A Comprehensive Review on the Addition of Natural Antioxidants in Mayonnaise to Prevent Oxidation.

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Abstract:

Mayonnaise can be defined as an oil-in-water emulsion and consist of 70-80 % oil. It is consumed globally in huge amount. The quality of mayonnaise can be deteriorated by the lipid oxidation. Oily nature of mayonnaise is a main reason for lipid oxidation. Lipid oxidation reduced the shelf life of mayonnaise and produce undesirable off-flavor. It is a major problem of food industry. It produces negative impact on the quality attributes and consumer acceptability of product. Synthetic Antioxidants are also used to inhibit lipid oxidation such as BHT and BHA. But consumers have negative impressions on chemical containing product. Additionally, there are also some studies available which shows some serious side-effects of synthetic antioxidants. Therefore, there is increasing interest for the addition of natural antioxidants which are from the plant sources and contains phenolic compounds. Natural antioxidants increase the quality characteristics of mayonnaise by preventing it from rancidity. In this review, all the natural antioxidants and their effects are discussed in mayonnaise with detail. Addition of natural antioxidants in mayonnaise result in reduction of Thiobarbituric acid (TBA) which is responsible for oxidation. The use of natural antioxidants in the mayonnaise for prevention of lipid oxidation problem should be promoted.

Keywords: Natural Antioxidants, Mayonnaise, Characteristics, Rancidity, Lipid Oxidation

Introduction:

Mayonnaise is an oil-water emulsion and ranked as most consumed food emulsion. It is primarily produced by dispersing oil in vinegar, egg yolk and spices (Alvarez-Sabatel et al., 2018). Mayonnaise is consumed globally in very high amount. It consists of sixty-five to eighty percent of fat which is responsible for its characteristic texture, flavor and shelf life (Sun et al., 2018). Mayonnaise is unstable due to oil-in-water emulsion and being stabilized by different processing techniques (Mollakhalili Meybodi et al., 2014). Quality deterioration of lipid-based food is caused by lipid oxidation (Abeyrathne et al., 2021). Food emulsions with high concentrations of unsaturated fats like mayonnaise are prone to lipid oxidation. The oxidation reactions cause the production of free radicals. Antioxidants can be added to processed foods to avoid oxidation (Jacobsen et al., 2013). The change in formula ingredients can have impact on both the quality attributes and consumer acceptability. But it should be considered that stability of food products which are stabilized by emulsion can be oxidized during processing or storage (McClements, 2015). Most of the antioxidants present in market are synthetic and have been proven to be toxic and carcinogenic (Shahin et al., 2014).

The oily nature of mayonnaise is responsible for its deterioration by lipid oxidation. Natural and synthetic antioxidants have been proven to delay oxidation and extend shelf life (Ghorbani et al., 2016). Antioxidants have always been of interest for decades. The exploration of natural sources of antioxidants has continued for a long time (Zehiroglu & Sarikaya, 2019). Mayonnaise samples treated with ethanolic extract of sage (Salvia officinalis L.) indicated that free radicals were lower in the samples as compare to BHA treated and without treatment (Rasmy et al., 2012). Plant has antioxidants properties along with aromatic effects (Reuter et al., 2010).

Almost all parts of plants including leaves, roots, stems, fruit, seeds and bark can be the valuable sources of natural antioxidants (Bouaziz et al., 2008). Fruits contain various phytochemicals which exhibit antioxidant properties (Ehtasham Amin et al., 2023). Synthetic antioxidants had been examined to assess the safety and get approval from accreditation bodies for proper use in processed foods at acceptable levels on the basis of trial. Synthetic antioxidant is being widely used in many countries but there are many doubts for their safety (Shahidi, 2005). Phenolic compounds from plants have gained attention because of their nutritional and functional properties specially antioxidant activity (Bubonja-Sonje et al., 2011).

That trend of using plant extracts is being promoted for their antioxidant activity to prevent lipid oxidation and expand the shelf life of fat-based foods (Farhadi et al., 2016). The incorporation of natural antioxidants in fat rich foods is an effective way to avoid the deterioration caused by ROS (reactive oxygen species) (Mármol et al., 2017).

Natural Antioxidants in Mayonnaise and Effects:
Essential Oil of Achillea millefolium subsp. Millefolium:

Three different concentrations of oil derived from Achillia molifus species is used to check the ability of oils to inhibit oxidation of oil in mayonnaise. Essential oil of *Achillea millefolium subsp. Millefolium* was added in Mayonnaise in three different concentrations namely E0.1=3.83mg/ml, E0.2=5.85mg/ml and E0.3=7.2mg/ml individually. The experiment shows that the essential oil of Achillia mollifus effect on peroxide value, thiobarbituric acid value (TBA) aniside value. Essential oil when used in concentration of E0.3 (7.2mg/ml) shown the lowest peroxide value of 3.95 ± 0.05 after 6 months of storage time as compared to control 10.45 ± 0.15.in terms of Thiobarbiyuric acid value the results were the lowest TBA value (15.09 ± 1.00) was shown after 3 months of storage when EO.3 concentration was used as compared to control 41.12 ± 0.8.The aniside value and TBHQ is also affected by the essential oil of specie as E02 gave the lowest anisidine value of 5.971 ± 1.00 as compared to control (22.84 ± 2.50) and TBHQ (Tert-butylhydroquinone) which is a synthetic antioxidant used in different type of food like mayonnaise (2.414 ± 0.20) after 6 months of storage. More ever the oils of achillia mollifus also affect the flavor of mayonnaise appreciately as When essential oil concentration increased from 3.83mg/ml to 5.85mg/ml the flavor grade improved by 4.65. (Ahmadi-Dastgerdi et al., 2019).

Ferulago angulata extracts:

The extract of ferulago angulata help in the prevention of oxidation in mayonnaise and extends its shelf life. Ferulago angulata extracts was prepared and added in three different concentrations 0.1%, 1% and 10% into mayonnaise and the effect of every concentration of mayonnaise is studied. The DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) radical scavenging activity of Ferulago angulata extracts was (63.94 ± 0.24) when used in 10% concentration. Ferulago angulata extracts has an intermediate effect on the Peroxide values during storage period and aniside value remain unaffected by the presence of this extract.one

disadvantage to use ferulago extract is that when it is used in mayonnaise it reduces the overall acceptability of mayonnaise. (Alizadeh et al., 2019).

Rosemary (Rosmarinus officinalis L.) essential oil:

Rosemary essential oil is prepared and added in three different concentrations in mayonnaise to check its action against the oxidation of mayonnaise. Rosemary essential oil with the concentration of 0.1%,1% and 10% is added in mayonnaise and examined its effect on oxidation. The hydroperoxide value of rosemary essential oil added to mayonnaise was 4.6 times less as compared the control sample. The DPPH radical scavenging activity increases with the increase in concentration of rosemary essential oil. The DPPH radical scavenging activity of Rosemary essential oil was 24.15 ± 0.98 when used in 10% concentration in mayonnaise. This shows that the addition of rosemary essential oil in mayonnaise help in the prevention of oxidation and extend its shelf life. (Alizadeh et al., 2019).

Rice bran extracts:

Rice bran extract is prepared in aqueous and ethanolic media. In aqueous media its concentration was 0.5% while in ethanolic media its concentration is 2% both of the concentration is added in mayonnaise and check its effect on prevention of oxidation in mayonnaise. Aqueous extract was less effective in the prevention of oxidation as compared to ethanolic extract while the ethanolic extract has dual benefits in mayonnaise first it help in the inhibition of oxidation and secondly it also lower the growth of microorganisms.so ethanol extract of rice bran is very effective to prevent the oxidation of mayonnaise with additional advantage in reduction of microbial growth (Martillanes et al., 2020).

Thyme Essential Oil:

Thyme essential oil in mayonnaise is used in PCl (Polycaprolactone) nanoparticles and were applied to mayonnaise to evaluate the antioxidant property of this oil. The most obvious effect is indicated on TBARS value and hydroperoxide value after 8 days of storage. In oven after 8 days of storage at 63 ± 3oC, TBARS value was 0.075 ± 0.007 compared to control 0.080 ± 0.010. and Hydroperoxide value after 8 days of storage in oven at 63 ± 3oC was 3.1 ± 0.2 compared to control 11.9 ± 0.8. According to these tests significant reduction in the oxidation of mayonnaise added with thyme essential oil can be verified (Passos et al., 2019).

Processed Beetroot (Beta vulgaris L.):

Beetroot contains different compounds which is used to prolong the shelf life of mayonnaise by preventing oxidation. Beetroot contains betanin, Indica xanthin and several other polyphenols whose concentration varies on the basis of processing technique used either microwaved, roasted or boiled. Especially when boiled beetroot contains betanin and Indica xanthin at a concentration of 221.3 ± 1.8 mg/mL and 122.4 ± 8.9 mg/m respectively and polyphenols at the concentration of 279.6 ± 21.9 mg/ml. At this concentration processed beetroot has significant impact on FRAP value which is 4.8 ± 0.1. With the addition of beetroot, no significant difference was observed between the acceptability scores of reformulated mayonnaises with beetroot and control sample (Raikos et al., 2016).

Pistachio Green Hulls Extracts:

Pistachio green hull (PGH) extract is also playing an important role in inhibiting the oxidation of mayonnaise. Firstly, PGH extract was encapsulated in nanoliposomes and then different concentration is used to check its effect on oxidation. The concentration used was 500 and 1000 mg/kg either free (EX) or incorporated and added to mayonnaise. The experiment shows that

the extract help in reducing the peroxide and TBA value. NL-2-1000 showed the lowest peroxide value of 23.23 ± 2.61 as compared to control sample (68.56 ± 4.70) after 4 months of storage period. In terms of TBA NL-2-1000 showed the lowest TBA value after 4 months of storage period. NLs having 1000mg/kg of phenolic compounds have the highest inhibitory efficiency on total viable and fungal counts. So, PGH extract at the concentration of 1000 mg/kg is efficient in the inhibition of oxidation and total viable fungal counts in the mayonnaise as compared to the concentration of 500 mg/kg (Rafiee et al., 2018).

Black Cumin Oil:

In the experiment two concentrations Mayo-5% and Mayo-20% were prepared each containing black cumin oil in different concentrations to evaluate its beneficiary effect on the oxidation of mayonnaise. The result shown that Mayo-20% impact largely on hyperoxide value. It inhibited the rate of hydroperoxide formation by 51.04% as compared to control by the end of 28 day but it has the problem that it is not accepted by consumer on the other hand mayonnaise formulation with less black cumin oil has less effect on the inhibition of oxidation but it has the highest consumer acceptability level (Ozdemir et al., 2018).

Tangerine (C. reticulata var. Arryana) Peels extracts:

The most important features of Tangerine peel extract are that it has great amount of flavonones in it. Supercritical fluid extraction technique is employed to extract the flavonones from its peel. Different concentrations of flavanone were obtained by super critical fluid extraction under different extraction conditions each having different oxidation inhibition percentage. As the concentration of flavonone vary the rate of inhibition of oxidation is also vary accordingly in the experiment. It is checked that Tangerine peel having %Flavanone (3.17 ± 0.11mg/g) shows %inhibition of 89.22 ± 0.88.this concentration of flavonone is most effective as compared to other concentrations because it inhibit the oxidation of mayonnaise almost up to 90% (Franco-Arnedo et al., 2020).

Cashew (Anacardium occidentale L.) Leaf Extract:

Cashew extract was added to mayonnaise at concentration levels of 100 and 200 mg/kg. When experiment is performed the results suggested that Cashew leaf extract at the concentration of 200 mg/kg is more effective in inhibition of oxidation because it has more significant role in lowering the peroxide, TBARS value and p-aniside value which are the mainly used in determining the oxidation of a product. One additional benefit of cashew extract after inhibiting the oxidation and extending the shelf life of mayonnaise is that it efficiently retard the formation of rancid and fishy odor in the mayonnaise which otherwise lower the acceptability and quality of mayonnaise (Chotphruethipong & Benjakul, 2019).

Essential Oil of Citronella (Cympogon Nardus):

The oil of citronella has two major antioxidant compounds in it one is citronella (48.73%) and the other is geraniol (33.39%), Citronella Essential Oi (CEO) was added in mayonnaise oil 50, 100 and 150 µl/100 gm. In the experiment it mainly affects the peroxide value (PV) when added in mayonnaise at different concentrations at 50µl and 100µl concentration 58.99 and 75.00 percent inhibition of oil oxidation in terms of PV value occurred. CEO also has some additional advantages when used in mayonnaise. It Lowered the total bacterial and fungi count at concentration of 100µl/100g It does not have significant effect on texture of the added product. Citronella also effect the appearance characteristics of mayonnaise as At 100µl/100g concentration citronella gave better appearance rating score on (El-Kholany, 2017).

Essential oil of Geranium (Pelargonium graveolens):

Geranium contain a major antioxidant compound in it as geranial (40.49%). Geranium Essential Oil (GEO) was added in mayonnaise in three different concentrations which are 50,100 and 150µl/100mg.At all concentrations in mayonnaise Geranium Essential oil found to inhibit oxidation by lowering the PV value but the most effective are 100 and 150µl/100mg Geranium oil at concentration of 100µl and 150µl showed inhibition of 39.05 and 52.07 percent in terms of PV value. It can be seen that the concentration of 150µl inhibit the PV value by more than 50%. It also affects the microbial load of the product. It lowered the total bacterial and fungi count at concentration of 100µl/100g.it has no significant effect on the texture of mayonnaise. Moreover, GEO also effect the appearance properties of the mayonnaise at 150µl/100g concentration citronella gave better appearance rating score (El-Kholany, 2017).

Hydrolyzed Rapeseed Cake Extract:

Crude Rapeseed Cake has less phenolic content. Therefore, we hydrolyze the rapeseed cake to increase its phenolic content and make it more effective, it was added in three concentrations of 100ppm, 250ppm or 500ppm.It prevent the oxidation and extend the shelf life of mayonnaise by inhibiting the peroxide value and thiobarbituric acid value Its lower PV values (13.5meq/kg) after 6 weeks was observed as compared to control. It also lowers 2-thiobarbituric acid-reactive substances value (66.2µg/100 g) after 8 weeks was observed compared to control. So, it can be seen that it is very effective against the oxidation of mayonnaise and increases its stability (Kim & Lee, 2017).

Apple Peel Extract:

Apple Peel Extract use in four concentration of apple peel extract was used with 0.5%,0.75%, 1% and 1.25% to study the antioxidant properties in mayonnaise. The effect of apple peel on the stability of mayonnaise is studied and found that the apple peel extract largely on the peroxide value and p-aniside value during testing the oxidation inhibition characteristics and found that the concentration of 1.25% is more effective Apple peel with concentration of 1.25% show the least peroxide value and Aniside value which are 1.3±0.04 meq/kg and 3.42±0.09mmol kg1 (Khalid et al., 2021).

Microcrystalline Cellulose Obtained from Almond Residue:

Microcrystalline cellulose obtained from almond residue act as a natural antioxidant and experiment shows that it is more effective than synthetic antioxidants which are BHT and α-tocopherol. Three different concentration of almond extract is used with 0.2,0.4 and 0.6% Almond Extract Microcrystalline Cellulose obtained from Almond Residue (AE-MCC-AS). The concentration of 0.6% is more effective in final results. AE-MCC-AS at the concentration of 0.6% has Shown the better effect in preventing oil oxidation (Unver et al., 2021).

Olive mill waste water with phenolic extract:

Olive oil extraction produces by-product which can be used as a natural source of antioxidant, such as olive mill waste water, because it has high content of phenolic compounds. Two different enriched mayonnaise sample were prepared, one containing 50g of phenolic extract (EMPEA) and second containing 45g of phenolic extract (EMPEB) obtained from olive mill waste water. EMPEA showed 33 % resistance to rancidity at the end of storage period (43 days) while EMPEB showed 58% higher resistance to rancidity compared to the control. Further, the sensory parameters variation caused by the addition of phenolic extract can be overcome with addition of ingredients that will improve the color and taste of the mayonnaise (De Bruno et al., 2021).

Thyme (Zataria multiflora Boiss) Essential Oil as natural antioxidant:

Essential oils have the potential to lower the oxidative damage caused in oily products. Essential oil from Multiflora plant was extracted and added to mayonnaise in a concentration of 0 to 150 μg/ml. In total 14 different component were identified. However major components responsible for showing antioxidant activity carvacrol, thymol, a-terpinene, a-pinene,3-octanone and carvacrol acetate. During the storage period of six months, immediately after the production of mayonnaise, no difference was observed in TBA value. But after this period the TBA index increase significantly, the sample containing the thyme essential oil, its TBA index increased from 0.18 to 3.53 mg MDA/kg in the six months storage time (Ahmadi-Dastgerdi et al., 2022).

Protein products from sesame seeds:

Protein products from seasame seeds is also effectively reduced the oxidation of oily emulsions products like mayonnaise three different types of samples prepared from seasame seeds and checked for their affect in the inhibition of oxidation. These sample were seasame oil, full-fat flour and protein concentrate. The experiment shows that seasame oil is more antioxidant activity product made from sesame seeds has different compounds which has antioxidative effect in emulsion like mayonnaise e.g. Phytosterol (Bugaets et al., 2021).

Cucumis Sativus Seeds;

Extract obtained from the kernels of Cucumis Sativus Seeds was added in the mayonnaise in the concentration of 200ppm.Aqeous extract was used to study the effect of CCS as it contains a high proportion of antioxidants and polyphenols. The effectiveness of CCS extracts in mayonnaise was measured using TBARS value. Over the 5 weeks of storage time mayonnaise containing the CCS extract showed the lower TBARS value as compared to control and the sample containing a synthetic antioxidant BHT. In the last week of 5 weeks storage period TBARS value of control sample reached to 0.51 MAD kg-1 which was 52 % higher than sample containing CCS extract at 4ºC.Therefore it has been shown that CCS extract containing polyphenols controlled the lipid oxidation effectively (Azhagu Saravana Babu et al., 2016).

Spice Added Mayonnaise:

When spices are added in mayonnaise it has a great impact in reducing the DPPH activity so it has beneficial effect in inhibiting the oxidation in mayonnaise and prolong its storage life. Different spices like Rosemary, Ginger, Black Pepper and are added in the concentration of 100,500 and 1000 μg/ml in mayonnaise. The experiment has shown that among the four-extract examined rosemary exhibited strongest activity against the DPPH and has the scavenging effect up to 91.26% at the concentration of 1000 μg/ml. Other spices and concentration of 100 and 500 is not inhibited DPPH value largely. Rosemary essential oil reduce the DPPH activity almost twice. it indicates that if we increase the concentration of spices the oxidation activity is reduced and storage life is extended (Kwon et al., 2015).

Combination of hydrophilic green tea extract and lipophilic tocopherol mixture:

The combination of hydrophilic green tea extract and lipophilic tocopherol mixture is also proved beneficial in preventing the oxidation when added to mayonnaise at different concentration. The experiment shows that when green tea extract and tocopherol at the concentration of 500ppm each is mixed and added in mayonnaise the result indicate that the

mixture is more effective in oxidation as compared to BHT Mixture of green tea extract and tocopherol (GTT) show the antioxidant activity by inhibiting the formation of pentanal to 50.87 ± 12.82 as compared to BHA 25.76 ± 5.22 after 15 days of storage (Ghorbani Gorji et al., 2019).

Tartary Buckwheat Hull Extract:

Tartary Buckwheat hull extract is added in mayonnaise in different concentration but the concentration of 0-08% w/w was seen as more effective. In the experiment mayonnaise added with Tartary buckwheat hull extract is checked for their antioxidant potential after storage of 31 days. By the end of 31st day of storage control show the highest TBA value (0.1mg-1) while mayonnaise added with Tartary buckwheat hull extract show the lowest TBA value (0.047mg-1). The lower TBA value in Tartary buckwheat extract as compared to control prove that the extract has antioxidant activity (Park et al., 2019).

Table 1: All scientific findings about addition of natural antioxidant in mayonnaise.

Natural Antioxidant	Antioxidant Concentration	Key Findings	Reference
Essential Oil of *Achillea millefolium subsp. Millefolium*	Essential oil of *Achillea millefolium subsp. Millefolium* was added in Mayonnaise in three different concentrations namely E0.1=3.83mg/ml, E0.2=5.85mg/ml and E0.3=7.2mg/ml individually.	Essential oil when used in concentration of E0.3 (7.2mg/ml) shown the lowest peroxide value of 3.95 ± 0.05 after 6 months of storage time at 4 Ċ as compared to control 10.45 ± 0.15. The lowest TBA value (15.09 ± 1.00) was shown after 3 months of storage when EO.3 concentration was used as compared to control 41.12 ± 0.8. The TOTOX value using EO3 was 17.305±2.0 as compared to control 43.74±3.75.	(Ahmadi-Dastgardi et al., 2019)

Ferulago angulata extracts	*Ferulago angulata* extracts was prepared and added in three different concentrations 0.1%, 1% and 10% into mayonnaise.	The DPPH radical scavenging activity of *Ferulago angulata* extracts was (63.94 ± 0.24) when used in 10% concentration.	(Alizadeh et al., 2019)
Rosemary *(Rosmarinus officinalis L.)* essential oil	Rosemary essential oil was prepared in three different concentrations 0.1%, 1% and 10% by adding methanol and then added to mayonnaise.	The hydroperoxide value of rosemary essential oil was 4.6 times less as compared to the control sample at the end of storage period of 6 months. The DPPH radical scavenging activity of Rosemary essential oil was 24.15 ± 0.98 when used in 10% concentration.	(Alizadeh et al., 2019)
Rice bran extracts	Two concentrations Aqueous and Ethanolic in 0.5% and 2% was prepared and added to mayonnaise.	Aqueous extract showed the lower values of oxidation inhibition. Ethanolic extract was proven to be most effective in both inhibiting oxidation and microbiological growth.	(Martillanes et al., 2020)
Thyme Essential Oil	Thyme essential oil in PCL nanoparticles were applied to mayonnaise	After 8 days of storage in oven at 63 ± 3^{o}C, TBARS value was 0.075 ± 0.007 compared to control 0.080 ± 0.010. And Hydroperoxide valaue at the same condition was 3.1±0.2 as compared to control 11.9±0.8	(Passos et al., 2019)
Processed Beetroot (*Beta vulgaris L.*)	Beetroot contains betanin, indicaxanthin and several other	When boiled beetroot containing (Betanin 221.3 ± 1.8 mg/mL,	(Raikos et al., 2016)

	polyphenols whose concentration varies on the basis of processing technique used either microwaved, roasted or boiled.	Indicaxanthin 122.4 ± 8.9 mg/mL and Polyphenols 279.6 ± 21.9 mg/mL) was used as an antioxidant agent it gave FRAP value of 4.8 ± 0.1.	
Pistachio Green Hulls Extracts	PGH extracts was encapsulated in nanoliposomes and then different concentrations (500 and 1000 mg/kg) either free (EX) or incorporated (NL) was added to mayonnaise.	NL-2-1000 showed the lowest peroxide value of 23.23 ± 2.61 as compared to control sample (68.56 ± 4.70) after 4 months of storage period. NL-2-1000 showed the TBA value of 0.92±0.7 as compared to control 1.85±0.14 after 4 months of storage period.	(Rafiee et al., 2018)
Black Cumin oil	Two concentrations Mayo-5% Black Cummin Oil and Mayo-20% Black Cummin Oil were prepared.	Mayo-20% inhibited the rate of hydroperoxide formation by 51.04% as compared to control by the end of 28 days. Mayo-20% has PV valaue of 17.66±1.93 as compared to Mayo-Control 36.07±1.51.	(Ozdemir et al., 2018)
Tangerine (*C. reticulata var. Arryana*) Peels extracts	Different concentrations of flavanone were obtained by super critical fluid extraction under different extraction conditions each having different oxidation inhibition percentage.	%Flavanone (3.17 ± 0.11mg/g) shows %inhibition of 89.22 ± 0.88. The extract is effective against the oxidation of mayonnaise even better than BHA.	(Franco-Arnedo et al., 2020)

Cashew *(Anacardium occidentale L.)* Leaf Extract	Cashew extract was added to mayonnaise at concentration levels of 100 and 200 mg/kg.	Cashew extract at both levels effectively retard the formation of rancid and fishy odor in mayonnaise. Cashew extract at 200mg/kg has shown lower peroxide value, TBARS and p-anisidine value.	(Chotphruethipong & Benjakul, 2019)
Essential oil of Citronella (*Cymbopogon nardus*)	Major antioxidant compound in it was citronella (48.73%) and geraniol (33.39%), CEO was added in mayonnaise oil 50, 100 and 150 µl/100 gm.	At 50µl and 100µl concentration 58.99 and 75.00 percent inhibition of oil oxidation in terms of PV value occurred.	(El-Kholany, 2017)
Essential oil of Geranium (*Pelargonium graveolens*)	Major antioxidant compound in it was geraniol (40.49%), GEO was added in mayonnaise oil 50, 100 and 150 µl/100 gm.	Geranium oil at concentration of 100µl and 150µl showed inhibition of 39.05 and 52.07 percent in terms of PV value.	(El-Kholany, 2017)
Hydrolyzed Rapeseed Cake Extract	Hydrolyzed rapeseed has high phenolic content compared to crude, it was added in three concentrations of 100ppm, 250ppm or 500ppm	Lower PV values (13.5meq/kg) after 6 weeks was observed as compared to control. Lower 2-thiobarbituric acid-reactive substances value (66.2µg/100 g) after 8 weeks was observed compared to control.	(Kim & Lee, 2017)
Carotino Oil to develop Carotene-rich Mayonnaise	Three formulations were made; Mayonnaise with only Carotino oil (MC), Carotino and Palm oil (MCS) and Palm oil (MS).	Lowest peroxide value was obtained by MCS 9.40 ± 0.131 compared to other formulations. MC shown the highest free radical	(Haniff et al., 2020)

		scavenging activity of 25.1 ± 0.35 compared to other formulations.	
Apple peel extract	Three concentration of apple peel extract was used with 0.5%,0.75%, 1% and 1.25% to study the antioxidant properties in mayonnaise.	Apple peel with concentration of 1.25% show The least peroxide value and Aniside value which are 1.3±0.04 meq/kg and 3.42±0.09mmol kg1.	(Khalid, et al 2021)
Microcrystalline Cellulose Obtained From almond residue	Three concentrations with 0.2,0.4 and 0.6% of AE-MCC-AS.	AE-MCC-AS at the concentration of 0.6% has Show the better effect in preventing oil oxidation Then BHT and α-tocopherol.	(Unver, et al 2021)
olive mill waste water with phenolic extract	Mayonnaise with 50 and 45g phenolic extract is prepared named $EMPE_A$ and $EMPE_B$ respectively.	At the end of 45 days storage 58% resistant to Rancidity is observed in $EMPE_B$	(De Bruno et al., 2022)
Thyme (*Zataria multiflora* Boiss) Essential Oil as natural antioxidant	Antioxidant activity of *Z. multiflora* Boiss essential oil at different concentrations (0–150 μg/g) compared to synthetic antioxidants TBHQ.	The TBA index of mayonnaise containing Essential oil is increased from 0.18 to 3.53 As compared to control from 0.22 to 7.12 MDA/kg which shows the antioxidant activity Of zataria multiflora boiss essential oil.	(Ahmadi-Dastgerdi et al., 2022)
Protein products from sesame seeds	Sesame oil, full-fat flour, protein concentrate are made from seasame seeds.	Product made from sesame seeds has different compounds which have	(Bugaets et al., 2021)

		antioxidative effect in emulsion like mayonnaise e.g Phytosterol.	
Cucumis sativus seeds	Cucumis sativus seeds at the concentration of 200ppm incorporated in mayonnaise.	TBARS value for the control sample was 52% higher as compared with the sample treated with seeds of cucumis sativus.	(Azhagu Saravana Babu et al., 2016)
Spice-added Mayonnaise	Different spices like Rosemary,Ginger,Black pepper and Oregano are added in the concentration of 100,500 and 1000 µg/ml in mayonnaise.	Among the four-extract examined rosemary exhibited strongest activity against the DPPH and has the scavenging effect up to 91,26% at the concentration of 1000 µg/ml.	(Kwon et al., 2015)
combination of hydrophilic green tea extract and lipophilic tocopherol mixture	Green tea extract and tocopherol at the concentration of 500ppm each is mixed and added in mayonnaise	Mixture of green tea extract and tocopherol (GTT) show the antioxidant activity by inhibiting the formation of pentanal to 50.87 ± 12.82 as compared to BHA 25.76 ± 5.22 after 15 days of storage.	(Ghorbani Gorji et al., 2019)
Tartary buckwheat hull extract	Tartary Buckwheat hull extract is added in mayonnaise in the concentration of 0-08% w/w..	By the end of 31st day of storage control show the highest TBA value (0.1mg^{-1}) while mayonnaise added with tartary buckwheat hull extract show the lowest TBA value (0.047mg^{-1}).	(Park et al., 2019)

Conclusion:

Mayonnaise is oil-in-water emulsion semisolid product which are made from blending of oil, vinegar, spices and egg yolk. It contains 78% to 80% oil. Egg yolk is a main ingredient in it which are responsible for its stability. Lipid oxidation is a major problem in mayonnaise which can result in undesirable off flavor. Rancidity is the major problem caused by lipid oxidation in mayonnaise and also result in reduction of shelf life of product. To prevent this problem many synthetic oxidants are used but people don't like the product which contains any chemical. Natural antioxidants such as from plant sources are used in mayonnaise to improve the quality characteristic of product. Natural antioxidants reduced the Thiobarbiyuric acid (TBA) which is responsible for oxidation. Addition of natural antioxidants in mayonnaise to prevent lipid oxidation is favorable. It should be promoted the use of natural antioxidants in mayonnaise. The effects of natural antioxidants in other products should also be checked.

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References:

Ahmadi-Dastgerdi, A., Ezzatpanah, H., Asgary, S., Dokhani, S., Rahimi, E., & Gholami-Ahangaran, M. (2019). Oxidative stability of mayonnaise supplemented with essential oil of Achillea millefolium ssp millefolium during storage. Food Science and Technology, 13(1). 34-44. https://doi.org/10.15673/fst.v13i1.1340

Alizadeh, L., Abdolmaleki, K., Nayebzadeh, K., & Shahin, R. (2019). Effects of tocopherol, rosemary essential oil and Ferulago angulata extract on oxidative stability of mayonnaise during its shelf life: A comparative study. Food chemistry, 285, 46-52.

Martillanes, S., Rocha-Pimienta, J., Gil, M. V., Ayuso-Yuste, M. C., & Delgado-Adámez, J. (2020). Antioxidant and antimicrobial evaluation of rice bran (Oryza sativa L.) extracts in a mayonnaise-type emulsion. Food chemistry, 308, 125633.

Passos, R. B. D., Bazzo, G. C., Almeida, A. D. R., Noronha, C. M., & Barreto, P. L. M. (2019). Evaluation of oxidative stability of mayonnaise containing poly ε-caprolactone nanoparticles loaded with thyme essential oil. Brazilian Journal of Pharmaceutical Sciences, 55.

Raikos, V., McDonagh, A., Ranawana, V., & Duthie, G. (2016). Processed beetroot (Beta vulgaris L.) as a natural antioxidant in mayonnaise: Effects on physical stability, texture and sensory attributes. Food Science and Human Wellness, 5(4), 191-198.

Rafiee, Z., Barzegar, M., Sahari, M. A., & Maherani, B. (2018). Nanoliposomes containing pistachio green hull's phenolic compounds as natural bio-preservatives for mayonnaise. European Journal of Lipid Science and Technology, 120(9), 1800086.

Ozdemir, N., Kantekin-Erdogan, M. N., Tat, T., & Tekin, A. (2018). Effect of black cumin oil on the oxidative stability and sensory characteristics of mayonnaise. Journal of food science and technology, 55, 1562-1568.

Franco-Arnedo, G., Buelvas-Puello, L. M., Miranda-Lasprilla, D., Martínez-Correa, H. A., & Parada-Alfonso, F. (2020). Obtaining antioxidant extracts from tangerine (C. reticulata var. Arrayana) peels by modified supercritical CO2 and their use as protective agent against the lipid oxidation of a mayonnaise. The Journal of Supercritical Fluids, 165, 104957.

Chotphruethipong, L., & Benjakul, S. (2019). Use of cashew (Anacardium occidentale L.) leaf extract for prevention of lipidoxidation in Mayonnaise enriched with fish oil. Turkish Journal of Fisheries and Aquatic Sciences, 19(10), 825-836.

El-Kholany, E. (2016). Utilization of essential oils from Citronella and Geranium as natural preservative in mayonnaise Ebtehal. Int. J. Microbiol. Biotechnol, 1, 49-59.

Kim, Y. S., & Lee, J. H. (2017). Effects of hydrolyzed rapeseed cake extract on the quality characteristics of mayonnaise dressing. Journal of food science, 82(12), 2847-2856.

Haniff, M., Yahaya, S. A., Aziz, N. S., Wan Mustapha, W. A., Sofian-Seng, N. S., Rahman, H. A., ... & Lim, S. J. (2020). Development of carotenoid-rich mayonnaise using Carotino oil. Journal of Food Processing and Preservation, 44(9), e14688.

Ghorbani Gorji, S., Calingacion, M., Smyth, H. E., & Fitzgerald, M. (2019). Effect of natural antioxidants on lipid oxidation in mayonnaise compared with BHA, the industry standard. Metabolomics, 15, 1-14.

Khalid, M. U., Shabbir, M. A., Mustafa, S., Hina, S., Quddoos, M. Y., Mahmood, S., ... & Rafique, A. (2021). Effect of Apple peel as an antioxidant on the quality characteristics and oxidative stability of mayonnaise. Applied Food Research, 1(2), 100023.

Ünver, N., & Çelik, Ş. (2021). Effect of antioxidant-enriched microcrystalline cellulose obtained from almond residues on the storage stability of mayonnaise. Journal of Food Processing and Preservation, 45(7), e15613.

De Bruno, A., Gattuso, A., Romeo, R., Santacaterina, S., & Piscopo, A. (2022). Functional and Sustainable Application of Natural Antioxidant Extract Recovered from Olive Mill Wastewater on Shelf-Life Extension of "Basil Pesto". Applied Sciences, 12(21), 10965.

Ahmadi-Dastgerdi, A., Fallah, N., Zokaei, M., & Gholami-Ahangaran, M. (2022). The role of Thyme (Zataria multiflora Boiss) essential oil as natural antioxidant on the lipid oxidation in mayonnaise. Journal of Food Quality, 2022.

Bugaets, N., Usatikov, S., Tereshchenko, I., Shamkova, N., & Bugaets, O. (2021, September). The effect of protein products from sesame seeds on the oxidative stability of emulsion products. In IOP Conference Series: Earth and Environmental Science (Vol. 839, No. 2, p. 022079). IOP Publishing.

Azhagu Saravana Babu, P., Vajiha Aafrin, B., Archana, G., Sabina, K., Sudharsan, K., Radha Krishnan, K., ... & Sukumar, M. (2016). Polyphenolic and phytochemical content of Cucumis sativus seeds and study on mechanism of preservation of nutritional and quality outcomes in enriched mayonnaise. International Journal of Food Science & Technology, 51(6), 1417-1424.

Kwon, H., Ko, J. H., & Shin, H. S. (2015). Evaluation of antioxidant activity and oxidative stability of spice-added mayonnaise. Food science and biotechnology, 24, 1285-1292.

Park, B. I., Kim, J., Lee, K., Lim, T., & Hwang, K. T. (2019). Flavonoids in common and tartary buckwheat hull extracts and antioxidant activity of the extracts against lipids in mayonnaise. Journal of Food Science and Technology, 56, 2712-2720.

Alvarez-Sabatel, S., de Marañón, I. M., & Arboleya, J. C. (2018). Impact of oil and inulin content on the stability and rheological properties of mayonnaise-like emulsions processed by rotor-stator homogenisation or high-pressure homogenisation (HPH). Innovative Food Science & Emerging Technologies, 48, 195-203.

Jacobsen, C., Sørensen, A. D., & Nielsen, N. S. (2013). Stabilization of omega-3 oils and enriched foods using antioxidants. In Food enrichment with omega-3 fatty acids (pp. 130-149). Woodhead Publishing.

McClements DJ. Food emulsions: principles, practices, and techniques. Boca Raton: CRC Press; 2015.

Sun, C., Liu, R., Liang, B., Wu, T., Sui, W., & Zhang, M. (2018). Microparticulated whey protein-pectin complex: A texture-controllable gel for low-fat mayonnaise. Food Research International, 108, 151-160.

Zehiroglu, C., & Ozturk Sarikaya, S. B. (2019). The importance of antioxidants and place in today's scientific and technological studies. Journal of food science and technology, 56(11), 4757–4774.

Rasmy, N. M., Hassan, A. A., Foda, M. I., & El-Moghazy, M. M. (2012). Assessment of the antioxidant activity of sage (Salvia officinalis L.) extracts on the shelf life of mayonnaise.

Shahin, R., Nayebzadeh, K., Alizadeh, L., & Mohammadi, A. (2014). Antioxidant effect of tocopherol and TBHQ on oil oxidation over the shelf life of mayonnaise.

Mollakhalili Meybodi, N., Mohammadifar, M. A., & Naseri, A. R. (2014). Effective factors on the stability of oil-in-water emulsion-based beverage: a review. Journal of food quality and hazards control, 1(3), 67-71.

Ghorbani Gorji, S., Smyth, H. E., Sharma, M., Fitzgerald, M. (2016). Lipid oxidation in mayonnaise and the role of natural antioxidants: A review. Trends in Food Science & Technology, 56, 88–102.

Abeyrathne, E. D. N. S., Nam, K., & Ahn, D. U. (2021). Analytical methods for lipid oxidation and antioxidant capacity in food systems. Antioxidants, 10(10), 1587.

Reuter, J.; Merfort, I.; Schempp, C.M. Botanicals in dermatology: An evidence-based review. Am. J. Clin. Dermatol. 2010, 11, 247–267.

Bouaziz, M., Fki, I., Jemai, H., Ayadi, M., & Sayadi, S. (2008). Effect of storage on refined and husk olive oils composition: Stabilization by addition of natural antioxidants from Chemlali olive leaves. Food Chemistry, 108(1), 253-262.

Shahidi, F. (Ed.). (2005). Bailey's Industrial Oil and Fat Products, Industrial and Nonedible Products from Oils and Fats (Vol. 6). John Wiley & Sons.

Bubonja-Sonje, M., Giacometti, J., & Abram, M. (2011). Antioxidant and antilisterial activity of olive oil, cocoa and rosemary extract polyphenols. Food Chemistry, 127(4), 1821-1827.

Farhadi, K., Esmaeilzadeh, F., Hatami, M., Forough, M., & Molaie, R. (2016). Determination of phenolic compounds content and antioxidant activity in skin, pulp, seed, cane and leaf of five native grape cultivars in West Azerbaijan province, Iran. Food chemistry, 199, 847-855.

Mármol, I., Sánchez-de-Diego, C., Jiménez-Moreno, N., Ancín-Azpilicueta, C., & Rodríguez-Yoldi, M. J. (2017). Therapeutic applications of rose hips from different Rosa species. International journal of molecular sciences, 18(6), 1137.

Ehtasham Amin, S., Khan, A., Kanwal, N., Khan, A., atiq, S., Faizan Shaukat, M., Abu Bakar, M., Bilal, M., Sana, F., Shahzad, Q., Muzamil, M., & Authors, C. (2023). Metabolomic Profiling of Fruits: Biochemical Pathways and Quality Indices (Vol. 19). http://xisdxjxsu.asia