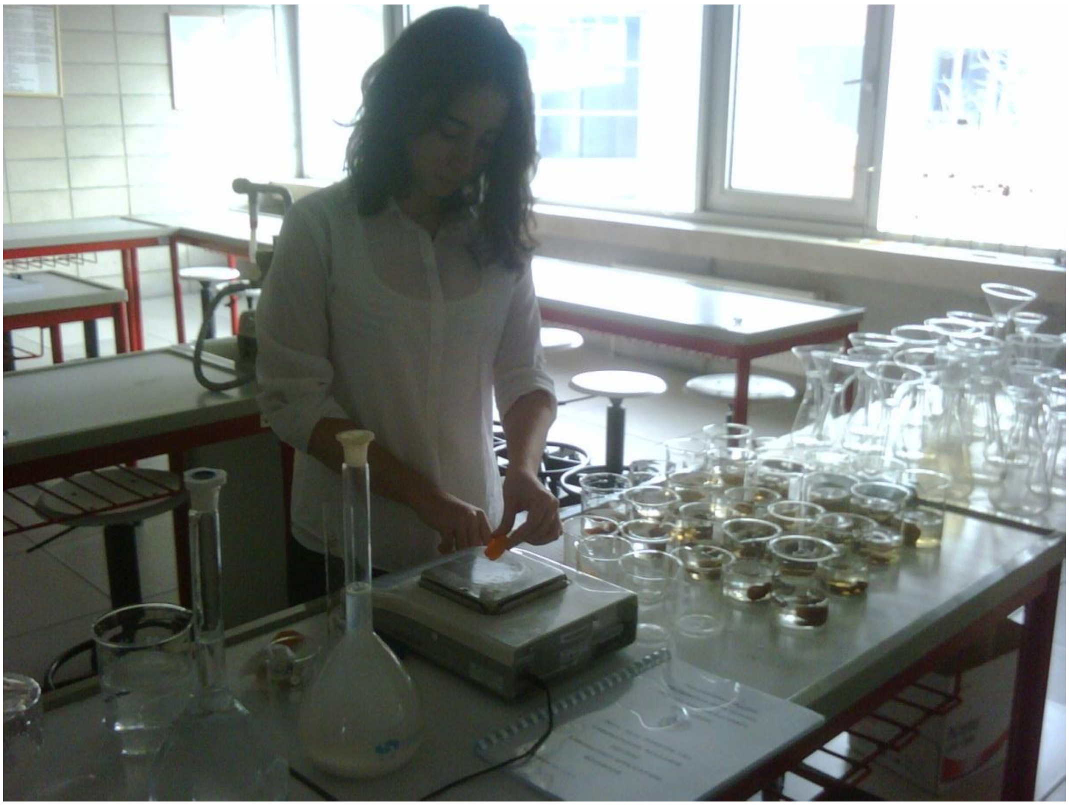


Figure 2. Dried fruits were weighted before immersing them in water

Figure 3. The fruits were scrubbed to extract as much as sulfur dioxide from the skin as possible.

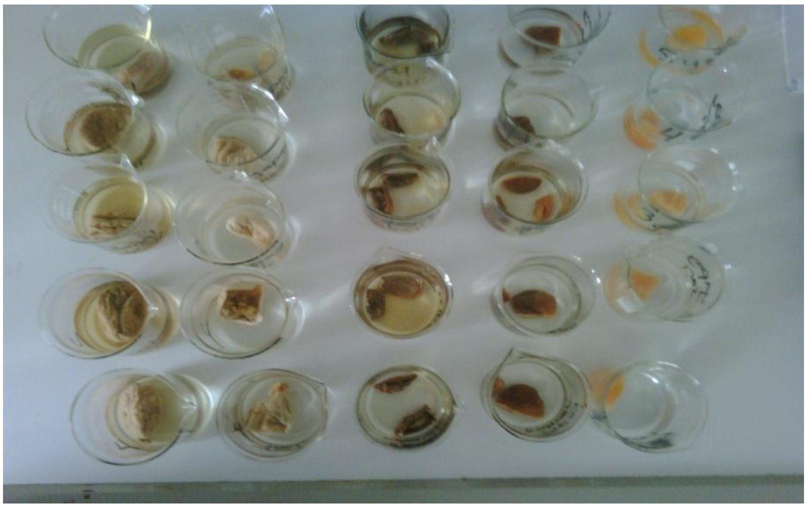


Figure 4. Dried fruits were left immersed in pure water for 1 day. After one day the fruits had absorbed some of the water and looked more similar to their original forms.

Figure 5. Fruit pieces were filtered out.

Figure 6. 30.0 ± 0.1 mL of 3% H_2O_2 then 3-4 drops of 3M $BaCl_2$ were added all trials

Figure 7. The solutions were filtered out so that the $BaSO_4$ precipitate was left on the filter

Figure 8. The solutions were run through the filter papers afterwards the filter papers were left to dry for 1 week

Figure 9. Most of the $BaSO_4$ precipitate (white) was left stuck to the bottom of the Erlenmeyer flasks in trials with artificially dried yellow apricots

Figure 10. The filter papers were weighted after drying and the weight of the filter papers were subtracted to find the weight of $BaSO_4$ precipitate