Jurnal Penelitian Kelapa Sawit. 1997. 5(2): 93-108
Indonesian Journal of Oil Palm Research, 1997, 5(2): 93-108

FORMULASI MINYAK MARGARIN DENGAN PENDEKATAN *LINEAR PROGRAMMING*

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ABSTRAK

Minyak sawit dan minyak inti sawit beserta fraksi-fraksinya merupakan bahan yang baik untuk berbagai aplikasi di bidang pangan termasuk margarin. Margarin merupakan produk emulsi dengan tipe emulsi air di dalam minyak yang dibuat dari fase minyak, fase air, emulsifier, dan bahan lainnya seperti bahan penambah aroma, pewarna dan vitamin, serta antioksidan. Fase minyak margarin sangat menentukan sifat fisik margarin. Pada penelitian ini telah dilakukan formulasi minyak margarin menggunakan linear programming *yang dapat menghemat waktu dan bahan. Hasil penelitian memperlihatkan bahwa komposisi bahan baku yang disarankan untuk pembuatan minyak margarin hanya dipengaruhi oleh perbedaan fungsi kendala. Pengujian kesesuaian titik leleh minyak margarin hasil formulasi dengan margarin acuan memperlihatkan bahwa titik leleh minyak margarin hasil formulasi mendekati titik leleh margarin acuan.*

Kata kunci : margarin, formulasi, pendekatan *linear programming*, minyak sawit, minyak inti sawit

PENDAHULUAN

Minyak sawit dan minyak inti sawit beserta fraksi-fraksinya merupakan bahan yang baik untuk berbagai aplikasi di bidang pangan disebabkan oleh komposisi asam lemak dan trigliseridanya. Minyak sawit mengandung sekitar 50,2% asam lemak jenuh, 39,3% asam lemak tak jenuh tunggal dan 10,5% asam lemak tak jenuh ganda. Panjang rantai asam lemak yang terdapat di dalam trigliserida minyak sawit berkisar antara 12 sampai 20 karbon (4). Minyak sawit yang berbentuk semi padat terutama mengandung asam palmitat, asam oleat, dan asam linoleat masing-masing sebanyak 44,0%, 39,2%, dan 10,1% (7). Minyak inti sawit bersifat lebih jenuh dibandingkan dengan minyak sawit dengan kandungan asam lemak jenuh sebesar 84% (8).

Minyak sawit dan minyak inti sawit beserta fraksi-fraksinya banyak digunakan untuk pembuatan produk-produk emulsi misalnya margarin. Margarin merupakan produk emulsi dengan tipe emulsi air di dalam minyak yang dibuat dari minyak dan lemak pangan. Margarin, menurut definisi Codex, harus mengandung minyak tidak kurang dari 80% dan mengandung air tidak lebih dari 16%. Margarin dibuat dengan cara membuat emulsi antara fase minyak dengan fase air. Emulsi tersebut kemudian dikristalkan sebagian melalui proses pendinginan secara cepat yang dilanjutkan dengan proses plastisisasi atau teksturisasi (7).

Bahan baku pembuatan margarin antara lain adalah campuran minyak yang membentuk fase minyak; air dan atau susu yang membentuk fase air; emulsifier, dan bahan lainnya seperti bahan penambah aroma, pewarna dan vitamin, serta antioksidan. Fase minyak margarin sangat menentukan sifat fisik margarin. Oleh karena itu, dalam formulasi margarin perlu dilakukan lebih dahulu formulasi minyak margarin. Formulasi minyak margarin dapat dilakukan secara coba-coba, sebagaimana yang dilakukan untuk formulasi produk vanaspati (5), namun cara ini kurang menguntungkan karena membutuhkan banyak bahan dan waktu uji coba yang lama. Berdasarkan latar belakang itulah, penelitian ini dilakukan dengan tujuan untuk menggambarkan pemakaian *linear programming* untuk formulasi minyak margarin yang hemat waktu dan bahan.

BAHAN DAN METODE

Bahan

Bahan yang dipergunakan dalam formulasi minyak margarin ini adalah olein, minyak makan merah, minyak inti sawit, stearin, dan minyak sawit yang telah dimurnikan, dipucatkan, dan dideodorisasi. Olein, minyak inti sawit, stearin, dan minyak sawit yang telah dimurnikan, dipucatkan, dan dideodorisasi diperoleh dari PT Pamina Adolina, PT Perkebunan Nusantara IV, Sumatera Utara. Minyak makan merah dibuat dari olein mentah yang dihilangkan *gum*nya dengan asam fosfat dan dinetralisasi dengan Na_2CO_3 menurut cara yang telah dikembangkan oleh Pusat Penelitian Kelapa Sawit (1). Produk margarin yang dijadikan acuan adalah salah satu margarin meja komersial buatan Indonesia.

Metode

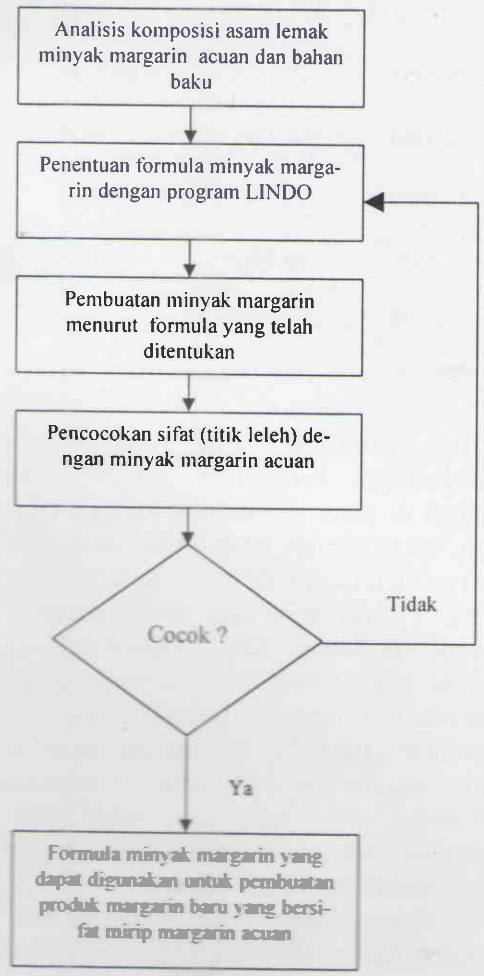
Penelitian ini dibagi menjadi dua tahapan yaitu tahap penentuan formula minyak margarin dengan model *linear programming* dan tahap pembuatan minyak margarin berdasarkan formula tersebut. Model *linear programming* diselesaikan dengan mempergunakan paket program komputer LINDO (*Linear Interactive Discrete Optimizer*). Kedua tahapan tersebut digambarkan pada Gambar 1.

Model *linear programming* mempunyai tiga unsur utama yaitu variabel keputusan, fungsi tujuan dan kendala-kendala fungsional. Baik fungsi tujuan maupun kendala-kendala fungsional dituangkan ke dalam fungsi matematika linier. Oleh karena itu agar paket program LINDO dapat berjalan dengan sempurna maka dilakukan tahapan berikut:

1. Penentuan variabel keputusan, yaitu berupa bahan baku minyak margarin antara lain stearin (ST), olein (OL), minyak inti sawit (PKO), minyak makan merah (MMM), dan minyak sawit yang telah dimurnikan, dipucatkan, dan dideodorisasi (RBD).
2. Penentuan fungsi tujuan.
3. Penentuan fungsi kendala yang didasarkan atas komposisi asam lemak minyak margarin acuan dan komposisi asam lemak bahan baku minyak margarin.

Hasil olahan program LINDO memuat informasi penyelesaian optimal, yaitu nilai fungsi tujuan, nilai optimal variabel keputusan, nilai variabel *slack* dan *surplus,* dan nilai *dual price*. Di antara hasil olahan program LINDO tersebut yang dipergunakan untuk keperluan formulasi minyak margarin hanyalah nilai optimal variabel, yang dalam hal ini adalah jumlah masing-masing bahan baku yang disarankan untuk formulasi minyak margarin.

Pembuatan minyak margarin (fase minyak) dilakukan dengan cara pencampuran. Sifat yang dipergunakan untuk keperluan pencocokan dengan acuan adalah titik leleh. Titik leleh dianalisis menurut metode AOCS Cc 1-25 (2) mempergunakan tabung kapiler. Komposisi asam lemak dianalisis dengan kromatografi gas.



Gambar 1. Formulasi minyak margarin dengan program LINDO

Metil ester asam lemak dianalisis dengan kromatografi gas Shimadzu model GC-14B (Shimadzu Co., Jepang) yang dilengkapi dengan detektor ionisasi nyala dan kolom pak dengan GP 3%-2310/2% SP-2300 pada 100/200 Chromosorb W, dijalankan pada suhu kolom 200°C, suhu injeksi 250°C, temperatur detektor 230°C, laju alir nitrogen 50 ml/menit. Luas area puncak dan persentase relatif metil ester asam lemak ditentukan menggunakan integrator Shimadzu Chromatopack C-R6A.

HASIL DAN PEMBAHASAN

Hasil pengamatan sifat-sifat margarin acuan dan minyak-minyak yang digunakan sebagai bahan baku dalam formulasi minyak margarin disajikan pada Tabel 1. Berdasarkan komposisi asam lemaknya maka minyak margarin acuan dapat ditiru formulasinya dengan cara mencampurkan secara langsung berbagai bahan baku yang digunakan. Bahan-bahan baku tersebut tidak perlu dimodifikasi terlebih dahulu. Asam lemak minyak margarin acuan terdiri dari asam lemak dengan rantai karbon berkisar dari 12 sampai 18 dan didominasi oleh asam palmitat dan oleat. Semua asam lemak tersebut terdapat pada bahan baku yang akan dipergunakan.

Linear programming dengan program LINDO yang dipergunakan untuk formulasi minyak margarin dalam penelitian ini tidak diarahkan untuk meminimumkan biaya atau memaksimumkan keuntungan sebagaimana yang sering dilakukan dalam formulasi produk pada berbagai penelitian terdahulu (3,6,9). Oleh karena itu kelayakan dari segi biaya atau keuntungan dalam hal pencapaian fungsi tujuan, yang dinyatakan sebagai nilai fungsi

Tabel 1. Sifat-sifat minyak margarin acuan dan minyak-minyak bahan baku formulasi

Sifat	Minyak margarin acuan	Stearin	Olein	Minyak inti sawit	Minyak sawit dimurnikan, dipucatkan, dan dideodorisasi	Minyak makan merah
Komposisi asam lemak :						
- C 10:0				3,0003		
- C 12:0	5,6027			47,2357		
- C 14:0	3,4320	1,1849	1,0210	16,3761	1,0835	0,7990
- C 16:0	42,3213	56,8467	41,8392	8,5752	45,1169	39,4739
- C 18:0	4,0154	3,6113	3,3118	2,8983	4,4245	3,4925
- C 18:1	34,9871	30,3654	42,0811	17,9860	38,7143	44,5404
- C 18:2	9,6415	7,9918	11,7470	2,9230	10,6610	11,6284
Titik leleh (°C)	42,75	48,75	*	26,75	34,75	*

*titik leleh olein dan minyak makan merah tidak diamati karena olein dan minyak makan merah tersebut berbentuk cair pada suhu kamar

tujuan pada keluaran program LINDO, tidak menjadi hal yang diperhatikan. Yang menjadi perhatian adalah nilai optimal variabel, yang dalam hal ini adalah jumlah masing-masing bahan baku yang disarankan untuk formulasi minyak margarin. Meskipun kelayakan dari segi biaya atau keuntungan dalam hal pencapaian fungsi tujuan tidak dipentingkan, pengaruh pemisalan harga minyak-minyak bahan baku formulasi terhadap komposisi formula yang disarankan harus diteliti. Untuk keperluan penelitian ini, pemisalan harga dibuat dengan empat alternatif, yaitu a) harga sama untuk semua bahan baku, b) harga mengikuti kecenderungan yang terjadi di pasar sebenarnya (sebagai contoh harga olein lebih mahal dari pada harga stearin), c) harga mengikuti kecenderungan berlawanan dengan yang terjadi di pasar sebenarnya (sebagai contoh, harga stearin lebih mahal dari pada harga olein), dan d) harga acak/ sembarang. Hasil penelitian memperlihatkan bahwa pemisalan harga minyak-minyak bahan baku formulasi tidak berpengaruh terhadap komposisi formula yang disarankan (Tabel 2). Di samping itu, perlu dikemukakan di sini bahwa komposisi formula yang disarankan tidak dipengaruhi oleh maksimisasi fungsi tujuan atau minimisasi fungsi tujuan.

Sebagaimana telah dikemukakan, model *linear programming* mempunyai tiga unsur utama yaitu variabel keputusan, fungsi tujuan dan kendala-kendala fung-

Tabel 2. Pengaruh pemisalan harga minyak-minyak bahan baku formulasi terhadap komposisi formula minyak margarin yang disarankan

Pemisalan harga minyak-minyak bahan baku formulasi (Rp. / kg)	Fungsi tujuan dan fungsi kendala	Komposisi formula minyak margarin yang disarankan
ST = 1000 RBD = 1000 PKO = 1000 MMM = 1000 OL = 1000	Fungsi tujuan : Maks. atau Min. $Z = 1000ST + 1000RBD + 1000PKO + 1000MMM + 1000OL$ Fungsi kendala : $0,0 \le 3,0003PKO \le 0,4$ $5,2 \le 47,2357PKO \le 6,0$ $3,0 \le 1,1849ST + 1,0835RBD + 16,3761PKO + 0,7990MMM + 1,0210OL \le 3,8$ $41,9 \le 56,8467ST + 45,1169RBD + 8,5752PKO + 39,4739MMM + 41,8392OL \le 42,7$ $3,6 \le 3,6113ST + 4,4245RBD + 2,8983PKO + 3,4925MMM + 3,3118OL \le 4,4$ $34,6 \le 30,3654ST + 38,7143RBD + 17,9860PKO + 44,5404MMM + 42,0811OL \le 35,4$ $9,2 \le 7,9918ST + 10,6610RBD + 2,9230PKO + 11,6284MMM + 11,7470OL \le 10,0$	ST = 14,067% RBD = 74,504% PKO = 12,702%
ST = 1000 RBD = 1500 PKO = 2500 MMM = 3000 OL = 2000	Fungsi tujuan : Maks. atau Min. $Z = 1000ST + 1500RBD + 2500PKO + 3000MMM + 2000OL$ Fungsi kendala : $0,0 \le 3,0003PKO \le 0,4$ $5,2 \le 47,2357PKO \le 6,0$ $3,0 \le 1,1849ST + 1,0835RBD + 16,3761PKO + 0,7990MMM + 1,0210OL \le 3,8$ $41,9 \le 56,8467ST + 45,1169RBD + 8,5752PKO + 39,4739MMM + 41,8392OL \le 42,7$ $3,6 \le 3,6113ST + 4,4245RBD + 2,8983PKO + 3,4925MMM + 3,3118OL \le 4,4$ $34,6 \le 30,3654ST + 38,7143RBD + 17,9860PKO + 44,5404MMM + 42,0811OL \le 35,4$ $9,2 \le 7,9918ST + 10,6610RBD + 2,9230PKO + 11,6284MMM + 11,7470OL \le 10,0$	ST = 14,067% RBD = 74,504% PKO = 12,702%
ST = 3000 RBD = 2500 PKO = 1500 MMM = 1000 OL = 2000	Fungsi tujuan : Maks. atau Min. $Z = 3000ST + 2500RBD + 1500PKO + 1000MMM + 2000OL$ Fungsi kendala : $0,0 \le 3,0003PKO \le 0,4$ $5,2 \le 47,2357PKO \le 6,0$ $3,0 \le 1,1849ST + 1,0835RBD + 16,3761PKO + 0,7990MMM + 1,0210OL \le 3,8$ $41,9 \le 56,8467ST + 45,1169RBD + 8,5752PKO + 39,4739MMM + 41,8392OL \le 42,7$ $3,6 \le 3,6113ST + 4,4245RBD + 2,8983PKO + 3,4925MMM + 3,3118OL \le 4,4$ $34,6 \le 30,3654ST + 38,7143RBD + 17,9860PKO + 44,5404MMM + 42,0811OL \le 35,4$ $9,2 \le 7,9918ST + 10,6610RBD + 2,9230PKO + 11,6284MMM + 11,7470OL \le 10,0$	ST = 14,067% RBD = 74,504% PKO = 12,702%
ST = 7500 RBD = 750 PKO = 4525 MMM = 560 OL = 900	Fungsi tujuan : Maks. atau Min. $Z = 3000ST + 2500RBD + 1500PKO + 1000MMM + 2000OL$ Fungsi kendala : $0,0 \le 3,0003PKO \le 0,4$ $5,2 \le 47,2357PKO \le 6,0$ $3,0 \le 1,1849ST + 1,0835RBD + 16,3761PKO + 0,7990MMM + 1,0210OL \le 3,8$ $41,9 \le 56,8467ST + 45,1169RBD + 8,5752PKO + 39,4739MMM + 41,8392OL \le 42,7$ $3,6 \le 3,6113ST + 4,4245RBD + 2,8983PKO + 3,4925MMM + 3,3118OL \le 4,4$ $34,6 \le 30,3654ST + 38,7143RBD + 17,9860PKO + 44,5404MMM + 42,0811OL \le 35,4$ $9,2 \le 7,9918ST + 10,6610RBD + 2,9230PKO + 11,6284MMM + 11,7470OL \le 10,0$	ST = 14,067% RBD = 74,504% PKO = 12,702%

ST = stearin; RBD = minyak sawit yang dimurnikan, dipucatkan, dan dideodorisasi; PKO = minyak inti sawit; MMM = minyak makan merah; OL = olein sional. Oleh karena itu juga dilakukan penelitian mengenai pengaruh perbedaan fungsi-fungsi kendala terhadap komposisi formula yang disarankan. Perbedaan fungsi kendala dibuat dengan cara menetapkan simpangan kadar masing-masing asam lemak yang berbeda. Yang dimaksud dengan simpangan kadar asam lemak digambarkan sebagai berikut : misalkan ditetapkan simpangan kadar asam lemak sebesar 0,4% dan kadar asam laurat pada minyak margarin acuan sebesar 5,6% maka fungsi kendala untuk kadar asam laurat adalah (5,6 - 0,4)% < kadar asam laurat < (5,6 + 0,4)% atau 5,2% < kadar asam laurat < 6,0%.

Hasil penelitian memperlihatkan bahwa perbedaan fungsi-fungsi kendala yang diakibatkan oleh penetapan simpangan kadar asam lemak yang berbeda berpengaruh terhadap komposisi formula yang disarankan (Tabel 3). Makin kecil simpangan kadar asam lemak yang ditetapkan sebenarnya berdampak meningkatkan derajat kesesuaian antara komposisi asam lemak formula minyak margarin yang disarankan dengan margarin acuan. Oleh karena itu diusahakan agar simpangan kadar asam lemak sekecil mungkin. Namun, hasil penelitian (Tabel 3) memperlihatkan bahwa simpangan kadar asam lemak mempunyai nilai optimal agar jumlah semua bahan baku yang disarankan untuk formulasi minyak margarin mendekati 100%. Dengan simpangan kadar asam lemak ditetapkan 0,1; 0,2; 0,3; dan 0,4% maka jumlah semua bahan baku yang disarankan untuk formulasi minyak margarin berturut-turut adalah 94,366%, 96,807%, 99,248%, dan 101,128%. Berdasarkan hasil ini maka dapat disimpulkan bahwa simpangan kadar asam lemak yang optimal adalah antara 0,3% sampai 0,4% dengan komposisi formula minyak margarin yang disarankan terdiri dari stearin berkisar antara 12,584% - 14,067%, minyak sawit yang dimurnikan, dipucatkan, dan dideodorisasi berkisar antara 74,504% - 76,665%, dan minyak inti sawit berkisar antara 9,999% - 12,702%.

Berdasarkan komposisi formula minyak margarin yang disarankan oleh *linear programming* LINDO dilakukan pembuatan minyak margarin (fase minyak) dengan cara pencampuran dan pencocokan sifat titik leleh dengan minyak margarin acuan. Hasil penelitian memperlihatkan bahwa komposisi asam lemak dan titik leleh minyak margarin hasil formulasi sangat mendekati titik leleh dan komposisi asam lemak minyak margarin acuan (Tabel 4). Berdasarkan hasil ini dapat dinyatakan bahwa *linear programming* dapat digunakan untuk memformulasi minyak margarin secara cepat dan menghemat pemakaian bahan.

Tabel 3. Pengaruh simpangan kadar masing-masing asam lemak terhadap komposisi formula minyak margarin yang disarankan

Pemisalan harga minyak-minyak bahan baku formulasi (Rp. / kg)	Fungsi tujuan dan fungsi kendala	Komposisi formula minyak margarin yang disarankan
ST=1000 RBD=1500 PKO=2500 MMM=3000 OL=2000	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000MMM+2000OL$ Fungsi kendala : Simpangan 0,1 $0,0\le 3,0003PKO\le 0,1$ $5,5\le 47,2357PKO\le 5,7$ $3,3\le 1,1849ST+1,0835RBD+16,3761PKO+0,7990MMM+1,0210OL\le 3,5$ $42,2\le 56,8467ST+45,1169RBD+8,5752PKO+39,4739MMM+41,8392OL\le 42,4$ $3,9\le 3,6113ST+4,4245RBD+2,8983PKO+3,4925MMM+3,3118OL\le 4,1$ $34,9\le 30,3654ST+38,7143RBD+17,9860PKO+44,5404MMM+42,0811OL\le 35,1$ $9,5\le 7,9918ST+10,6610RBD+2,9230PKO+11,6284MMM+11,7470OL\le 9,7$	ST = 8,891% RBD=82,142% PKO=3,333%
ST=1000 RBD=1500 PKO=2500 MMM=3000 OL=2000	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000MMM+2000OL$ Fungsi kendala : Simpangan 0,2 $0,0\le 3,0003PKO\le 0,2$ $5,4\le 47,2357PKO\le 5,8$ $3,2\le 1,1849ST+1,0835RBD+16,3761PKO+0,7990MMM+1,0210OL\le 3,6$ $42,1\le 56,8467ST+45,1169RBD+8,5752PKO+39,4739MMM+41,8392OL\le 42,5$ $3,8\le 3,6113ST+4,4245RBD+2,8983PKO+3,4925MMM+3,3118OL\le 4,2$ $34,8\le 30,3654ST+38,7143RBD+17,9860PKO+44,5404MMM+42,0811OL\le 35,2$ $9,4\le 7,9918ST+10,6610RBD+2,9230PKO+11,6284MMM+11,7470OL\le 9,8$	ST = 10,738% RBD=79,404% PKO=6,666%
ST=1000 RBD=1500 PKO=2500 MMM=3000 OL=2000	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000MMM+2000OL$ Fungsi kendala : Simpangan 0,3 $0,0\le 3,0003PKO\le 0,3$ $5,3\le 47,2357PKO\le 5,9$ $3,1\le 1,1849ST+1,0835RBD+16,3761PKO+0,7990MMM+1,0210OL\le 3,7$ $42,0\le 56,8467ST+45,1169RBD+8,5752PKO+39,4739MMM+41,8392OL\le 42,6$ $3,7\le 3,6113ST+4,4245RBD+2,8983PKO+3,4925MMM+3,3118OL\le 4,3$ $34,7\le 30,3654ST+38,7143RBD+17,9860PKO+44,5404MMM+42,0811OL\le 35,3$ $9,3\le 7,9918ST+10,6610RBD+2,9230PKO+11,6284MMM+11,7470OL\le 9,9$	ST = 12,584% RBD=76,665% PKO=9,999%
ST=1000 RBD=1500 PKO=2500 MMM=3000 OL=2000	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000MMM+2000OL$ Fungsi kendala : Simpangan 0,4 $0,0\le 3,0003PKO\le 0,4$ $5,2\le 47,2357PKO\le 6,0$ $3,0\le 1,1849ST+1,0835RBD+16,3761PKO+0,7990MMM+1,0210OL\le 3,8$ $41,9\le 56,8467ST+45,1169RBD+8,5752PKO+39,4739MMM+41,8392OL\le 42,7$ $3,6\le 3,6113ST+4,4245RBD+2,8983PKO+3,4925MMM+3,3118OL\le 4,4$ $34,6\le 30,3654ST+38,7143RBD+17,9860PKO+44,5404MMM+42,0811OL\le 35,4$ $9,2\le 7,9918ST+10,6610RBD+2,9230PKO+11,6284MMM+11,7470OL\le 10,0$	ST = 14,067% RBD=74,504% PKO=12,702%

ST = stearin; RBD = minyak sawit yang dimurnikan, dipucatkan, dan dideodorisasi; PKO = minyak inti sawit; MMM = minyak makan merah; OL = olein

Tabel 4. Sifat minyak margarin acuan dan minyak margarin hasil formulasi

Sifat	Minyak margarin acuan	Minyak margarin hasil formulasi
Komposisi asam lemak :		
- C 10:0		
- C 12:0	5,6027	6,7423
- C 14:0	3,4320	3,4823
- C 16:0	42,3213	42,2491
- C 18:0	4,0154	3,7372
- C 18:1	34,9871	34,6999
- C 18:2	9,6415	9,1498
Titik leleh (°C)	42,75	42,50

KESIMPULAN

Linear programming dapat diterapkan untuk memformulasi minyak margarin yaitu jumlah masing-masing bahan baku yang disarankan untuk formulasi minyak margarin. Penerapan *linear programming* tersebut tidak dipengaruhi oleh harga masing-masing bahan baku yang digunakan dalam formulasi, namun dipengaruhi oleh perbedaan fungsi kendala karena perbedaan penetapan simpangan kadar asam lemak.

Komposisi minyak margarin yang disarankan yang sesuai dengan minyak margarin acuan terdiri dari stearin berkisar antara 12,584% - 14,067%, minyak sawit yang dimurnikan, dipucatkan, dan dideodorisasi berkisar antara 74,504% - 76,665%, dan minyak inti sawit berkisar antara 9,999% - 12,702%.

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Margarine oil formulation using linear programming approach

Angga Jatmika

Abstract

Palm and palm kernel oils and their fractions are excellent ingredients for food applications such as margarines. Margarine is water in oil type emulsion products produced from fat phase, aqueous phase, emulsifier, and other ingredients such as flavoring agents, coloring agents, vitamins and antioxidants. The fat phase of the margarine determines the physical properties of margarine. This research was conducted to formulate margarine oil using linear programming approach which could reduce time and materials. Result of the study showed that recommended composition of raw materials for preparing margarine oil was affected only by difference of constraint functions. Testing of melting point of recommended margarine oil compared to reference margarine oil showed that the melting point of the re-commended margarine oil was close to that of reference margarine oil.

Keywords : margarine, formulation, linear programming approach, palm oil, palm kernel oil

Introduction

Palm and palm kernel oils and their fractions are excellent ingredients for food applications due to their fatty acid and triglyceride composition. Palm oil comprises about 50.2% saturated fatty acids, 39.3% monounsaturated fatty acids and 10.5% polyunsaturated fatty acids. The chain lengths of these fatty acids present in the triglycerides fall within a very narrow range from 12 to 20 carbons (4). Palm oil which is a semi-solid form contains mainly palmitic, oleic and linoleic acid of 44.0%, 39.2%, and 10.1%, respectively (7). Palm kernel oil is more saturated than palm oil which contains 84% saturated fats (8).

Palm and palm kernel oils and their fractions find a wide range of applications in the manufacture of emulsion products such as margarines. Margarine is water in oil type emulsion products produced principally from edible fats and oils. Margarine is defined by Codex to consist of not less than 80% fat and not more than 16% water. Margarine is made by emulsifying oils or fats with an aqueous phase. The emulsion is partly crystallized by rapid chilling continued with plasticization or texturization (7).

Materials used for margarine preparation were mixture of oil and fat which form a fat phase, water and or milk which form a aqueous phase, emulsifier, and other ingredients such as flavoring agents, coloring agents, vitamins and antioxidants. The fat phase of the margarine determines the physical properties of margarine. Hence, in the margarine formulation must be preceeded by formulation of the fat phase of margarine. Margarine oil formulation can be accomplished by trial and error approach as used for vanaspati formulation (5). This approach, however, is time consuming and needs more materials. Based on this background, this research was conducted to illustrate a linear programming approach for margarine oil formulation.

Materials and Methods

Materials

Materials used for margarine oil (fat phase) formulation were palm olein, red palm oil, palm kernel oil, palm stearin, and refined, bleached, deodorized palm oil. Palm olein, palm kernel oil, palm stearin, and refined, bleached, deodorized palm oil were obtained from PT Pamina Adolina, PT Perkebunan Nusantara IV, North Sumatera. Red palm oil was made from crude olein, degummed by phosphoric acid and neutralized by Na_2CO_3 according to method developed by Indonesian Oil Palm Research Institute (1). This research used commercial table margarine made in Indonesia as reference margarine.

Methods

This study was divided into two stages that is determination of margarine oil formula by linear programming model and preparation of margarine oil based on that formula. Linear programming model was calculated by LINDO (*Linear Interactive Discrete Optimizer*) computer program. The two stages of study was illustrated on Figure 1.

Linear programming model has three main components that is decision variable, objective function and constraint functions. Both of the objective function and constraint functions were made in the linear equations. Hence, in order for LINDO to run optimal, there are three stages that should be done as follow :

1. Determination of decision variables, in this case, te decision variables are oils for raw materials of the margarine oil formulation such as palm stearin (ST), palm olein (OL), palm kernel oil (PKO), red cooking oil (MMM), and refined, bleached, deodorized palm oil (RBD).
2. Determination of objective function.
3. Determination of constraint functions based on fatty acid composition of reference margarine oil and oils used for raw materials of the formulation.

The output of the LINDO computer program inform optimal solution which consist of objective function value, optimal decision variable value, value of slack and surplus variable, and dual price value. Among of the output LINDO computer program that used for this margarine oil formulation was only optimal decision variable value which illustrated the recommended quantity of each oils of raw materials for margarine oil formulation.

Margarine oil (fat phase) preparation was carried out by blending. The property used for matching with the reference was melting point. Melting point was analyzed according to AOCS method Cc 1-25 (2) using capillary tube. Fatty acid composition was analyzed by gas chromatography. The fatty acid methyl esters (FAME) were analyzed on a Shimadzu model GC 14B (Shimadzu Co., Japan) equipped with a flame ionization detector and a column packed with GP 3%-2310/2% SP 2300 on 100/200 Chromosorb W support, operated at a column temperature of 200°C, injection port temperature of 250°C and FID temperature of 230°C, under a nitrogen flow rate of 50 ml/min. The peak area and relative percentage of FAME were obtained with Shimadzu integrator C-R6A Chromatopack.

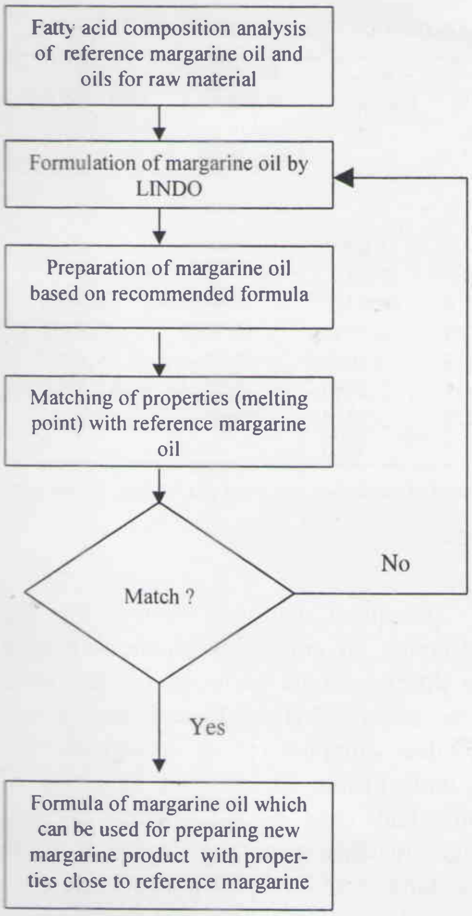

Figure 1. Formulation of margarine oil using program LINDO

Results and Discussion

Result of the observation on the properties of reference margarine oil and oils used for raw material of the formulation was shown at Table 1. Based on their fatty acid composition, that reference margarine oil can be duplicated by straight blending of the oils used for raw material of the formulation. The oils used for raw material of the formulation did not need any modification. The fatty acids of the reference margarine oil consist of fatty acids with carbon chain length range from 12 - 18 and dominated by palmitic and oleic acids. All of the fatty acids are found in oils used for raw material of the formulation.

Linear programming using LINDO computer program used in this margarine oil formulation was not aimed to minimize the cost or maximize the return as often it has been done in the products formulation by preceding research (3,6,9). Hence, the feasibility of cost or return in term of objective function achievement, was expresed as objective function value in the output of LINDO computer program, e.g. the recommended quantity of each oils used for raw material of margarine oil formulation. Although, the feasibility of cost or return in term of objective function achievement was not important, the effect of raw materials price assumption on the recommended composition of oil margarine formula must be further studied. For the current study, the raw materials price assumption was made according to four alternatives: a) equal price for all of the oils for raw material of margarine oil formulation, b) trend of the normal market price (for example, palm olein was more expensive than palm stearin), c) price assumption contrary with normally trend of the market price (for example, palm stearin was more expensive than palm olein), and d) random price assumption. Result of the study showed that the price assumption of oils used for raw materials of formulation did not affect the recommended composition of oil margarine

Table 1. Properties of reference margarine oil and oils for raw materials in the formulation

Properties	Reference margarine oil	Palm stearin	Palm olein	Palm kernel oil	Refined, bleached, deodorized palm oil	Red cooking oil
Fatty acid composition (%) :						
- C 10:0				3.0003		
- C 12:0	5.6027			47.2357		
- C 14:0	3.4320	1.1849	1.0210	16.3761	1.0835	0.7990
- C 16:0	42.3213	56.8467	41.8392	8.5752	45.1169	39.4739
- C 18:0	4.0154	3.6113	3.3118	2.8983	4.4245	3.4925
- C 18:1	34.9871	30.3654	42.0811	17.9860	38.7143	44.5404
- C 18:2	9.6415	7.9918	11.7470	2.9230	10.6610	11.6284
Melting point (°C)	42.5	49.0	*	27.0	35.0	*

*)melting point of palm olein and red cooking oil were not determined because palm olein and red cooking oil were in the liquid form in the room temperature

formula (Table 2). In addition to above result, other result showed that maximization or minimization of objective function did not affect the recommended composition of oil margarine formula.

As already stated that a linear programming model has three main components that is decision variable, objective and constraint functions. Therefore, study of the effect of difference functions constraint on recommended composition of margarine oil formula also was carried out. The difference functions constraint was generated by variation of individual fatty acid content deviation. For explanation of the individual fatty acid content deviation, it was illustrated as follow : for example, the deviation of individual (each) fatty acid was given of 0.4% and lauric acid content of the margarine oil reference was 5.6% so constraint function for lauric acid content fall on (5.6-0.4)% < lauric acid content < (5.6+0.4)% or 5.2% < lauric acid content < 6.0%.

Result of the study showed that the difference of constraint functions caused by differences in deviation of individual fatty acids content affected on recommended composition of margarine oil formula (Table 3). Lower deviation of individual fatty acids content, in fact, could increase matching degree between the fatty acid composition of reference margarine oil and recommended margarine oil formula. Therefore, it must be attempted to minimize the deviation of individual fatty acids content. Data on Table 3, however, showed that the deviation of individual fatty acids content has an optimal value in order to the quantity of each oils used for raw material of margarine oil formulation closed to 100%. If the deviation of individual (each) fatty acid was 0.1, 0.2, 0.3, and 0.4% then the quantity of each oils used for raw material of margarine oil formulation will be of 94.366%, 96.807%, 99.248%, and 101.128%, respectively.

Table 2. Effect of price assumption on recommended composition of oil margarine formula

Price assumption of oils for raw material in the formulation (Rp./kg)	Objective function and constraint functions	Recommended composition of oil margarine formula
ST = 1000 **RBD = 1000** **PKO = 1000** **MMM = 1000** **OL = 1000**	Objective function : Max. or Min. $Z = 1000ST + 1000RBD + 1000PKO + 1000MMM + 1000OL$ Constraint functions : $0.0 \le 3.0003PKO \le 0.4$ $5.2 \le 47.2357PKO \le 6.0$ $3.0 \le 1.1849ST + 1.0835RBD + 16.3761PKO + 0.7990MMM + 1.0210OL \le 3.8$ $41.9 \le 56.8467ST + 45.1169RBD + 8.5752PKO + 39.4739MMM + 41.8392OL \le 42.7$ $3.6 \le 3.6113ST + 4.4245RBD + 2.8983PKO + 3.4925MMM + 3.3118OL \le 4.4$ $34.6 \le 30.3654ST + 38.7143RBD + 17.9860PKO + 44.5404MMM + 42.0811OL \le 35.4$ $9.2 \le 7.9918ST + 10.6610RBD + 2.9230PKO + 11.6284MMM + 11.7470OL \le 10.0$	ST = 14.067% RBD = 74.504% PKO = 12.702%
ST = 1000 RBD = 1500 PKO = 2500 MMM = 3000 OL = 2000	Objective function : Max. or Min. $Z = 1000ST + 1000RBD + 1000PKO + 1000MMM + 1000OL$ Constraint functions : $0.0 \le 3.0003PKO \le 0.4$ $5.2 \le 47.2357PKO \le 6.0$ $3.0 \le 1.1849ST + 1.0835RBD + 16.3761PKO + 0.7990MMM + 1.0210OL \le 3.8$ $41.9 \le 56.8467ST + 45.1169RBD + 8.5752PKO + 39.4739MMM + 41.8392OL \le 42.7$ $3.6 \le 3.6113ST + 4.4245RBD + 2.8983PKO + 3.4925MMM + 3.3118OL \le 4.4$ $34.6 \le 30.3654ST + 38.7143RBD + 17.9860PKO + 44.5404MMM + 42.0811OL \le 35.4$ $9.2 \le 7.9918ST + 10.6610RBD + 2.9230PKO + 11.6284MMM + 11.7470OL \le 10.0$	ST = 14.067% RBD = 74.504% PKO = 12.702%
ST = 3000 **RBD = 2500** **PKO = 1500** **MMM = 1000** **OL = 2000**	Objective function : Max. or Min. $Z = 1000ST + 1000RBD + 1000PKO + 1000MMM + 1000OL$ Constraint functions : $0.0 \le 3.0003PKO \le 0.4$ $5.2 \le 47.2357PKO \le 6.0$ $3.0 \le 1.1849ST + 1.0835RBD + 16.3761PKO + 0.7990MMM + 1.0210OL \le 3.8$ $41.9 \le 56.8467ST + 45.1169RBD + 8.5752PKO + 39.4739MMM + 41.8392OL \le 42.7$ $3.6 \le 3.6113ST + 4.4245RBD + 2.8983PKO + 3.4925MMM + 3.3118OL \le 4.4$ $34.6 \le 30.3654ST + 38.7143RBD + 17.9860PKO + 44.5404MMM + 42.0811OL \le 35.4$ $9.2 \le 7.9918ST + 10.6610RBD + 2.9230PKO + 11.6284MMM + 11.7470OL \le 10.0$	ST = 14.067% RBD = 74.504% PKO = 12.702%
ST = 7500 RBD = 750 PKO = 4525 MMM = 560 OL = 900	Objective function : Max. or Min. $Z = 1000ST + 1000RBD + 1000PKO + 1000MMM + 1000OL$ Constraint functions : $0.0 \le 3.0003PKO \le 0.4$ $5.2 \le 47.2357PKO \le 6.0$ $3.0 \le 1.1849ST + 1.0835RBD + 16.3761PKO + 0.7990MMM + 1.0210OL \le 3.8$ $41.9 \le 56.8467ST + 45.1169RBD + 8.5752PKO + 39.4739MMM + 41.8392OL \le 42.7$ $3.6 \le 3.6113ST + 4.4245RBD + 2.8983PKO + 3.4925MMM + 3.3118OL \le 4.4$ $34.6 \le 30.3654ST + 38.7143RBD + 17.9860PKO + 44.5404MMM + 42.0811OL \le 35.4$ $9.2 \le 7.9918ST + 10.6610RBD + 2.9230PKO + 11.6284MMM + 11.7470OL \le 10.0$	ST = 14.067% RBD = 74.504% PKO = 12.702%

ST = palm stearin; RBD = refined, bleached, deodorized palm oil; PKO = palm kernel oil; MMM = red cooking oil; OL = palm olein

Table 3. Effect of deviation of individual fatty acids content on recommended composition of margarine oil formula

Price assumption of oils for raw material in the formulation (Rp./kg)	Objective function and constraint functions	Recommended composition of oil margarine formula
ST=1000 RBD=1500 PKO=2500 MMM=3000 OL=2000	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000MMM+2000OL$ Constrain functions : Deviation 0.1 $0.0\le 3.0003PKO\le 0.1$ $5.5\le 47.2357PKO\le 5.7$ $3.3\le 1.1849ST+1.0835RBD+16.3761PKO+0.7990MMM+1.0210OL\le 3.5$ $42.2\le 56.8467ST+45.1169RBD+8.5752PKO+39.4739MMM+41.8392OL\le 42.4$ $3.9\le 3.6113ST+4.4245RBD+2.8983PKO+3.4925MMM+3.3118OL\le 4.1$ $34.9\le 30.3654ST+38.7143RBD+17.9860PKO+44.5404MMM+42.0811OL\le 35.1$ $9.5\le 7.9918ST+10.6610RBD+2.9230PKO+11.6284MMM+11.7470OL\le 9.7$	ST = 8.891% RBD=82.142% PKO=3.333%
ST=1000 RBD=1500 PKO=2500 MMM=3000 OL=2000	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000MMM+2000OL$ Constrain functions : Deviation 0.2 $0.0\le 3.0003PKO\le 0.2$ $5.4\le 47.2357PKO\le 5.8$ $3.2\le 1.1849ST+1.0835RBD+16.3761PKO+0.7990MMM+1.0210OL\le 3.6$ $42.1\le 56.8467ST+45.1169RBD+8.5752PKO+39.4739MMM+41.8392OL\le 42.5$ $3.8\le 3.6113ST+4.4245RBD+2.8983PKO+3.4925MMM+3.3118OL\le 4.2$ $34.8\le 30.3654ST+38.7143RBD+17.9860PKO+44.5404MMM+42.0811OL\le 35.2$ $9.4\le 7.9918ST+10.6610RBD+2.9230PKO+11.6284MMM+11.7470OL\le 9.8$	ST = 10.738% RBD=79.404% PKO=6.666%
ST=1000 RBD=1500 PKO=2500 MMM=3000 OL=2000	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000MMM+2000OL$ Constrain functions : Deviation 0.3 $0.0\le 3.0003PKO\le 0.3$ $5.3\le 47.2357PKO\le 5.9$ $3.1\le 1.1849ST+1.0835RBD+16.3761PKO+0.7990MMM+1.0210OL\le 3.7$ $42.0\le 56.8467ST+45.1169RBD+8.5752PKO+39.4739MMM+41.8392OL\le 42.6$ $3.7\le 3.6113ST+4.4245RBD+2.8983PKO+3.4925MMM+3.3118OL\le 4.3$ $34.7\le 30.3654ST+38.7143RBD+17.9860PKO+44.5404MMM+42.0811OL\le 35.3$ $9.3\le 7.9918ST+10.6610RBD+2.9230PKO+11.6284MMM+11.7470OL\le 9.9$	ST = 12.584% RBD=76.665% PKO=9.999%
ST=1000 RBD=1500 PKO=2500 MMM=3000 OL=2000	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000MMM+2000OL$ Constrain functions : Deviation 0.4 $0.0\le 3.0003PKO\le 0.4$ $5.2\le 47.2357PKO\le 6.0$ $3.0\le 1.1849ST+1.0835RBD+16.3761PKO+0.7990MMM+1.0210OL\le 3.8$ $41.9\le 56.8467ST+45.1169RBD+8.5752PKO+39.4739MMM+41.8392OL\le 42.7$ $3.6\le 3.6113ST+4.4245RBD+2.8983PKO+3.4925MMM+3.3118OL\le 4.4$ $34.6\le 30.3654ST+38.7143RBD+17.9860PKO+44.5404MMM+42.0811OL\le 35.4$ $9.2\le 7.9918ST+10.6610RBD+2.9230PKO+11.6284MMM+11.7470OL\le 10.0$	ST = 14.067% RBD=74.504% PKO=12.702%

ST = palm stearin; RBD = refined, bleached, deodorized palm oil; PKO = palm kernel oil; MMM = red cooking oil; OL = palm olein

Table 4. Properties of reference margarine oil and recommended margarine oil

Properties	Reference margarine oil	Recommended margarine oil
Fatty acid composition:		
- C 10:0	-	-
- C 12:0	5.6027	6.7423
- C 14:0	3.4320	3.4823
- C 16:0	42.3213	42.2491
- C 18:0	4.0154	3.7372
- C 18:1	34.9871	34.6999
- C 18:2	9.6415	9.1498
Melting point (°C)	42.75	42.50

Based on that result, it was concluded that the optimal value of deviation of individual (each) fatty acid falls between 0.3% to 0.4% with recommended composition of margarine oil formula consisted of palm stearin falls between 12.584% to 14.067%, refined, bleached, deodorized palm oil falls between 74.504% to 76.665%, and palm kernel oil falls between 9.999% to 12.702%.

Based on composition of margarine oil formula recommended by LINDO computer program, preparation of margarine oil (fat phase of margarine) was carried out using blending technique. The melting point of this recommended margarine oil was close to that of reference margarine oil. Result of the study showed that the fatty acid composition and melting point of the recommended margarine oil were close to those of reference margarine oil (Table 4). Based on these results, it could be concluded that linear programming model might be used for fast formulation of margarine oil and saving the material used.

Conclusions

Linear programming could be applied for margarine oil formulation in term of the quantity of each oils used for raw material of margarine oil formulation. Application of the linear programming was not affected by price level of each oils used for raw material of margarine oil formulation, but was affected by the difference of constraint functions due to difference given deviation of individual fatty acid content.

The recommended composition of margarine oil formula which was close to reference margarine oil consisted of palm stearin falls between 12.584% to 14.067%, refined, bleached, deodorized palm oil falls between 74.504% to 76.665%, and palm kernel oil falls between 9.999% to 12.702%.

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