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Summary and conclusion

The present study aimed to improve the constructure, rheological, and sensory properties of low-fat Ras cheese via the application of some modifications on the conventional procedure of cheese making as well as the use of some additives such as fat replacer or transglutaminase enzyme. Therefore this work was divided into two parts as follows:

Part I: **Effect of some modifications on the ordinary Ras cheese making on the properties and quality of the resultant low-fat cheese, during ripening.**

Ras cheese was made from pasteurized cow's milk as described in the following treatments:

Treatment 1 (T1): Made from cow's milk (**3%** fat) and served as full-fat control cheese.

Treatment 2 (T2): Made from cow's milk (**1.5**% fat), without any modifications (control, 2).

Treatment 3 (T3): Made from cow's milk (**1.5%** fat) and the resultant curd washed by warm water (35c/5min.) after the scalding process was terminated.

Treatment 4 (T4): Made from cow's milk (**1.5**% fat) and the resultant curd (after scalding) rinsed in the same whey after adding **0.1**% soudium citrate/5min.

Treatment 5 (T5): Alike treatment 4 but the percent of sod. citrate was **0.2**%/5min.

The resultant cheeses of the five treatments were ripened at **8 ± 2C** for **90** days, then analysed when fresh and during 3 months of ripening for chemical composition, microbiological, rheological and sensory properties. Results gained could be summarized as follows:

A. Chemical Composition:

A.I. Gross Composition:

A.1.1: Moisture:

- Reduction of the fat content of cheese milk by 50% resulted in apparent increase in the moisture content and a decrease in the dry matter content in the resultant fresh low fat cheese (LFC) (T2) and during ripening, compared to full-fat control cheese (FFC), (T1).
- Washing the curd by warm water (T3) or rinsing it in the same whey containing sod. Citrate (T4 and T5) had no pronounced effect.

A.1.2: Titratable acidity (TA) and pH value:

- Reduction the fat content in LFC, decreased the TA of cheese.
- Washing the curd of LFC by warm water decreased greatly its TA compared to the other treatments, owing to the replacement of the rich medium (whey) surrounded the curd by poor medium (water), which consequently affected on the activity and growth of lactic acid bacteria.
- Sodium citrate effect on the TA was not apparent when compared with LFC (control, 2).

A.1.3: Fat and Fat/dry matter (F/DM):

- Fat and F/DM contents of LFC were decreased greatly as the cheese milk fat was decreased to 1.5%.
- Treated the curd (after scalding) by warm water or sod. Citrate resulted in slight decrease in both fat and F/DM contents compared with LFC (control 2).

A.1.4: Salt and Salt/moisture (S/M):

- FFC (T1) was found to possess the lowest salt content than the other treatments, during ripening.

- Treating the curd of LFC by warm water or sod. citrate had no obvious effect on the salt and S/M contents, during ripening. Citrate treatments (T4 and T5) had the highest S/M along the ripening period.
- Salt contents were found relatively near among the LF-cheeses along the ripening period.

A.1.5: Total Protein (TP):

- Reducing cheese fat led to increase the TP content in the resultant cheeses compared to FFC (T1).
- Washing or rinsing processes of the curd of LFC had slightly decrease on the TP content of fresh and ripened cheeses.

A.II. Proteolysis:

- Reducing cheese fat content, water washing and rinsing processes led to delay the rate of proteolysis (SN/TN & NPN/TN) in the resultant LFC compared to FFC (control, T1). Water washing cheese (T3) recorded the lowest values.

A.III. Lipolysis (TVFA):

- There are negative relationship between the fat content of cheese and the TVFA content of fresh and ripened cheeses.
- Washing the curd by warm water (T3) slightly decreased the values of TVFA, while treated it by sod. Citrate increased slightly these values, along the ripening period.
- FFC (T1) had the highest values throughout the ripening, followed by sod. citrate treatments (T4 and T5) and water washing cheese (T3) which had the lowest values, respectively.

A.IV. Ripening period:

- As the ripening period advanced, the moisture contents of all treatments were decreased. On the other hand, salt, fat, acidity, protein, proteolysis and lipolysis of the five treatments were gradually increased reaching the maximum values at the end of the ripening period.

B. Microbiology evaluation:

- Reduction of fat cheese content resulted in proportional reduction in the counts of all bacterial populations total viable (TC), lactic acid bacteria (LAB), proteolytic bacteria (PB) and lipolytic bacteria (LB) of fresh and ripened cheeses.
- Treating the curd of LFC by warm water or sod. citrate was found to have little effect on these bacterial populations, during ripening.
- During ripening, TC and LAB were increased up to 15 days of ripening then decreased gradually with the progression of the ripening period. PB and LB behaved another trend, so it increased continuously reaching the highest counts at the end of the ripening period.
- FFC and LFC (T2) recorded the highest values of these populations during ripening.

C: Rheology (Textural profiles):

C.I. Hardness (Firmness):

- There are reverse relationship between cheese hardness and its fat content along the ripening period. FFC (T1) had the lowest values whereas water washed LFC (T3) recorded the highest ones.
- Washing the curd by warm water or sod. citrate had low effect during ripening.

- Cheese hardness showed closer relationship with the chemical composition of the cheese.

C.2: Cohesiveness:

- It decreased as the fat content of cheese decreased. Control cheese (T1) gained the highest values while cheese treated with the higher concentration of sod. citrate had the lowest ones.
- Treated cheeses (T3 , T4 and T5) exhibited a slightly lower values, after 15 days and during ripening, compared to LFC (T2).

C.3: Springiness:

- Springiness property of cheese took the same trend of hardness along the ripening period. So, it increased as the fat content of cheese decreased.
- Springiness of washed or rinsed treatments was found slightly higher than LFC (T2).
- LFC (T2) had lower springiness values than the other LFC-treatments throughout the ripening period. FFC (T1) recorded the lowest value while water washed cheese (T3) obtained the highest value.

C.4: Gumminess and Chewiness:

- A reverse relationship was noticed between gumminess and chweiness of cheese and its fat content, during ripening.
- Gumminess and chewiness of treated cheeses (T3 , T4, and T5) were slightly higher than LFC (T2), during ripening.
- FF-control cheese had the lowest values throughout the ripening period.

C.5. Ripening Period:

- A direct relationship was found between the texture profiles of cheese and the ripening period.

- Texture profiles of cheese were significantly affected by changes in the chemical composition of cheese and the maturation process.

D. Cheese structure:

- F/DM, M/NFS, PH and S/M playing important role in the assessment of cheese quality (***Gilles & Lawrence, 1973***).
- Decreasing the fat content of cheese, decreased the values of M/NFS and F/DM. FFC (T1) was found to have the higest values during ripening.
- S/M values were approximately near among the five treatments, throughout the ripening period.
- Treated cheeses showed M/NFS, M/P and F/DM approximately near and slightly lesser than LFC (T2). This means that these processes did not improve greatly the structure of the resultant LF-cheeses.
- As the ripening period advanced, M/NFS and M/P were decreased while the other parameters (S/M and F/DM) were increased.

E. Organoleptic properties:

- FFC was the best organoleptical cheese, along the ripening period. It had clean acid flavrour and smooth body and texture.
- Washing the curd by warm water had pronounced effect on the resultant cheese which characterized by flat flavour and firm body and texture during ripening. Sodium citrate cheese (T4 and T5) were not of superior properties than the other LF-cheeses.
- LFC (T2) was ranked organoleptically after FFC and sod-citrate cheeses were superior than water washed cheese, which had the lowest scores during ripening.

Generally, it was found that FFC was the best treatment, during ripening, followed by T2, T4, T5 and T3, in order. LFC (T2) was ranked

the best LFC compared with the other treatments, because of its good chemical composition and other properties, throughout the ripening period. The previous modifications had no greatly effect on the resultant LFC which characterized by inferior rheological and organoleptical properties than FFC.

Part II: **Effect of adding fat replacer or transglutaminase enzyme to cheese milk on the chemical, microbiological, rheological, microstructure and sensory properties of Low-fat Ras cheese during ripening.**

Results of Part I, which focused on the improvement of LF-Ras cheese body and texture by carring out some modifications on the ordinary cheese-making procedure (i.e. washing the curd, after the end of scalding process, by warm water 35C /5min). or rinsing it in the same whey, after adding sod. citrate, for 5min. revealed that no obvious improvement was achieved and the same defects in the constructure of LFC still present. Therefore attempts were continued in this part to reach this goal, using another means such as fat-replacer or transglutaminase enzyme (TGase). Experimental procedure included five treatments, and low-fat Ras cheese was made as follow's:

Treatment, 1 (T1): Full-fat cheese made from pasteurized cow's milk of **3%** fat, (control).

Treatment, 2 (T2): Low-fat cheese made from pasteurized cow's milk of **1.5%** fat.

Treatment, 3 (T3): Low-fat cheese made from pasteurized cow's milk of **1.5%** fat containing **0.18g** simplesse **100/100kg** milk.

Treatment, 4 (T4): Low-fat cheese made from pasteurized cow's milk of **1.5%** fat containing **0.25g** TGase **/ 1kg milk.**

Treatment, 5 (T5): Low-fat cheese made from pasteurized cow's milk of **1.5%** fat containing **0.5g** TGase / 1kg milk.

The resultant cheese of all treatments were ripened at 8 ± 2C for 90 days and analysed for chemical , microbiological , rheological , microstructure, and sensory properties when fresh and after 15, 30, 60 and 90 days of ripening. Results obtained could be summarized as follows:

A. Chemical Composition:

A.1. Gross Composition:

A.I.1. Moisture:

- Moisture contents of LFC treated with fat-replacer (FR) or TGase were higher than LFC (T2) and FFC (T1), either when fresh and during ripening.
- Dry matter contents of all treatments behaved reverse trend to moisture, during ripening.

A.1.2. Acidity and PH value:

- The reduction of cheese fat, the reduction of titratable acidity (TA).
- Addition of FR to cheese milk (T3) led to increase the percent of TA compared to FFC (T1), during ripening, whereas an opposite trend was observed when TGase (T4 and T5) was used.
- pH values took reverse trend to TA, during ripening.

A.1.3. Fat and F/DM:

- Fat and F/DM contents of FFC (T1) were the highest, along the ripening period.
- Fat and F/DM among the other treatments were slightly near in the fresh cheeses, and LFC treated with FR (T3) or TGase (T4 and T5) had higher values, during ripening , than LFC (T2).

A.1.4. Salt and Salt/moisture (S/M):

- Salt contents of treated cheeses (T3, T4 and T5) were increased than the corresponding one of FFC (control), during ripenng.
- S/M behaved oppostite trend where it was highest in FFC (T1) than the others. variations in the chemical composition among all cheeses were responsible for that.

A.1.5. Total protein (TP):

- A reverse relationship was noticed between fat content of cheese and the protein content.
- Addition of FR or TGase increased the protein contents than LFC (T2) and FFC (T1), during ripening.
- TGase LFC (T4 and T5) possessed the highest values followed by FR-LFC (T3), LFC (T2) and FFC (T1), in order.

A.1.6: Ripening period:

- Moisture contents of all treatments were decreased while salt, acidity, fat and protein contents were increased as the ripening period progressed.

A.II. Proteolysis:

- Reducing the fat content of LF-cheese, decreased slightly the rate of proteolysis (SN/TN & NPN/TN) in the resultant cheeses compared with FFC (T1), during ripening.
- Addition of FR or TGase to cheese milk, increased the rate of proteolysis during ripening, than FFC and LFC (T2).
- The highest rate of proteolysis noticed was in TGase LFC followed by FR-LFC.
- A direct relationship was found between the ripening period and the rate of proteolysis of all treatments.

A.III. Lipolysis :

- Decreasing the fat content in LFC led to a decrease in its TVFA content, during ripening.
- Addition of FR or TGase, increased the liberation of the TVFA in the resultant cheese, compared with FFC and LFC (T2).
- The highest level of TVFA was observed in FR-LFC followed by TGase, FFC and LFC (T2) respectively.
- TVFA of all treatments increased with the progression of the ripening period.

B- Microbiological Examination:

- Decreasing the fat content of cheese led to decreasing the counts of the viable microorganisms (TC, LAB, PB and LB) during ripening.
- FFC contained the highest counts, throughout the ripening period.
- Addition of FR or TGase resulted in higher counts of these populations than LFC (T2) along the ripening period.
- Counts of TC and LAB increased in all treatments up to 15 days of ripening then decreased up to the end of ripening.
- Counts of PB and LB were increased continuously in all treatments during ripening.

C. Rheology :

C.1. Firmness (Hardness) :

- Firmness of FFC was lower than the other treatments, during ripening.
- LFC (T2) had the highest firmness values, during ripening.
- Addition of FR or TGase reduced the firmness of the resultant cheeses compared to LFC (T2).

- TGase cheese containing the highest dose of enzyme had values of firmness near from the control cheese, during ripening, and considered the best structure improvement treatment.

C.2. Cohesiveness :

- Cohesiveness of FFC were found higher than the other LFC treatments, during ripening.
- LFC (T2) had inferior values than FFC (control).
- FR or TGase improved the cohesiveness values of LFC.
- TGase treatment containing the highest level of enzyme, (T5), had values near from FFC and higher than the rest treatments, along the ripening period.
- There was a postivie relationship between cohesiveness value and the ripening period.

C.3. Springiness :

- There was indirectly relationship between springiness value and fat content of cheese, along the ripening period.
- LFC (T2) had the highest values of springiness.
- Springiness values of FR or TGase cheeses were decreased, throughout the ripening period, compared with LFC (T2).
- Control FFC had the lowest values of springiness, during ripening.
- TGase LFC (T5) had springiness value closely near to control one, at the end of the ripening period.

C.4. Gumminess & Chewiness :

- LFC (T2) was gummier and chewier than the other treatments, during ripening.
- FFC had the lowest values, during ripening (with the exception of 90 days TGase cheese (T5)).

- FR or TGase improved greatly these two texture profiles, along the ripening period compared to LFC (T2).
- Reducing the fat of cheese increased these values during ripening.
- As the ripening period advanced, the values of Gumminess and chewiness were increased.

D- Structure Properties :

Generally it is worth to note that, there are a direct relationship between the following factors or parameters (M/NFS, M/P, S/M and F/DM) affecting the structure of cheese and its quality during ripening. These parameters playing a crucial role in the microbiological and biochemical reactions took placed in cheese during ripening. FF-control cheese was characterized by the superior structure than the other treatments throughout the ripening period owing to its higher percents of F/DM and M/NFS.

E- Cheese Microstructure :

Scanning the microstructure of LF and FF Ras cheese by electron microscope pointed out, generally, the following results:

1- Fresh Cheeses :

- LFC (T2) was characterized by considerably few vacules or voids, more dense and extensive protein matrix (PM), large stretches of continuous PM interspersed with serum channels (which may explain the hard and rubbery body and texture), compact body and texture and translucent appearance.
- FFC (T1) was characterized by greatly different microstructure than LFC. It had PM interspersed liberally with fat globules, opaque appearance, larger vacules or pockets, more pits and fissers, spongy-like appearance and open texture.

- Addition of FR (T3) or TGase enzyme (T4 and T5) altered and improved greatly the PM of the resultant cheeses, compared to LFC, to be near from FFC. It characterized, also, by more dense noncontinous PM with globular or granules clusters, spongy-like PM (as close as shown in FFC), more uiform fat droplets voids, treatment (had the highest level of enzyme) showed PM microstructure slightly better than FRC (T3) and greatly near from FFC.

2- 90 days cheese ripening :

- At the end of the ripening period, the microstructure of all treatments were variably changed owing to the biochemical reactions took placed throughout the maturation process as follows:
- PM was fused more as a result of the dissociation of the casein micelles by the ripening agents resulting in homogenous structure.
- Decreasing the number and size of voids as a result of increasing the rate of PM fusion, during ripening.
- Decreasing the open structure noticed in fresh cheeses.
- Presence of some spherical small casein or protein clusters in a fewer numbers in LFC, as a result of decreasing the compact and continuous PM by proteolysis.
- Addition of FR or TGase increased the rate of fusion, homogenous, translucent appearance and the uniformity of fat droplets voids, compared to fresh cheeses. Decreasing greatly the compact structure noticed in LFC as well as the size and number of voids.
- TGase cheese (T5) showed the best PM microstructure among the ripened treated cheeses (T2, T3 and T5), and this microstructure was found had features closely near to the FFC.
- Sensory evaluations confirmed the former observations of (T5) cheese which was characterized by good rheological and organoleptic properties slightly prefered than FR-cheese and near from FFC.

F. Organoleptic Properties :

- Reduction of cheese fat had a reverse effect on the organoleptic properties of the resultant cheese.
- Adding FR or TGase to LF-cheese, improved greatly its sensory properties especially the body and texture.
- Control FF-cheese was found the best treatment follow by TGase LF-cheese (had the higher level of enzyme), FR LF-cheese and LF-cheese in order.
- Organoleptic properties of all cheeses greadully improved as the ripening period proceeded.

The present study revealed, generally, that the modifications which carried out on the cheese-making procedure (Part I) had no obvious effect and did not improve the structure of LFC along the ripening period. Addition of FR or TGase (Part II) greatly improved the body and texture and the other properties of LFC to an extent to be near from FFC, throughout the ripening period. TGase cheese contained the highest level of enzyme (0.5g/1kg milk) had slightly better properties than FRC and considered the best treatment in this study. So we recommended to apply the fromer conclusion in the improvement of LF Ras cheese structure.