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# IMPROVING LOW-FAT PROCESSED CHEESE SAUCES USING DIFFERENT FAT REPLACERS

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## SUMMARY

*Processed cheese* sauces were formulated with three levels of fat: full-fat (FF), reduced-fat (RF) and low-fat (LF). The fat content of FF was adjusted to 20% to be comparable to commercial cheese sauces. Reduction of fat was achieved by reducing the amount of Ras cheese in the formulated blends and incorporating fat replacers to improve the properties of the resultant cheese sauces. The fat replacers used include: corn starch, modified starch, wheat starch, rice starch, oats powder and Simplesse®100. The use of fat replacers improved the quality of sauces and the best treatments were that containing oats as they achieved the highest scores for organoleptic properties when fresh and after 3 mo. of storage. The incorporating of oats has relevance both from technology and nutritional properties and they contain dietary fibers, which enhance their potential to improve the health and well-being of consumers and they can be considered as a functional food.

Key words: fat replacers, full fat, low fat, reduced fat.

## Introduction

With increasing consumer awareness, the focal point of the food industry is reducing fat and calories consumption. Low-fat, low calories foods, which look and taste similar to their full-fat, higher calories counter-parts are eagerly sought by the consumer.

Researchers in the food and industries dairy have concentered on developing food products which are nutritious and palatable and which contain substantially reduced levels of fat containing ingredients. The most concern dairy industry, is producing, low-fat products, such as skimmed milk, successfully marketed. The high fat levels associated with processed cheese products have been thought to be necessary to maintain a desirable creamy mouthfeel associated with pasteurized processed cheese products. In case of processed cheese products there are several fat replacers have been used for reducing the fat in such products *i.e* (starch derivatives, microparticulated proteins, modified starches, flour, .... ***etc.***)

Much researches has focused on improving reduced fat cheese flavour and texture **(Drake and Swanson, 1995)**. Removal of fat from cheese produces undesirable textures and flavours. Typical texture defects include excessive firmness. Using of fat replacers introduce a new concern to food and dairy manufacturers.

To improve acceptability of reduced-fat and low-fat cheese texture may be through the use of compounds that partially or fully replace fat and simulate its properties **(Jonse, 1996)**. **Brummel & Lee (1990)** studied the use of hydrocolloid fat mimetics on physical and sensory properties of reduced-fat processed cheese spreads and sauces concluded that textures were comparable to full-fat cheese spreads and sauces.

So, the aim of this study is to reduce fat content of cheese sauces and improve the texture and flavour of cheese sauce, by incorporating fat replacers.

## MATERIALS AND METHODS

**Materials:**

Ras cheese used in manufacture of processed cheese sauces was obtained from Dairy Sci, Dept. Moshtoher Faculty of Agriculture, Benha University, Egypt, emulsifying salt Yoha $S_{203}$ was obtained from JOHA BK Ladenburg corp., GmbH, Ladenburg, Germany and purchased from local market. Corn starch was obtained from the starch and glucose company, Cairo, Egypt. Modified corn starch was obtained from Misr for Food Additives (MIFAD), Badr city, Cairo, Egypt. Unmodified wheat starch S5127 was obtained from sigma chemical Co., USA. Rice starch RF-W1120F8141 was obtained from Comet Rice ingredients company, USA. Flavorinia Oats were obtained from Cairo market and was dried and grounded to fine powders. Commercial native starch was purchased from the local market, produced by the Egyptian Company for starch and glucose Alexandria Egypt. Simplesse®100 obtained from Kelco Biopolymers (Dorset House, Regent Park, Kingston Road, Leatherhead, UK) and purchased from local market. Commercial fine grade sodium chloride was obtained from EL-Nasr Saline Co., Alexandria, Egypt. Cheese flavour, was obtained from Misr for Food Additives (MIFAD), Badr city, Cairo, Egypt. Maltodextrin was obtained from Misr for Food Additives (MIFAD), Badr city, Cairo, Egypt. The Nisin use was produced by Zhjiang silver elephant Bio-Engineering Co., Chin, and were obtained from Amzon international trading, Giza, Egypt. Potassium sorbate was obtained from EL-Nasr for chemicals industries, Cairo, Egypt and used as a preservative. Pure corn oil premium quality "Crystal'' was purchased from the local market, produced by Arma Company, Egypt.

**Methods:**

**Manufacture of Processed cheese sauce:**

Processed cheese sauces were manufactured as follows:

Medium ripened Ras cheese was cut into small pieces and milled. The suitable amount of the milled cheese was used according to their percent in the mix, corn oil, maltodextrin, fat replacer, cheese flavour and emulsifying salts were added consecutively in laboratory style processed kettle (Stephans Universal machine, Swizerland) of 2.5kg capacity. All the ingredients were mixed together for about 1 min before processing. The mixtures were cooked for 10 min at 95°C under vacuum 25 PSI, using continuous direct heat steam and then mixing at 1500 rpm for 1min. The melted processed cheese sauces were poured into leader glass jars (100 ml) and capped directly after filling. The resultant cheese sauces were cooled and stored at 5±1°C and then analyzed when fresh and monthly up to 3 months.

**Chemical Analysis:**

**Total solids, fat, total nitrogen, Ash, salt and titratable acidity contents** of processed cheese sauces were determined according to the method described by **AOAC (2005), IDF (2001), BSI, (1988), BSI (1976)** and **BSI, (2010), respectively.** pH was measured using pH meter JENCO model 1671, USA. TVFA content was determined according to the method of **Kosikowski (1982).** Carbohydrate content of all samples was calculated by difference as described by **(Ceirwyn, 1995)** using the following formula: Total carbohydrates% = 100 - (%fat + %protein +%ash + %moisture)

**Physical properties**

Oil separation and viscosity of the sauces were determined according to **Thomas, (1973), Viturawong *et al.*, (2008), respectively**.

**Sensory Evaluation:**

The processed cheese sauce samples were organoleptically evaluated using **IDF (1997)**. Cheese scoring was carried out by 10 of the experimented Staff members of Dairy Sci, Dept., Fac. of Agri., Moshtohor, Benha Unvi., Egypt.

**Statistical analysis:**

The experimental data were analyzed using the general linear models procedure of the Statistical Analysis System **(SAS, 2006).**

Processed cheese sauces were formulated with three levels of fat: full (FF), reduced (RF) and low (LF). Full-fat sauces were designed to approximate the fat content of commercial cheese sauces 20/100g serving **(Marsh, 1980)**. Reduced- and low-fat sauces were designed to meet approximate legal definition of the terms; reduced –fat sauces have at least 25% less fat than the full-fat product and low fat sauces have no more than 3g/serving **(FDA, 1995).** It was worthwhile to reduce the amount of Ras cheese in the formulated blend and incorporating fat replacers to improve the properties of the resultant processed cheese sauces. The fat replacers used include:

Corn starch T1, Modified starch T2, Wheat starch T3, Rice starch T4, Oats powder T5, simplesse®100 T6. Three replicates were made from each treatment and analysed each in duplicate.

**Table (1): Chemical composition of ingredients used in reduced- and low-fat processed cheese sauces manufactured using different fat replacers.**

| Ingredients | %T.S | F/DM | %T.N | %Ash | %CHO |
|---|---|---|---|---|---|
| Ras cheese | 68.62 | 40.00 | 3.5 | 3.5 | 2.79 |
| Corn starch | 89.00 | 0.59 | 0.05 | 0.46 | 87.69 |
| Modified corn starch | 88.00 | 0.50 | 0.05 | 0.44 | 86.80 |
| Wheat starch | 92.60 | 0.55 | 0.04 | 0.39 | 91.44 |
| Rice starch | 87.00 | 0.57 | 0.06 | 0.44 | 85.68 |
| Oat powder | 93.95 | 4.80 | 1.74 | 3.33 | 73.03 |
| Simplesse®100 | 95.60 | 2.30 | 6.01 | 3.2 | 51.75 |

## Results and discussion

### Chemical composition of different processed cheese sauces:

The total solids of all cheese sauces were adjusted to contain 25%; thus, the differences between treatments were very slight (Table 2). The moisture content of all samples are within ~±0.5% of target moisture. These results are in accordance with **Spanier (1986)** who mentioned that the moisture of cheese sauces should be 70 to 85%. **Lee *et al*, (2004)** stated that a small variation in moisture content caused large changes in the rheological, physical and physico-chemical properties of processed cheese products, especially of low moisture contents. They added that the poor emulsions stability associated with the low moisture content. This may be consequence of many factors as water is known to be important in processed cheese emulsion stability **(Berger *et al*, 1993)**, it is possible that there is insufficient water to fully hydrate the protein and/or melting salt system. Results of **Fat/DM** clear that it was very high in the control than the other treatments. This was because of the highest fat, protein and ash contents in the full-fat cheese sauce than the reduced and low-fat cheese sauces. Data revealed that every kind of cheese sauce containing the same fat content. There were slight differences of Fat/DM due to the differences in the composition of the

added fat replacers; but there was a great difference between the kinds of sauces (full-, reduced- and low-fat cheese sauces)

**Table (2): Formulae of reduced-fat and low-fat processed cheese sauces with using different fat replacers (g/100g).**

| Formulas | Reduced-fat | | | | | | | Low-fat | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | T1 | T2 | T3 | T4 | T5 | T6 | T1 | T2 | T3 | T4 | T5 | T6 |
| Ras cheese | 20 | 13 | 13 | 13 | 13 | 13 | 13 | 3 | 3 | 3 | 3 | 3 | 3 |
| Native starch | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 10 |
| Corn oil | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| Salt | 0.7 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| ES* | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Cheese flavour | 0.25 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Malto dextrin | 0.0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| Fat replacer** | 0.0 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 |
| Water | 68.6 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 | 70.6 | 74.5 | 74.5 | 74.5 | 74.5 | 74.5 | 74.5 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

*ES= Emulsifying salt

** T1: corn starch, T2: Modified corn starch, T3: Wheat starch, T4: Rice starch, T5: Oat powder, T6: Simplesse®100

*** To all formulae 0.025 g/100 nisin and 0.1 g/100 g potassium sorbate were added .

It was obvious that **the TN** varies in the different types of cheese sauces which is related to differences in the Ras cheese amount in the blends; but differences were slight between treatments in the same type. This was due to composition of the added fat replacers as it was higher in oat and simplesse®100 than other treatments. **The ash** content was the highest in the control due to the high amount of the Ras cheese in the blend. The slight differences between treatments are attributed to the ingredients of the blends. It was observed that the oats sauce which contains dietary fibers was the highest in every group of treatments.

The chemical composition of the processed cheese sauces were reported to be changed very slightly during storage at the refrigeration temperature (5°C). The results are in accordance with **Abd El Salam *et al*, (1996); Hamed *et al*, (1997); Mohamed, (2004); and Hussein *et al*, (2005)** as they mentioned that processed cheese products are almost stable in their gross components through cold storage.

**pH value and acidity %**

The pH value and acidity % of full-fat sauces, reduced- and low-fat of processed cheese sauces are stated in table 4, 5. The pH value of the sauce is important to balance bacterial and pathogens growth with desirable texture and/ or taste. The pH can be manipulated by addition of emulsifier salts such as phosphate and /or sodium citrate. Thus, the pH of the blends should be adjusted during the manufacture of processed cheese sauces.

The pH values of different processed cheese sauces in this current study are in accordance with the range given by **Rispoli *et al*, (1987)** as they mentioned that pH of the sauce ranged from 5.1 to 6.6. They added that the sauce should contain a buffer selected from the group consisting of sodium citrate and potassium citrate or phosphate. Optionally combinations of these buffers may be utilized, and it may be incorporated into the dairy based sauce at a level from about 0.1 to 3%. The results also agree with **Saad (2011)** who used the same levels of salts and gave the same range of pH. **Klostermeyer, (1989)** reported that the pH value of all good processed cheese and processed cheese products range from pH 5.3 to 6.2. Looking for the effect of storage on the cheese sauces it was noticeable that the pH of the cheese sauces gradually decreased during the cold storage.

**Table (3): Chemical composition (%) of reduced and low-fat processed cheese sauce treatments manufacture using different fat replace.**

| Treatments | | T.S | Fat | Fat/DM | T.N | Ash | T.S | Fat | Fat/DM | T.N | Ash |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | | $25.24^{C}_{D}$ | $10.20_{A}$ | $40.41^{A}$ | $1.17^{A}$ | $3.651_{A}$ | Low-fat sauces | | | | |
| | | Reduced-fat sauces | | | | | | | | | |
| T1 | | $25.38^{C}$ | $5.51^{B}$ | $21.71^{D}$ | $1.06^{A}_{B}$ | $2.855_{B}$ | $25.20^{C}_{D}$ | $1.02^{E}$ | $4.05^{I}$ | $0.926^{B}$ | $2.255_{C}$ |
| T2 | | $25.24^{C}_{D}$ | $5.56^{B}$ | $22.03^{C}$ | $1.02^{A}_{B}$ | $2.409_{C}$ | $25.21^{C}_{D}$ | $1.12^{CD}_{E}$ | $4.44^{H}$ | $0.974^{B}$ | $2.319_{C}$ |
| T3 | | $25.59^{B}$ | $5.53^{B}$ | $21.61^{D}_{E}$ | $1.04^{A}_{B}$ | $2.416_{C}$ | $25.29^{C}_{D}$ | $1.05^{E}$ | $4.15^{I}$ | $0.924^{B}$ | $2.246_{C}$ |
| T4 | | $25.27^{C}_{D}$ | $5.61^{B}$ | $22.20^{B}$ | $1.06^{A}_{B}$ | $2.359_{C}$ | $25.27^{C}_{D}$ | $1.22^{CD}$ | $4.83^{G}$ | $0.999^{A}_{B}$ | $2.239_{C}$ |
| T5 | | $25.18^{D}$ | $5.61^{B}$ | $22.28^{B}$ | $1.07^{A}_{B}$ | $2.859_{B}$ | $25.21^{C}_{D}$ | $1.28^{C}$ | $5.08^{F}$ | $0.964^{A}_{B}$ | $2.349_{C}$ |
| T6 | | $25.81^{A}$ | $5.54^{B}$ | $21.46^{E}$ | $1.10^{A}_{B}$ | $2.416_{C}$ | $25.28^{C}_{D}$ | $1.22^{CD}$ | $4.83^{G}$ | $1.120^{A}_{B}$ | $2.216_{C}$ |
| Range | Max | 25.81 | 5.61 | 22.28 | 1.10 | 2.859 | 25.29 | 1.28 | 5.08 | 1.120 | 2.349 |
| | Mini | 25.18 | 5.51 | 21.46 | 1.02 | 2.359 | 25.20 | 1.02 | 4.05 | 0.924 | 2.216 |
| Average | | 25.41 | 5.56 | 21.88 | 1.06 | 2.552 | 25.24 | 1.15 | 4.56 | 0.985 | 2.249 |
| S.D | | ±0.056 | ±0.056 | ±0.056 | ±0.056 | ±0.056 | ±0.056 | ±0.056 | ±0.056 | ±0.056 | ±0.056 |

** T1: corn starch, T2: Modified corn starch, T3: Wheat starch, T4: Rice starch, T5: Oat powder, T6: Simplesse®100.
Values with the same letters in each column are non- significant differences

From the statistical analysis point of view for the produced processed cheese sauces from different treatments and the cold storage period up to 3 months, their was non-significant differences between the storage periods. However, their was a significant differences between the treatment and the control cheese. When fresh and during the interval storage periods up to 3 months.

Concerning the titratable acidity of processed cheese sauces, it was fond that with the progress of cold storage, the acidity gradually increased taking the opposite trend of the pH value. The increase of the acidity of cheese sauces may be due to the chemical changes occurred in emulsifying salts specially during storage. These results agree with Hussein *et al*, (2005). Moreover, the increase of acidity may be attributed to the addition of different fat replacers to the blends which may contain some enzymes which cause hydrolysis of some compounds in the sauces due to the enhancing of bacterial growth.

**Soluble nitrogen content (SN)**

low-fat processed cheese sauces

Soluble nitrogen of processed cheese sauces with different treatments are presented in Table 6. There was a pronounced variation in SN content of the sauces according to different amount of Ras cheese in the blends. A slight differences were observed between treatments due to contents of protein in used fat replacers used; for example it was the highest in the processed cheese sauce made with simplesse®100 than the other treatments.

**Table (4): The pH values of reduced and low-fat processed cheese sauce treatments manufactured using different fat replacers during storage.**

| Treatments | | Fresh | 1 month | 2months | 3months | Fresh | 1 month | 2months | 3months |
|---|---|---|---|---|---|---|---|---|---|
| Control (full fat) | | 5.75 | $5.72^{ABCD}$ | $5.68^{AB}$ | $5.65^{A}$ | Low-fat sauces | | | |
| | | Reduced-fat sauces | | | | | | | |
| T1 | | $5.88^{B}$ | $5.87^{A}$ | $5.78^{A}$ | $5.68^{A}$ | $5.59^{B}$ | $5.57^{D}$ | $5.44^{D}$ | $5.41^{CB}$ |
| T2 | | $5.89^{A}$ | $5.78^{ABC}$ | $5.75^{AB}$ | $5.66^{A}$ | $5.51^{B}$ | $5.48^{DE}$ | $5.44^{D}$ | $5.42^{CB}$ |
| T3 | | $5.85^{B}$ | $5.82^{AB}$ | $5.78^{A}$ | $5.69^{A}$ | $5.56^{B}$ | $5.54^{CD}$ | $5.47^{DC}$ | $5.38^{C}$ |
| T4 | | $5.89^{A}$ | $5.85^{A}$ | $5.80^{A}$ | $5.75^{A}$ | $5.69^{B}$ | $5.66^{CD}$ | $5.64^{ABC}$ | $5.58^{AB}$ |
| T5 | | $5.82^{B}$ | $5.80^{ABC}$ | $5.78^{A}$ | $5.75^{A}$ | $5.73^{B}$ | $5.68^{CD}$ | $5.66^{AB}$ | $5.61^{A}$ |
| T6 | | $5.80^{B}$ | $5.78^{ABC}$ | $5.70^{A}$ | $5.65^{A}$ | $5.63^{B}$ | $5.58^{D}$ | $5.52^{BDC}$ | $5.53^{B}$ |
| Range | Max | 5.89 | 5.87 | 5.80 | 5.75 | 5.73 | 5.66 | 5.66 | 5.61 |
| | Mini | 5.80 | 5.78 | 5.70 | 5.65 | 5.51 | 5.48 | 5.44 | 5.38 |
| Average | | 5.86 | 5.82 | 5.77 | $5.70^{A}$ | 5.62 | 5.57 | 5.53 | 5.49 |
| S.D | | ±0.082 | ± 0.056 | ± 0.056 | ± 0.056 | ±0.082 | ± 0.056 | ± 0.056 | ± 0.056 |

** T1: corn starch, T2: Modified corn starch, T3: Wheat starch, T4: Rice starch, T5: Oat powder, T6: Simplesse®100. Values with the same letters in each column are non- significant differences

**Table (5): The acidity (%) of reduced- and low-fat processed cheese sauce treatments manufactured using different fat replacers during storage.**

| Treatments | | Fresh | 1 month | 2months | 3months | Fresh | 1 month | 2months | 3months |
|---|---|---|---|---|---|---|---|---|---|
| Control (full fat) | | $1.09^{A}$ | $1.10^{A}$ | $1.17^{AB}$ | $1.23^{AB}$ | Low-fat sauces | | | |
| | | Reduced-fat sauces | | | | | | | |
| T1 | | $0.82^{B}$ | $0.86^{B}$ | $1.03^{AB}$ | $1.07^{B}$ | $0.94^{AB}$ | $0.97^{AB}$ | $1.08^{AB}$ | $1.21^{AB}$ |
| T2 | | $0.85^{B}$ | $0.88^{B}$ | $1.07^{AB}$ | $1.19^{AB}$ | $0.87^{B}$ | $0.89^{B}$ | $1.12^{AB}$ | $1.13^{AB}$ |
| T3 | | $0.99^{AB}$ | $1.02^{AB}$ | $1.07^{AB}$ | $1.22^{AB}$ | $0.99^{AB}$ | $1.08^{A}$ | $1.22^{A}$ | $1.26^{AB}$ |
| T4 | | $0.85^{B}$ | $0.99^{AB}$ | $1.11^{AB}$ | $1.20^{AB}$ | $0.89^{B}$ | $0.99^{AB}$ | $1.14^{AB}$ | $1.29^{A}$ |
| T5 | | $0.88^{B}$ | $0.89^{B}$ | $1.02^{AB}$ | $1.07^{B}$ | $0.91^{AB}$ | $0.93^{AB}$ | $1.04^{AB}$ | $1.10^{AB}$ |
| T6 | | $0.89^{B}$ | $1.05^{AB}$ | $1.10^{AB}$ | $1.15^{AB}$ | $0.86^{B}$ | $1.04^{A}$ | $1.14^{AB}$ | $1.18^{AB}$ |
| Range | Max | 0.99 | 1.05 | 1.11 | 1.22 | 0.99 | 1.08 | 1.22 | 1.29 |
| | Mini | 0.82 | 0.86 | 1.02 | 1.07 | 0.86 | 0.89 | 1.04 | 1.10 |
| Average | | 0.88 | 0.95 | 1.07 | 1.15 | 0.91 | 0.98 | 1.12 | 1.20 |
| S.D | | ± 0.056 | ± 0.056 | ± 0.056 | ± 0.056 | ± 0.056 | ± 0.056 | ± 0.056 | ± 0.056 |

** T1: corn starch, T2: Modified corn starch, T3: Wheat starch, T4: Rice starch, T5: Oat powder, T6: Simplesse®100. Values with the same letters in each column are non- significant differences

During cold storage, the SN% increased gradually after 3months. Proteolysis occurs during ageing of the cheese sauce which may be primarily to residual proteolysis activity in the casein/caseinate especially that occurs by the enzymes activity of resistant heat proteinases present in the products. The results coincided with **Abd El-Hamid *et al*, (2000a)** and **Awad**

**(2003a)**. It was also, reported that the proteolytic enzymes plasmin (in the cheese curd) is the main agent responsible for the proteolytic and rheological changes which occur during storage of the cheese sauces, **(Mulvihill& McCarthy, 1993, 1994; Abd El- Hamid *et al*, 2000a).**

**Table (6): Soluble nitrogen content (%) of reduced and low-fat processed cheese sauce treatments manufactured using different fat replacers during storage.**

| Treatments | | Fresh | 1 month | 2months | 3months | Fresh | 1 month | 2months | 3months |
|---|---|---|---|---|---|---|---|---|---|
| | | S.N | S.N | S.N | S.N | S.N | S.N | S.N | S.N |
| Control (full fat) | | $0.989^{A}$ | $1.005^{A}$ | $1.013^{A}$ | $1.029^{A}$ | Low-fat sauces | | | |
| | | Reduced-fat sauces | | | | | | | |
| T1 | | $0.347^{B}$ | $0.394^{BC}$ | $0.450^{BC}$ | $0.485^{BCD}$ | $0.278^{B}$ | $0.315^{BC}$ | $0.360^{CD}$ | $0.388^{BCD}$ |
| T2 | | $0.351^{B}$ | $0.362^{BC}$ | $0.448^{BC}$ | $0.507^{BC}$ | $0.281^{B}$ | 0.290 | $0.358^{BCD}$ | $0.405^{BCD}$ |
| T3 | | $0.356^{B}$ | $0.434^{BC}$ | $0.466^{BC}$ | $0.499^{BCD}$ | $0.284^{B}$ | $0.347^{BC}$ | $0.372^{BCD}$ | $0.399^{BCD}$ |
| T4 | | $0.321^{B}$ | $0.366^{BC}$ | $0.384^{BCD}$ | $0.395^{BCD}$ | $0.257^{B}$ | $0.292^{C}$ | $0.307^{D}$ | $0.316^{CD}$ |
| T5 | | $0.340^{B}$ | $0.376^{BC}$ | $0.400^{BCD}$ | $0.426^{BCD}$ | $0.272^{B}$ | $0.300^{BC}$ | $0.320^{CD}$ | $0.341^{CD}$ |
| T6 | | $0.438^{B}$ | $0.486^{B}$ | $0.551^{B}$ | $0.560^{B}$ | $0.350^{B}$ | $0.388^{BC}$ | $0.441^{BC}$ | $0.448^{BCD}$ |
| Range | Max | $0.438^{B}$ | $0.486^{B}$ | $0.551^{B}$ | $0.560^{B}$ | $0.350^{B}$ | $0.388^{BC}$ | $0.441^{BC}$ | $0.448^{BCD}$ |
| | Mini | $0.321^{B}$ | $0.362^{BC}$ | $0.384^{BCD}$ | $0.395^{BCD}$ | $0.257^{B}$ | $0.290^{C}$ | $0.307^{D}$ | $0.316^{CD}$ |
| Average | | 0.359 | 0.403 | 0.450 | 0.479 | 0.287 | 0.322 | 0.360 | 0.383 |
| S.D | | ±0.056 | ±0.056 | ±0.056 | ±0.056 | ±0.056 | ±0.056 | ±0.056 | ±0.056 |

** T1: corn starch, T2: Modified corn starch, T3: Wheat starch, T4: Rice starch, T5: Oat powder, T6: Simplesse®100. Values with the same letters in each column are non- significant differences

**Table (7): Total volatile fatty acid values (TVFA) of reduced and low-fat processed cheese sauce treatments manufactured using different fat replacers during storage.**

| Treatments | | Fresh | 1 month | 2months | 3months | Fresh | 1 month | 2months | 3months |
|---|---|---|---|---|---|---|---|---|---|
| Control (full fat) | | $19.2^{A}$ | $20^{A}$ | $23.4^{A}$ | $27.1^{A}$ | Low-fat sauces | | | |
| | | Reduced-fat sauces | | | | | | | |
| T1 | | $14.5^{D}$ | $16.1^{E}$ | $19.5^{C}$ | $20.9^{C}$ | $12.5^{HI}$ | $14.1^{J}$ | $16.5^{I}$ | $19.5^{G}$ |
| T2 | | $14.2^{E}$ | $16.2^{E}$ | $19.2^{D}$ | $20.6^{D}$ | $12.1^{J}$ | $14.4^{HI}$ | $17.9^{F}$ | $20.6^{D}$ |
| T3 | | $15.3^{C}$ | $16.9^{C}$ | $18.5^{E}$ | $19.6^{FG}$ | $13.1^{G}$ | $14.5^{H}$ | $16.2^{J}$ | $19.6^{FG}$ |
| T4 | | $14.6^{D}$ | $16.6^{D}$ | $18.4^{E}$ | $20.3^{E}$ | $12.6^{H}$ | $15.6^{F}$ | $17.4^{G}$ | $20.3^{E}$ |
| T5 | | $15.9^{B}$ | $17.5^{B}$ | $19.4^{C}$ | $20.4^{E}$ | $13.7^{F}$ | $15.1^{G}$ | $17.4^{G}$ | $21.4^{B}$ |
| T6 | | $14.3^{E}$ | $16.2^{E}$ | $19.7^{B}$ | $20.6^{D}$ | $12.3^{I}$ | $14.2^{I}$ | $16.7^{H}$ | $19.7^{F}$ |
| Range | Max | $15.90^{B}$ | $17.50^{B}$ | $19.70^{B}$ | $20.90^{C}$ | $13.7^{F}$ | $15.6^{H}$ | $17.9^{F}$ | $21.4^{B}$ |
| | Mini | $14.20^{E}$ | $16.10^{E}$ | $18.40^{E}$ | $19.60^{FG}$ | $12.1^{J}$ | $14.1^{J}$ | $16.2^{J}$ | $19.5^{G}$ |
| Average | | 14.80 | 16.58 | 19.12 | 20.40 | 12.7 | 14.7 | 17.0 | 20.2 |
| S.D | | ± 0.056 | ± 0.056 | ± 0.056 | ± 0.056 | ±0.056 | ±0.056 | ±0.056 | ±0.056 |

TVFA= ml 0.1N NaOH/100g. ** T1: corn starch, T2: Modified corn starch, T3: Wheat starch, T4: Rice starch, T5: Oat powder, T6: Simplesse®100.

**Total volatile fatty acids (TVFA)**

Data revealed that, the fresh processed cheese sauces contained different levels of TVFA according to the amount of Ras cheese presented in the blends as it was high in the full-fat (control) and the lowest was in the low-fat cheese sauces. The different fat replacers added cause some differences between treatments as it was reported that the oats (4.5% fat) caused a higher level of TVFA either in reduced-or low-fat cheese sauces than the other treatments.

During storage, the TVFA content gradually increased probably due to the activity of some lipolytic heat resistant enzymes which reactivated during cold storage at (5°C) and making an analysis for fat in sauces. The results are in agreement with those given by **Aly *et al,* (1995) and Othman *et al,* (2005).**

**Physical properties**

**Oil separation index (OSI)**

The extent of such free oil formation is an indication of how well fat is emulsified in cheese **(Shimp, 1985)**. Results revealed that the control (full-fat sauce) had higher fat content in proportion with protein content, this may cause an adverse effect in the protein bonds and give a lose protein network. That could also cause the cheese to has un-emulsified properly and easy to loose fat **(Shimp, 1985)**. Furthermore, lower fat content with the presence of maltodextrin and different fat replacers in the cheese matrix in other treatments would give a stronger network and leads to lower oil separation. During the storage, the control sample continued to increase of OSI while the other treatments can absorb the separated oil and water from the phase. This decrease of OSI during storage was increased due to the increase in acidity and soluble nitrogen. The results agree with those of **Abd El-Hamid *et al,* (2000b) and Awad (2003)**. Moreover, some differences were observed for OSI of the different treatments which could be explained by the different fat globule size distribution and the disruption of protein matrix. These results are in accordance with **Mounsey& O'Riodan (2001)**. By the end of the storage period the OSI in the control still increase and higher than all of the other treatments.

**Table (8): Oil separation index of reduced and low-fat processed cheese sauce treatments manufactured using different fat replacers during storage period at ~5°C.**

| Treatments | | Fresh | 1 month | 2months | 3months | Fresh | 1 month | 2months | 3months |
|---|---|---|---|---|---|---|---|---|---|
| Control (full fat) | | $24.17^{A}$ | $28.66^{A}$ | $36.44^{A}$ | $37.36^{A}$ | Low-fat sauces | | | |
| | | Reduced-fat sauces | | | | | | | |
| T1 | | $19.66^{C}$ | $16.36^{D}$ | $13.32^{D}$ | $9.85^{B}$ | $15.66^{H}$ | $17.36^{C}$ | $12.32^{F}$ | $5.85^{H}$ |
| T2 | | $20.33^{B}$ | $18.22^{B}$ | $15.65^{B}$ | $8.96^{C}$ | $18.33^{D}$ | $16.22^{D}$ | $13.65^{C}$ | $5.96^{H}$ |
| T3 | | $15.63^{H}$ | $12.33^{I}$ | $10.47^{H}$ | $8.99^{C}$ | $14.63^{I}$ | $12.33^{I}$ | $10.47^{H}$ | $5.99^{H}$ |
| T4 | | $16.99^{F}$ | $14.21^{G}$ | $12.66^{E}$ | $8.55^{D}$ | $15.99^{G}$ | $14.21^{G}$ | $10.66^{G}$ | $5.55^{I}$ |
| T5 | | $17.65^{E}$ | $13.21^{H}$ | $12.38^{F}$ | $8.85^{C}$ | $17.65^{F}$ | $15.21^{E}$ | $12.21^{F}$ | $7.36^{F}$ |
| T6 | | $19.33^{E}$ | $15.36^{E}$ | $10.21^{I}$ | $8.36^{E}$ | $14.33^{J}$ | $14.36^{F}$ | $9.38^{J}$ | $6.85^{G}$ |
| Range | Max | $20.33^{B}$ | $18.22^{B}$ | 15.65 | $9.85^{B}$ | $18.33^{D}$ | $17.36^{C}$ | $13.65^{C}$ | $7.36^{F}$ |
| | Mini | 15.63 | $12.33^{I}$ | 10.21 | $8.36^{E}$ | $14.33^{J}$ | $12.33^{I}$ | $9.38^{J}$ | $5.55^{I}$ |
| Average | | 18.27 | 14.95 | 12.45 | 8.93 | 16.10 | 14.95 | 11.45 | 6.26 |
| S.D | | $19.66^{C}$ | $16.36^{D}$ | $13.32^{D}$ | $9.85^{B}$ | ±0.056 | ±0.056 | ±0.056 | ±0.056 |

** T1: corn starch, T2: Modified corn starch, T3: Wheat starch, T4: Rice starch, T5: Oat powder, T6: Simplesse®100. Values with the same letters in each column are non- significant

**Viscosity (cP)**

The viscosity decreased with increasing the shear rate through changing the viscometer speed to higher level. There was different flow behavior with various levels of fat in the blends. The lowest viscosity values were observed with the control; while the other treatments varied in their viscosities mainly due to the different composition of raw materials incorporated in base blends **(Hagras *et al,* 2003)**. Addition of maltodextrin and fat replacers to the different treatments of reduced-and low-fat processed cheese sauces exhibited higher viscosity values and improved and stabilized well the body& texture. It was obvious that cheese sauce with corn starch had the highest viscosity values, while that contained simplesse®100 showed the lowest viscosity compared to other cheese sauces with fat replacers. The differences in viscosity values could be related to the differences among the added fat replacers for their capacity of binding water that caused different gel strength which affected the viscosity of the sauce blends **(Guinee *et al,* 1994)**. Moreover, these differences may be due to amaylose content, swelling ability, the shape and size of the starch granules **(Considine *et al* (2010)**.

The cold storage of processed cheese sauces for 3months exhibited a reduction in viscosity values for all treatments including control which still the lowest. Also, the sauce containing simplesse® show the lowest viscosity compared to the other treatments containing fat replacers; meanwhile, the corn starch sauce exhibits the highest viscosity. Changes in viscosity values occurred in the cheese sauces during storage may be attributed to changes in the composition of starch gel matrix and partial protein hydrolysis which affected the state of protein in the emulsion. Moreover, other factors such as changes in acidity %, SN content, action of emulsifying salts, may affect the behaviour of viscosity of sauce treatments **(Younis *et al,* 1991).**

**Sensory evaluation**

The results demonstrated no marked differences for the outer appearance of all fresh and stored processed cheese sauces including the control as they scored (9) except that made with simplesse®100 which got (8) as its colour was not shiny enough. Addition of maltodextrin and fat replacers to the blends of all treatments excluding **control** improved the properties of the cheese sauces especially its viscosities and body and textures of the resultant sauces. Moreover, the incorporation of fat replacers in the processed cheese formulation increased the flavour and water binding characteristic **(Kelly, 1986)**.

The interaction between added fat replacers and protein in sauce (usually casein) has been shown to influence the rheological properties of the resultant processed cheese product **(Guinee *et al,* 2004)**. **Mounsey and O'Riodan (2001)** reported that the addition of 3% of different native starch types to rennet casein based imitation cheese changed the meltability and texture properties of cheese. These changes of the physical properties were attributed to modification of the structure of the imitation cheeses. **Monnsey &O'Riodan (2001)** stated that the changes were dependent on the type of starch added.

Due to textural properties, the control which is devoid of maltodextrin and fat replacer exibited lower creaminess and consistency, lower viscosity and have greater elasticity than the rest of the sauces.

It was obvious from the results that all cheese sauces received means about 90 or more for all attributes showing that they were well accepted by panelists.

Concerning the control sample, it achieved the lowest scores either when fresh or after storage period up to 3 months. There was some water separation because it was devoided of maltodextrin and fat replacers (containing starch) and consequently the reduction of the ability of holding water **(Bemiller &Whistler, 1996)**. Types of starches and ratios used are critical in order to achieve proper mouthfeel. The inclusion of sodium phosphate also,

improves the mouthfeel. The mouthfeel of all cheese sauces was higher than the control. The cheese sauces are non-browning products with a smooth creamy consistency and a low solid content. The sensory scores of all produced cheese sauces slightly increased after 1 month of cold storage, except the control which decreased through all the storage periods. The changes could related to changes in the chemical composition of the processed cheese sauces **(Abd El-Salam *et al,* 1996; Hamed *et al,* 1997)**. The flavour of all processed cheese sauces was much better when fresh and after the storage for 3 months impaired slightly the flavour and aroma.

In a conclusion, all the processed cheese sauces were accepted by the panelists. Sauces containing fat replacers gained scores higher than the control and that containing simplesse®. The best treatment was for that containing oats as it achieved the highest scores either when fresh or after storage periods. Moreover, it is considered "healthy and functional food". On the other hand, incorporation of oats into food products has relevance both from food technology and nutritional perspectives.

**Table (13): Sensory evaluation of reduced fat processed cheese sauce treatments manufactured using different fat replacers during storage.**

| Treatments | Outer appearance (10) | Body & texture (50) | flavor (40) | Total score (100) | Outer appearance (10) | Body & texture (50) | flavor (40) | Total score (100) |
|---|---|---|---|---|---|---|---|---|
| | Reduced-fat sauces | | | | Low-fat sauces | | | |
| **Fresh** | | | | | | | | |
| **Control** | $9^{A}$ | $42^{C}$ | $38^{A}$ | $89^{E}$ | $9^{A}$ | $42^{D}$ | $38^{A}$ | $89^{D}$ |
| **T1** | $9^{A}$ | $45^{AB}$ | $37^{AB}$ | $91^{C}$ | $9^{A}$ | $44^{C}$ | $38^{A}$ | $91^{C}$ |
| **T2** | $9^{A}$ | $44^{B}$ | $37^{AB}$ | $90^{D}$ | $9^{A}$ | $44^{C}$ | $38^{A}$ | $91^{C}$ |
| **T3** | $9^{A}$ | $46^{A}$ | $37^{AB}$ | $92^{B}$ | $9^{A}$ | $45^{B}$ | $38^{A}$ | $92^{B}$ |
| **T4** | $9^{A}$ | $45^{AB}$ | $36^{B}$ | $90^{D}$ | $9^{A}$ | $45^{B}$ | $37^{B}$ | $91^{C}$ |
| **T5** | $9^{A}$ | $46^{A}$ | $38^{A}$ | $93^{A}$ | $9^{A}$ | $46^{A}$ | $38^{A}$ | $93^{A}$ |
| **T6** | $9^{A}$ | $45^{AB}$ | $37^{AB}$ | $90^{D}$ | $8^{B}$ | $45^{B}$ | $36^{C}$ | $89^{D}$ |
| **1 month** | | | | | | | | |
| **Control** | $8^{B}$ | $42^{C}$ | $37^{AB}$ | $87^{E}$ | $8^{B}$ | $42^{C}$ | $38^{A}$ | $88^{D}$ |
| **T1** | $9^{A}$ | $45^{B}$ | $38^{A}$ | $92^{C}$ | $9^{A}$ | $46^{A}$ | $37^{B}$ | $92^{B}$ |
| **T2** | $9^{A}$ | $45^{B}$ | $38^{A}$ | $92^{C}$ | $9^{A}$ | $46^{A}$ | $37^{B}$ | $92^{B}$ |
| **T3** | $9^{A}$ | $46^{AB}$ | $37^{AB}$ | $92^{C}$ | $9^{A}$ | $46^{A}$ | $37^{B}$ | $92^{B}$ |
| **T4** | $9^{A}$ | $47^{A}$ | $38^{A}$ | $93^{B}$ | $8^{B}$ | $45^{B}$ | $37^{B}$ | $90^{C}$ |
| **T5** | $8^{B}$ | $46^{AB}$ | $38^{A}$ | $94^{A}$ | $9^{A}$ | $46^{A}$ | $38^{A}$ | $93^{A}$ |
| **T6** | $9^{A}$ | $45^{B}$ | $37^{AB}$ | $91^{D}$ | $8^{B}$ | $45^{B}$ | $37^{B}$ | $90^{C}$ |
| **3 months** | | | | | | | | |
| **Control** | $8^{B}$ | $41^{C}$ | $37^{AB}$ | $86^{E}$ | $8^{B}$ | $41^{E}$ | $37^{B}$ | $86^{E}$ |
| **T1** | $9^{A}$ | $46^{AB}$ | $37^{AB}$ | $92^{C}$ | $9^{A}$ | $47^{A}$ | $37^{B}$ | $93^{A}$ |
| **T2** | $9^{A}$ | $46^{AB}$ | $37^{AB}$ | $92^{C}$ | $9^{A}$ | $45^{B}$ | $38^{A}$ | $92^{B}$ |
| **T3** | $9^{A}$ | $46^{AB}$ | $37^{AB}$ | $92^{C}$ | $9^{A}$ | $44^{C}$ | $38^{A}$ | $91^{C}$ |
| **T4** | $9^{A}$ | $46^{AB}$ | $38^{A}$ | $93^{B}$ | $9^{A}$ | $45^{B}$ | $38^{A}$ | $92^{B}$ |
| **T5** | $9^{A}$ | $47^{A}$ | $38^{A}$ | $94^{A}$ | $9^{A}$ | $46^{B}$ | $38^{A}$ | $93^{A}$ |
| **T6** | $8^{B}$ | $45^{B}$ | $36^{B}$ | $89^{D}$ | $8^{B}$ | $43^{D}$ | $37^{B}$ | $88^{D}$ |

** T1: corn starch, T2: Modified corn starch, T3: Wheat starch, T4: Rice starch, T5: Oat powder, T6: Simplesse®100. Values with the same letters in each column are non- significant.

Statistical analysis for total scores of the sensory evaluation data of the produced processed cheese sauces *i.e* (reduced-fat and low-fat) compared with the control revealed that there are non-significant differences between the control and other treatments when fresh. However, during the cold storage at ~5°C indicated a significant difference between the control and different treatments. Also, there was significant differences between the treatments (made with Oat) and other treatments either in case of reduced-fat or low-fat sauces.

**Costs of recipes**

The total costs (100k) of the ingredients used for manufacturing processed cheese sauces by replacing the cheese in the base blend partially in reduced- and low-fat sauces with fat replacers. The results revealed that reducing the cheese amount in the base blend of reduced-fat decreased the total cost by 20.6 to 23.0%; while in low-fat processed cheese sauces, the reduction in the costs were from 56.2 to 59.9. Concerning incorporating the simplesse®100 as fat replacer in the reduced- fat and low-fat cheese sauces rased the price of sauces to be above the control. Thus it was suggested to avoid its use.

**Table (14): Costs in (LE) of the used ingredients in reduced-, low-fat processed cheese sauce blends containing different fat replacers (100kg).**

| Formulas | price L.E/ Kg | Control | Reduced- fat | | | | | | Low-fat | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | T1 | T2 | T3 | T4 | T5 | T6 | T1 | T2 | T3 | T4 | T5 | T6 |
| Ras cheese | 60 | 1200 | 780 | 780 | 780 | 780 | 780 | 780 | 180 | 180 | 180 | 180 | 180 | 180 |
| Native starch | 5 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 50 | 50 | 50 | 50 | 50 | 50 |
| Corn oil | 20 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| Salt | 2 | 1 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| Emulsifing salt | 12 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| Cheese flavour | 50 | 13 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Maltodextrin | 100 | - | 100 | 100 | 100 | 100 | 100 | 100 | 200 | 200 | 200 | 200 | 200 | 200 |
| Fat replacer** | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Corn starch | 12 | - | 39.6 | - | - | - | - | - | 79 | | - | - | - | - |
| Wheat starch | 5 | - | - | 16.5 | - | - | - | - | - | 33 | - | - | - | - |
| Modified starch | 7 | - | - | - | 23.1 | - | - | - | - | - | 46.2 | - | - | - |
| Rice starch | 10 | - | - | - | - | 33 | - | - | - | - | - | 66 | - | - |
| Oat powder | 12 | - | - | - | - | - | 39.6 | - | - | - | - | - | 79.2 | - |
| Simplesse®100 | 200 | - | - | - | - | - | - | 660 | - | - | - | - | - | 1320 |
| Nisin | 100 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Potassium sorbate | 50 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Total cost | - | 1295 | 1028 | 997 | 1004 | 1014 | 1021 | 1649 | 566 | 519 | 533 | 552 | 566 | 1806 |
| Cost reduction | | 100 | 20.6 | 23.0 | 22.4 | 21.6 | 21.2 | - | 56.3 | 59.9 | 58.8 | 57.4 | 56.3 | - |

## CONCLUSION

In a conclusion, all the processed cheese sauces were accepted by the panelists. Sauces containing fat replacers gained scores higher than the control and that containing simplesse®100. The best treatment was for that containing oats as it achieved the highest scores either when fresh and after storage periods. Moreover, it is considered "healthy and

functional food". On the other hand, incorporation of oats into food products has relevance both from food technology and nutritional perspectives.

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low-fat processed cheese sauces

## الملخص العربى

### تحسين مشهيات الجبن المطبوخ المنخفض الدهن باستخدام بدائل الدهون

الهدف من هذا البحث ان يتم خفض محتوي الدهن في مشهيات الجبن وتحسين القوام والنكهة في مشهيات الجبن باستخدام بدائل الدهون.مشهيات الجبن المطبوخ تم تقسيمها الي ثلاث مستويات من الدهن : كامل الدسم و قليل الدسم ومنخفض الدسم.

خفض الدهن يتم بتقليل نسبة الجبن في الخلطة وأستخدام بدائل الدهن: نشا الذرة T1 - النشا المعدل T2 - نشا القمح T3 - نشا الأرز T4 - الشوفان البودر T5 - السمبليسيT6 . تزداد درجات التحكيم في مشهيات الجبن المطبوخ خلال الشهر الاول من التخزين ثم تقل قليلا بعد 3 شهور ماعدا الكنترول الذي لا يظهر تقدما في الصفات خلال الشهر الاول . وقد لوحظ أن أضافة بدائل الدهون حسنت من صفات المشهيات وقد وجدت بعض الاختلافات الطفيفة في درجات التحكيم نتيجة لاختلاف هذه البدائل. وعموما كان أفضل العينات هي المحتوية علي الشوفان كما أنه له فوائد صحية ووظيفية كثيرة. هذا وقد اظهرت النتائج ان جميع المشهيات حصلت علي درجة 90 أو اكثر وهذا يظهر مدي أفضليتها وقبولها لدي المحكمين. وكانت أفضلها المحتوية علي الشوفان حيث أن الشوفان له خصائص تكنولوجية عالية كما أن من الاغذية الصحية والتي لها فوائد وظيفية.