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Gellan gum for reducing oil uptake in sev, a legume based product during deep-fat frying

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Abstract

Gellan gum, a high molecular weight anionic linear polysaccharide produced by pure culture fermentation from *Sphingomonas paucimobilis* ATCC 31461 is used in a variety of food applications that are based on its unique gelling profile. The present work reports on the effective use of gellan gum on the oil uptake of a traditional Indian deep-fat fried product, sev that is based on chickpea flour. The effect of addition of gellan gum at 0.25–0.75% (w/w) (based on chickpea flour) on the dough texture, and that of the sev prepared was also evaluated using TA.XT2i Texture Analyzer. Addition of gellan gum at 0.25% (w/w) markedly reduced the oil content in the sev from 37.02% in the control to 27.91%. The reduction in oil content beyond 0.25% gellan gum addition was not significant ($P = 0.05$). Furthermore, while addition of gellan gum significantly altered the texture of dough, it did not significantly affect the texture of sev ($P = 0.05$). Addition of 0.25% gellan gum in combination with sodium alginate (0.25–1.00%), carboxymethylcellulose (0.25–1.00%) or soy protein isolate (2.5–10.0%) did not affect oil uptake significantly ($P = 0.05$) as compared to that prepared by the addition of 0.25% gellan gum alone.

Keywords: Gellan gum; Deep-fat frying; Oil-uptake; Dough; Sev; Texture

1. Introduction

Fried foods form an integral part of diet all over the world. Fats and oils have unique properties including flavour and smooth feeling in the mouth, which improve overall food palatability and acceptability. Some fried products contain large amounts of fat, often reaching up to 40–45% of total product weight (Pinthus, Weinberg, & Saguy, 1993). The high oil content is often not essential for product quality and is disadvantageous to both the food processor and the consumer. Hence, reducing oil content of these products is an area of interest to researchers (Priya, Singhal, & Kulkarni, 1996). Many factors have been reported to affect oil uptake. Modification in any one of the given factors may affect oil uptake during frying. These include oil quality (Blumenthal, 1999), product and oil temperature, frying duration (Fan & Arce, 1986), initial moisture content (Pinthus et al., 1993), product shape and content, porosity (Pinthus, Weinberg, & Saguy, 1995), coating (Khalil, 1999), gel strength (Pinthus, Weinberg, & Saguy, 1992), initial interfacial tension (Pinthus & Saguy, 1994) and the method of frying. The simplest and most convenient method, which does not require variation in equipment design, is the use of additives to reduce the oil content (Priya et al., 1996). Addition of soy flour to donuts, amylose starch binders to French fries, film forming agents such as gelatin, powdered cellulose, alginates have been used to limit the fat uptake of fried foods (Pinthus et al., 1993).

Use of film forming hydrocolloids such as carboxymethylcellulose (CMC), hydroxypropylcellulose (HPC), hydroxypropylemethylcellulose (HPMC) and methylcellulose (MC) are particularly suitable in reducing the oil content in deep-fat fried foods (Gold, 1969; Keller, 1969; Willard & Roberts, 1968). This is attributed to the thermal gelation of

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these hydrocolloids at the frying temperature, which creates an oil-resistant film around the fried article and thereby lowering the oil absorption (Ang & Miller, 1991). Studies on the use of hydrocolloids to reduce the oil content in traditional products such as sev (Annapure, Singhal, & Kulkarni, 1999), *Papadams* (Annapure, Michael, Singhal, & Kulkarni, 1997), and *boondi* (Priya et al., 1996) showed the addition of film forming hydrocolloids to significantly reduce oil uptake during frying.

Sev is an Indian traditional snack food, most commonly prepared form chickpea flour. It is a fried savory resembling vermicelli, can also be made from other legumes (such as black gram) and cereals (generally rice) singly and in blends (Annapure, Singhal, & Kulkarni, 1998). Chickpea flour is made in to a dough by addition of water, and then it is extruded through a die (of varying diameters) in heated oil, the product is fried till it turns golden yellow and then removed from the oil. It is an extremely popular deep fried snack item consumed quiet frequently throughout India. It contains large amount of oil, reaching up to 40–45% of total product (Pinthus et al., 1993).

Gellan gum is used in a variety of food applications that includes water-based gels, confectionery, jams and marmalades, pie fillings and puddings, fabricated foods and dairy products (Sanderson & Clark, 1983). The use of gellan gum in combination with soy protein isolate for reducing oil uptake has been reported, but any study with sole gellan gum on this aspect has so far not reported (Rayner, Ciolfi, Maves, Stedman, & Mittal, 2000), but use of gellan gum solely for such a purpose has not so far been reported.

The objective of the present work is to study the effect of addition of gellan gum alone, and in combination with other hydrocolloids on the oil uptake of the sev and on texture characteristics of the sev and dough.

2. Materials and methods

2.1. Materials

Gellan gum, Kelcogel® was generously provided by C P Kelco, San Diego, California, USA. Sodium alginate and carboxymethylcellulose were purchased from HiMedia Laboratories Pvt. Ltd., Mumbai, India. Soy protein isolate was procured from Archer Daniels Midland (ADM), Decatur, Illinois, USA. Chickpea flour, refined groundnut oil of the brand 'Dhara', common salt of the brand 'Annapurna' were purchased from a local market of Mumbai, India.

2.2. Methods

2.2.1. Preparation of sev

Control sev was prepared from soft dough of chickpea flour obtained by adding the requisite of water and 2 g of salt to 100 g of flour and fried by extrusion through a hand operated extruder having a piston and die arrangement (1.3 mm) in to 300 ml of oil (175 ± 5 °C) for 40–45 s with turning after 20 s to ensure even frying.

2.2.2. Effect of addition of gellan gum

To study the effect of addition of gellan gum on the sev, dough with different concentrations of gellan gum (0%, 0.125%, 0.25%, 0.375%, 0.5%, 0.625% and 0.75% (w/w) of the chickpea flour) were prepared by adding the required quantity of gellan gum to the chick pea flour, and sev was prepared from these dough as per the method described above.

2.2.3. Effect of addition of gellan gum in combination with sodium alginate (SA), carboxymethylcellulose (CMC) and soy protein isolate (SPI)

Effect of addition of 0.25% gellan gum in combination with SA (0.25–1.00%), CMC (0.25–1.00%) and SPI (2.5–10.0%) was studied as for gellan gum alone. In the case of SPI, substitution was based on w/w basis of the chick pea flour.

2.2.4. Analysis of sev

2.2.4.1. Moisture content of dough and sev. Moisture was determined for all samples by drying in hot air oven at 105 °C until reaching a constant weight (AOAC, 1984).

2.2.4.2. Oil content of fried sev. This was done in triplicate using Soxhlet extraction for 16 h with petroleum ether (60–80 °C) as the solvent (AOAC, 1984).

2.2.4.3. Uptake ratio of the fried sev. The uptake ratio (U_R) was calculated from the moisture contents of dough and sev and oil content of sev using the formula given by Pinthus et al. (1993).

$$\text{Uptake ratio } (U_R) = \frac{\text{Oil content}}{[M_D - M_P](\%)}$$

where M_D and M_P are moisture content of dough and the product, respectively.

2.2.4.4. Texture of dough. Hardness and stickiness of the dough was measured by using 'TA.XT2i Texture Analyzer' (Stable Micro Systems, Surrey, England). Dough samples were placed on the blank plate. A plate having one hole of ~1 cm diameter was then placed on top of the sample. This plate provides weight around the test region to prevent lifting of the sample when the probe is withdrawn, hence avoiding inaccuracies in the results. The probe penetration test was then commenced. TA-XT2 settings used for evaluation of dough texture was carried out by using a 4 mm cylinder probe (P4) using a 5 kg load cell with test speed of 1 mm/s up to a distance of 2 mm, using a trigger force of 5 g, and a post-test speed of 10 mm/s.

2.2.4.5. Texture of sev. Hardness, fracturability and crispiness of sev was measured by using 'TA.XT2i Texture Analyzer'. The two adjustable supports of the rig base plate were placed at a suitable distance apart, so as to support the sample. The gap distance was kept constant for comparison purpose. The base plate was then positioned onto the heavy-duty platform. The heavy-duty platform was located, and locked in a position that enables the upper blade to be equidistant from the two lower supports. The sample was placed centrally over the supports just prior to testing. The TA-XT2 settings used for the evaluation of sev texture was carried out using a 3-point bending rig (HDP/3PB) and a 5 kg load cell on heavy-duty platform (HDP/90) with test speed of 1 mm/s up to a distance of 3 mm, using a trigger force of 5 g, and post-test speed of 10 mm/s.

2.2.4.6. Statistical analysis. The data obtained by replicate (triplicate or more) analysis were analyzed by ANOVA and Duncan's multiple-comparison test by using NCSS-PASS software. Statistical significance was accepted at a level of $P = 0.005$.

3. Results and discussion

3.1. Effect of gellan gum on oil uptake

Table 1 documents the effect of gellan gum on the amount of water required to form a dough suitable for extrusion, moisture content of the dough and that of the sev prepared there from, oil content and uptake ratio of sev. The effect of addition of gellan gum necessitated slight alteration in the amount of water needed so as to produce dough suitable for extrusion through the hand extruder. This judgment was made subjectively. Moisture content of sev was higher in samples prepared from added gellan gum up to 0.5% (w/w), and thereafter remained more or less constant.

Addition of gellan gum markedly affected the oil uptake by sev. Oil content of the control sev was the maximum (37.02%). It decreased significantly to 27.91% with increasing gellan gum concentration up to 0.25% (w/w) ($P = 0.05$), after which it did not change significantly. Uptake ratio of the sev also followed the same pattern. Films prepared from soy protein isolate and gellan gum has been used as coating for reducing the fat transfer in deep-fried potato fries and doughnut discs without any alteration in sensory evaluation (Rayner et al., 2000). It is speculated that in situ film formation could have taken place between the gellan gum and the protein present in the chickpea flour. However, this needs to be confirmed experimentally. Furthermore, the reason for insignificant fat content reduction beyond 0.25% gellan gum addition also needs to be explored.

These results confirmed that initial and final water content in the product has a major impact on oil uptake during deep fat frying. This phenomenon has already been proposed by Pinthus et al. (1993). As water retention is strongly affected by gellan gum, it may affect oil uptake during deep fat frying (Mashamo, Shinyashiki, & Mastsumura, 1996).

Oil uptake during frying is a surface phenomenon. An increased hydrophobic character of the surface would result in increased oil uptake during frying (Pinthus & Saguy, 1994). The ability of gellan gum to reduce oil uptake in sev can be attributed to its hydrophilic character.

Due to the thermal gelation of gellan gum at the frying temperature, it forms an oil-resistant film around the deep fried food products (Sworn, 2000). This film forming behaviour of gellan gum may be another reason for the observed reduction in oil uptake during frying.

3.2. Effect of gellan gum in combination with SA, CMC and SPI on oil uptake

Addition of gellan gum in combination with SA (0.25–1.00%), CMC (0.25–1.00%) and SPI (2.5–10.0%) did not show any significant effect on reduction of oil content when compared to 0.25% gellan gum (Table 2). Annapure et al. (1999) found 0.5% CMC alone to reduce the oil content in sev by 13.21%. Rayner et al. (2000) recommended a solution of 10% soy protein isolate with 0.05% gellan gum for coating foods such as doughnuts to reduce fat intake during deep-fat frying. However in our study we did not observe any significant reduction in oil uptake on addition gellan gum in combination with SPI compared to reduction in oil uptake obtained by gellan gum alone. This may probably be due to higher concentration of gellan gum used in our work.

Table 1
Effect of gellan gum on oil uptake by sev[A]

Gellan gum (% w/w)	Water added (g/100 g)	Moisture content of dough (%)	Moisture content of sev (%)	Oil content (%)[B]	Uptake ratio U_R
0.000 (Control)	45.0	36.81 ± 1.71	1.86 ± 0.13	37.02 ± 1.30c	1.05 ± 0.02c
0.125	45.0	37.23 ± 0.87	4.83 ± 0.11	31.63 ± 0.91d (14.55)	0.97 ± 0.01d
0.250	45.5	37.71 ± 1.46	6.25 ± 0.37	27.91 ± 1.36e (24.60)	0.88 ± 0.01e
0.325	46.0	38.83 ± 1.85	6.83 ± 0.21	26.51 ± 1.64e (28.39)	0.81 ± 0.01e
0.500	46.5	39.54 ± 1.33	7.11 ± 0.13	25.70 ± 1.28e (30.57)	0.79 ± 0.01e
0.625	47.0	40.41 ± 1.63	6.89 ± 0.27	25.91 ± 1.76e (30.01)	0.77 ± 0.01e
0.750	47.5	41.58 ± 0.95	7.56 ± 0.21	25.37 ± 1.68e (31.46)	0.75 ± 0.02e

Values in the same column with different letters are significantly different ($P = 0.05$) as measured by Duncan's multiple-comparison test.
[A] Result are mean ± SD of three determinations.
[B] Values within parenthesis indicate the % decrease in oil content as compared to control.

Table 2
Effect of addition of sodium alginate (SA), carboxymethylcellulose (CMC) or soy protein isolate (SPI) in addition to 0.25% gellan gum on oil uptake by sev[A]

Hydrocolloid (s) used	Water added (g/100 g)	Moisture content of dough (%)	Moisture content of sev (%)	Oil content (%)	Uptake ratio U_R
0.25% Gellan gum alone	45	38.14 ± 1.11	6.38 ± 0.36	27.63 ± 1.37b	0.87 ± 0.03
0.25% SA	45	37.42 ± 1.41	5.35 ± 0.16	27.48 ± 1.06b	0.86 ± 0.06
0.50% SA	45	39.23 ± 1.22	5.81 ± 0.38	28.29 ± 1.13b	0.84 ± 0.03
0.75% SA	47	38.74 ± 0.89	5.44 ± 0.28	26.48 ± 0.80b	0.79 ± 0.04
1.00% SA	47	42.51 ± 1.16	6.11 ± 0.32	29.66 ± 0.93b	0.81 ± 0.01
0.25% CMC	45	36.17 ± 1.24	5.83 ± 0.37	26.03 ± 0.98b	0.81 ± 0.04
0.50% CMC	45	35.83 ± 1.69	5.27 ± 0.34	25.35 ± 0.86b	0.83 ± 0.08
0.75% CMC	46	36.68 ± 1.97	6.14 ± 0.47	25.12 ± 1.21b	0.82 ± 0.06
1.00% CMC	46	37.89 ± 06	6.28 ± 0.19	25.50 ± 1.34b	0.80 ± 0.05
2.5% SPI	45	37.52 ± 1.25	4.94 ± 0.23	28.28 ± 0.78b	0.86 ± 0.05
5.0% SPI	45	37.32 ± 1.15	5.29 ± 0.41	28.93 ± 0.95b	0.90 ± 0.06
7.5% SPI	45	35.68 ± 1.37	6.25 ± 0.12	26.69 ± 1.10b	0.90 ± 0.04
10% SPI	45	36.76 ± 1.71	6.16 ± 020	26.79 ± 0.51b	0.87 ± 0.04

Values in the same column with different letters are significantly different ($P = 0.05$) as measured by Duncan's multiple-comparison test.
[A] Results are mean ± SD of three determinations.

3.3. Effect of gellan gum on texture of dough

Fig. 1 represents the typical texture or the expert exceed plot for measurement of dough hardness and stickiness. It was observed that, as a trigger force of 5 g was attained, the probe penetrated into the dough up to a depth of 2 mm. At this depth, the maximum force reading (i.e. the resistance to penetration) is obtained and translated as the hardness of the sample. When the probe withdraws from the sample, the total force required to do so is measured and recorded as the 'stickiness'. Table 3 documents the effect of addition of gellan gum on hardness and stickiness of chickpea flour dough. It was observed that hardness of dough decreased significantly with increasing gellan gum concentration ($P = 0.05$). This may be due to the water holding capacity of gellan gum. Stickiness of dough however increased with

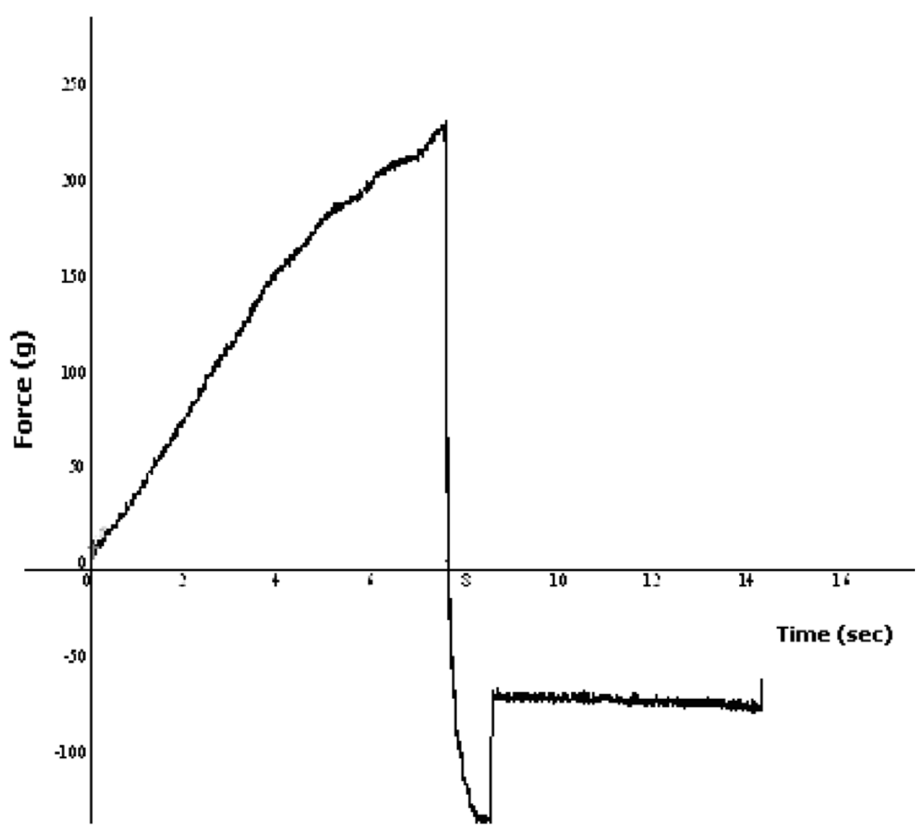

Fig. 1. A typical texture expert exceed plot for measurement of hardness and stickiness of dough.

Table 3
Effect of gellan gum on dough and sev characteristics[A]

% Gellan gum added (w/w)	Dough characteristics		Sev characteristics		
	Hardness (g)	Stickiness (g)	Hardness (g)	Fracturability (mm)	Crispiness (mm)
0.000	575.55 ± 16.29b	72.78 ± 3.65b	43.24 ± 2.74h	0.596 ± 0.036i	19.36 ± 1.19j
0.250	377.07 ± 15.52c	86.22 ± 2.23c	38.87 ± 2.66h	0.622 ± 0.039i	19.86 ± 0.86j
0.375	323.58 ± 20.45d	100.53 ± 2.89d	42.49 ± 1.62h	0.594 ± 0.028i	19.65 ± 1.52j
0.500	272.39 ± 11.40e	120.64 ± 2.79e	41.63 ± 1.58h	0.604 ± 0.032i	18.68 ± 1.59j
0.625	245.35 ± 12.26f	129.65 ± 2.06f	42.48 ± 2.79h	0.616 ± 0.023i	21.16 ± 1.87j
0.750	209.54 ± 9.59g	136.35 ± 2.12g	39.95 ± 1.35h	0.587 ± 0.029i	23.00 ± 1.83j

Values in the same column with different letters are significantly different ($P = 0.05$) as measured by Duncan's multiple-comparison test.
[A] Results are mean ± SD of five determinations.

Table 4
Effect of sodium alginate (SA), carboxymethylcellulose (CMC) or soy protein isolate (SPI) in addition to 0.25% gellan gum on dough and sev characteristics[A]

Hydrocolloid (s) used	Dough characteristics		Sev characteristics		
	Hardness (g)	Stickiness (g)	Hardness (g)	Fracturability (mm)	Crispiness (mm)
0. 25% Gellan gum alone	397.33 ± 20.50	88.16 ± 3.42	39.64 ± 1.78b	0.598 ± 0.021c	18.69 ± 1.15d
0.25% SA	390.66 ± 24.54	108.75 ± 4.18	41.23 ± 2.66b	0.645 ± 0.035c	17.65 ± 0.84d
0.50% SA	353.17 ± 20.45	141.36 ± 5.12	45.12 ± 1.81b	0.584 ± 0.026c	18.11 ± 1.15d
0.75% SA	321.25 ± 22.16	189.29 ± 3.16	39.65 ± 0.84b	0.591 ± 0.019c	17.56 ± 0.91d
1.00% SA	288.18 ± 18.27	236.18 ± 4.23	40.34 ± 1.58b	0.574 ± 0.020c	20.18 ± 1.35d
0.25% CMC	324.20 ± 17.23	96.21 ± 4.48	43.26 ± 1.22b	0.540 ± 0.036c	22.24 ± 1.45d
0.50% CMC	241.27 ± 12.29	112.16 ± 5.36	38.90 ± 1.12b	0.615 ± 0.031c	20.68 ± 1.20d
0.75% CMC	207.13 ± 10.89	127.68 ± 4.19	41.36 ± 2.14b	0.594 ± 0.020c	21.37 ± 1.35d
1.00% CMC	191.25 ± 14.23	139.35 ± 3.36	39.23 ± 1.52b	0.581 ± 0.012c	19.26 ± 1.37d
2.5% SPI	379.34 ± 17.36	86.71 ± 3.65	45.20 ± 1.36b	0.618 ± 0.014c	23.16 ± 1.36d
5.0% SPI	351.45 ± 15.56	98.24 ± 2.97	39.15 ± 2.13b	0.616 ± 0.027c	21.88 ± 1.76d
7.5% SPI	331.12 ± 21.19	112.17 ± 4.26	41.56 ± 1.65b	0.581 ± 0.034c	22.17 ± 1.49d
10% SPI	313.91 ± 13.85	121.78 ± 3.68	40.33 ± 1.60b	0.624 ± 0.016c	19.24 ± 1.64d

[A] Results are mean ± SD of five determinations.

an increase in gellan gum concentration in the dough. This could be attributed to the adhesiveness of gellan gum (Sanderson & Clark, 1983).

3.4. Effect of gellan gum in combination with SA, CMC and SPI on texture of dough

The hardness of dough decreased significantly on addition of increasing concentration of SA, CMC and SPI ($P = 0.05$). A similar trend was observed for stickiness of dough. With SA, even at 0.25%, the dough handling was very difficult (Table 4).

3.5. Effect of gellan gum on texture of sev

Fig. 2 represents the typical texture or expert exceed plot for analyzing texture of sev. Once the trigger force is attained, the force increases until such time as the sev fractures and falls into two pieces. This is observed as the maximum force and can be referred to as the 'hardness' of the sample. The distance at the point of break is the resistance of the sample to bend and hence relates to the 'fracturability' of the sample i.e. a sample that breaks at a very short distance has a high fracturability. The linear distance of the graph can be referred as crispness of the sev. Table 3 documents the effect of gellan gum on the characteristics of sev. It was found that addition of gellan gum did not significantly alter the hardness, fracturability or the crispiness of the sev ($P = 0.05$). It is interesting to note that although the moisture content of the sev had increased, it had not affected the textural characteristics of the sev. Thus, it can be inferred that moisture present in sev was bound with the gellan gum, which did not affect the sev characteristics (Mashamo et al., 1996).

3.6. Effect of gellan gum in combination SA, CMC and SPI on texture of sev

Addition of gellan gum in combination with SA, CMC and SPI did not significantly alter the hardness, fracturability or the crispiness of the sev ($P = 0.05$) (Table 4).

4. Conclusions

Addition of 0.25% (w/w) gellan gum to chickpea flour decreased oil content in the sev by 24.6%. Addition of gellan gum in combination with sodium alginate, carboxymethylcellulose or soy protein isolate did not significantly reduce the oil uptake in sev as compared to that of 0.25% gellan gum alone. Incorporation of all the additives altered the dough texture significantly, but not that of the sev.

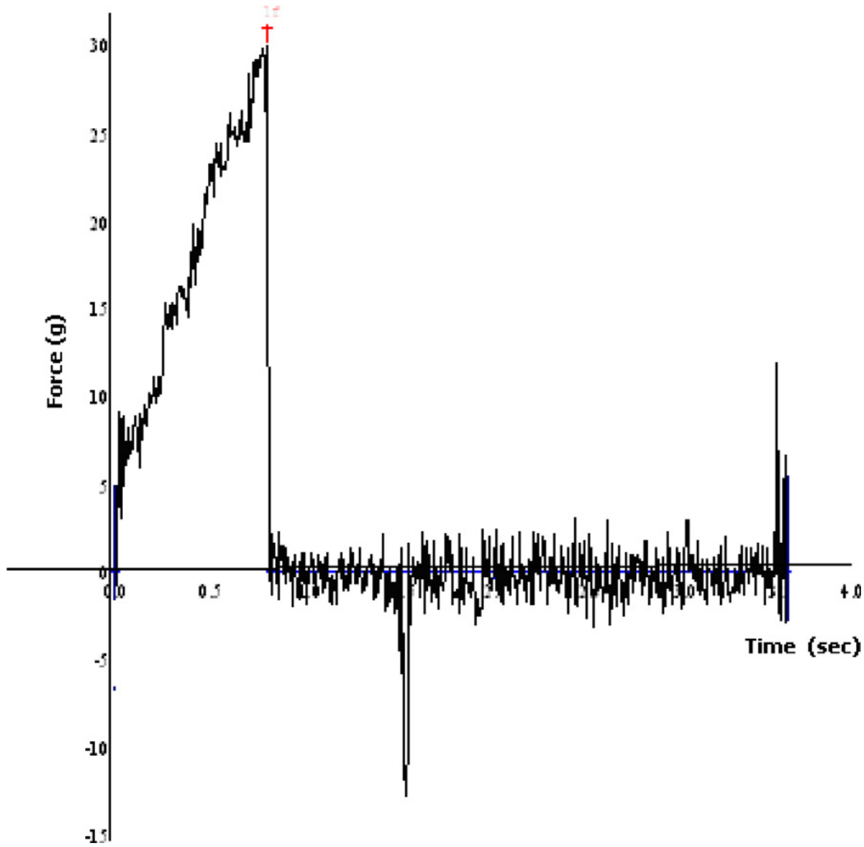

Fig. 2. A typical texture expert exceed plot for analyzing texture of sev.

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