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FORMULASI MARGARIN KAYA PROVITAMIN A DARI MINYAK SAWIT MERAH

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ABSTRAK

Penelitian mengenai pemanfaatan lebih lanjut dari minyak sawit merah telah dilakukan di Pusat Penelitian Kelapa Sawit. Tujuan penelitian ini adalah untuk menemukan formula tertentu dalam pembuatan margarin kaya provitamin A dari minyak sawit merah. Hasil penelitian ini menunjukkan bahwa minyak sawit merah dapat dijadikan sebagai bahan baku margarin kaya provitamin A. Margarin kaya provitamin A dapat dibuat dengan komposisi minyak margarin terdiri dari stearin 29,079%, minyak sawit yang dimurnikan, dipucatkan, dan dideodorisasi 24,385%, minyak inti sawit 11,041%, dan minyak sawit merah 34,000%. Pengujian kesesuaian sifat margarin tersebut memperlihatkan bahwa titik leleh dan komposisi asam lemak margarin hasil formulasi tidak jauh berbeda dengan titik leleh dan komposisi asam lemak margarin acuan. Kadar karoten margarin hasil formulasi adalah 84 ppm. Karoten tersebut sebagian besar mempunyai aktivitas provitamin A

Kata kunci: margarin, provitamin A, minyak sawit merah

PENDAHULUAN

Masyarakat Indonesia, terutama masyarakat yang tinggal di daerah perkotaan, banyak yang telah terbiasa mengkonsumsi margarin. Konsumsi margarin di Indonesia cenderung meningkat selama dasawarsa 1990-an. Peningkatan konsumsi tersebut diimbangi oleh peningkatan produksi. Selama periode 1991-1996 produksi margarin Indonesia rata-rata meningkat dengan laju peningkatan sebesar 15.02% (4).

Minyak sawit dan minyak inti sawit beserta fraksi-fraksinya banyak digunakan untuk pembuatan margarin. Margarin merupakan produk emulsi dengan tipe emulsi air di dalam minyak yang dibuat dari minyak dan lemak pangan. Menurut definisi Codex, margarin harus mengandung minyak tidak kurang dari 80% dan mengandung air tidak lebih dari 16%. Pembuatan margarin dilakukan 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 (6).

Bahan baku utama dalam pembuatan margarin antara lain adalah campuran minyak yang membentuk fase minyak, air dan atau susu yang membentuk fase air, dan emulsifier. Disamping itu seringkali ditambahkan bahan lain misalnya vitamin. Vitamin yang biasanya ditambahkan dalam margarin adalah vitamin A, D, E, dan K. Bila dapat dibuat formulasi margarin yang mengandung karoten yang memiliki aktivitas provitamin A maka penambahan vitamin A dapat dikurangi atau bahkan ditiadakan. Berdasarkan latar belakang

ini, penelitian ini dilakukan untuk menetapkan formulasi margarin kaya provitamin A yang dibuat dari minyak sawit merah.

BAHAN DAN METODE

Bahan

Bahan yang dipergunakan dalam formulasi margarin kaya provitamin A ini adalah minyak sawit merah, minyak inti sawit, stearin, minyak sawit yang telah dimurnikan, dipucatkan, dan dideodorisasi, susu bubuk tanpa lemak, garam, dan emulsifier. 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 sawit 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 margarin meja komersial buatan Indonesia.

Metode

Penelitian ini dibagi menjadi tiga tahapan yaitu 1) tahap penentuan formula minyak margarin dengan model *linear programming* menggunakan program *Linear Interactive Discrete Optimizer* (5), 2) tahap pembuatan minyak margarin berdasarkan formula tersebut, dan 3) tahap pembuatan margarin. Hasil olahan program LINDO yang dipergunakan untuk keperluan formulasi minyak margarin adalah nilai optimal variabel, yang dalam hal ini merupakan jumlah masing-masing bahan baku yang disarankan untuk formulasi minyak margarin.

Pembuatan minyak margarin (fase minyak) dilakukan dengan cara pencampuran. Sedangkan, pembuatan margarin dilakukan menurut metode Vaisey-Genser dan Vane (3). Sifat fisikokimia yang dipergunakan untuk keperluan pencocokan dengan margarin acuan adalah titik leleh dan komposisi asam lemak. Titik leleh dianalisis menurut metode AOCS Cc 1-25 (2) dengan mempergunakan tabung kapiler. Komposisi asam lemak dianalisis dengan kromatografi gas. 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 yang dijalankan pada suhu kolom 200°C, suhu injeksi 250°C, suhu detektor 230°C, laju alir 50 ml nitrogen/menit. Luas area puncak dan persentase relatif metil ester asam lemak ditentukan dengan menggunakan integrator Shimadzu Chromatopack C-R6-A. Selain titik leleh dan komposisi asam lemak juga dilakukan analisis kadar karoten dengan metode spektrofotometrik (8).

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 didekati formulasinya dengan cara mencampurkan secara langsung berbagai bahan baku yang digunakan.

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

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

*)Titik leleh minyak sawit merah tidak diamati karena minyak sawit merah berbentuk cair pada suhu kamar

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 dengan 18 dan didominasi oleh asam palmitat dan oleat. Semua asam lemak tersebut terdapat pada bahan baku yang akan dipergunakan untuk formulasi.

Hasil penelitian sebelumnya (5) memperlihatkan bahwa komposisi formula minyak margarin yang disarankan tidak menggunakan minyak sawit merah sebagai salah satu komponennya. Oleh sebab itu, dalam formulasi kali ini dimasukkan fungsi kendala tambahan yang ditujukan agar minyak sawit merah digunakan untuk formulasi minyak margarin. Dalam hal ini ditetapkan bahwa formula minyak margarin harus mengandung minyak sawit merah sekurang-kurangnya sebesar 30%.

Untuk menetapkan nilai optimal simpangan kadar asam lemak agar jumlah semua bahan baku yang disarankan untuk formulasi minyak margarin mendekati 100% dilakukan uji coba model dengan simpangan kadar asam lemak 0,1; 0,2; 0,3; 0,4; dan 0,5% (Tabel 2). Dengan simpangan 0,1; 0,2; 0,3; 0,4; dan 0,5% maka jumlah semua bahan baku yang disarankan untuk formulasi minyak margarin berturut-turut adalah 93,599; 96,041; 95,707; 99,609; dan 100,889%. Berdasarkan hasil ini maka dapat dinyatakan bahwa simpangan kadar asam lemak yang optimal adalah 0,4% dengan komposisi formula minyak margarin yang disarankan terdiri dari stearin 27,637%, minyak sawit

yang dimurnikan, dipucatkan, dan dideodorisasi 29,412%, minyak inti sawit 12,559%, dan minyak sawit merah 30,000%.

Prinsip utama dalam formulasi margarin kaya provitamin A adalah memasukkan minyak sawit merah dalam formulasi sebesar-besarnya. Namun, hasil uji coba model (Tabel 2) memperlihatkan bahwa minyak sawit merah yang digunakan hanya sebesar 30% walaupun di dalam fungsi kendala ditetapkan sekurang-kurangnya 30% (RPO $\geq$ 0.30). Berdasarkan hal ini, dilakukan uji coba model dengan fungsi kendala yang memungkinkan dimasukkannya minyak sawit merah dalam jumlah yang lebih besar, yaitu 31%, 32%, 33% dan seterusnya (Tabel 3).

Tabel 3 memperlihatkan bahwa dengan memasukkan minyak sawit merah dalam formulasi berturut-turut sebanyak 31, 32, 33, 34, dan 35% maka jumlah semua bahan baku yang disarankan untuk formulasi minyak margarin berturut-turut adalah 99,333; 99,057; 98,781; 99,505; dan 98,229%. Berdasarkan hasil ini maka dapat dinyatakan bahwa jumlah maksimal minyak sawit merah yang dapat digunakan dalam formulasi adalah 34% dengan komposisi formula minyak margarin yang disarankan terdiri dari stearin 29,079%, minyak sawit yang dimurnikan, dipucatkan, dan dideodorisasi 24,385%, minyak inti sawit 11,041%, dan minyak sawit merah 34,000%.

Pengamatan lebih seksama terhadap Tabel 2 memperlihatkan bahwa penambahan jumlah minyak sawit merah menyebabkan pengurangan jumlah minyak sawit yang dimurnikan, dipucatkan, dan dideodorisasi dan minyak inti sawit. Pengurangan jumlah minyak sawit yang dimurnikan, dipucatkan, dan dideodorisasi diperkirakan tidak akan banyak mempengaruhi mutu margarin. Namun, pengurangan jumlah minyak inti sawit diperkirakan dapat mempengaruhi mutu margarin bila jumlah minyak inti sawit yang digunakan dalam formulasi kurang dari 10%. Minyak inti sawit berpengaruh terhadap kecepatan meleleh margarin di dalam mulut (7). Hal ini juga memperkuat alasan untuk membatasi penggunaan minyak sawit merah dalam formulasi minyak margarin maksimal adalah 34%.

Berdasarkan komposisi formula minyak margarin yang didasarkan atas hasil *linear programming* LINDO dilakukan pembuatan minyak margarin (fase minyak) dengan cara pencampuran. Selanjutnya fase minyak ini dibuat menjadi margarin dengan campuran bahan lainnya. Komposisi margarin terdiri dari minyak margarin (fase minyak) 89,319%, susu bubuk tanpa lemak 2,627%, air 7,881%, serta garam dan emulsifier 0,173%.

Hasil penelitian memperlihatkan bahwa komposisi asam lemak dan titik leleh margarin hasil formulasi tidak jauh berbeda dengan komposisi asam lemak dan titik leleh margarin acuan (Tabel 4). Sedikit penyimpangan dalam komposisi asam lemak mungkin disebabkan oleh adanya fungsi kendala yang ditambahkan yaitu keharusan menggunakan minyak sawit merah, selanjutnya perbedaan komposisi asam lemak ini menyebabkan perbedaan titik leleh. Kadar karoten, yang sebagian besar memiliki aktivitas provita min A, pada margarin hasil formulasi adalah 84 ppm.

Tabel 2. Pengaruh simpangan kadar masing-masing asam lemak terhadap komposisi formula minyak margarin yang disarankan

Simpangan kadar masing-masing asam lemak	Fungsi tujuan dan fungsi kendala	Komposisi formula minyak margarin yang disarankan
0,1	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Fungsi kendala : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.3$ $0,0 \leq 3,0003PKO \leq 0,1$ $5,5 \leq 47,2357PKO \leq 5,7$ $3,3 \leq 1,1849ST+1,0835RBD+16,3761PKO+0,7990RPO \leq 3,5$ $42,2 \leq 56,8467ST+45,1169RBD+8,5752PKO+39,4739RPO \leq 42,4$ $3,9 \leq 3,6113ST+4,4245RBD+2,8983PKO+3,4925RPO \leq 4,1$ $34,9 \leq 30,3654ST+38,7143RBD+17,9860PKO+44,5404RPO \leq 35,1$ $9,5 \leq 7,9918ST+10,6610RBD+2,9230PKO+11,6284RPO \leq 9,7$	ST = 26,272% RBD=33,995% PKO=3,333% RPO=30,000%
0,2	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Fungsi kendala : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.3$ $0,0 \leq 3,0003PKO \leq 0,2$ $5,4 \leq 47,2357PKO \leq 5,8$ $3,2 \leq 1,1849ST+1,0835RBD+16,3761PKO+0,7990RPO \leq 3,6$ $42,1 \leq 56,8467ST+45,1169RBD+8,5752PKO+39,4739RPO \leq 42,5$ $3,8 \leq 3,6113ST+4,4245RBD+2,8983PKO+3,4925RPO \leq 4,2$ $34,8 \leq 30,3654ST+38,7143RBD+17,9860PKO+44,5404RPO \leq 35,2$ $9,4 \leq 7,9918ST+10,6610RBD+2,9230PKO+11,6284RPO \leq 9,8$	ST = 28,118% RBD=31,257% PKO=6,666% RPO=30,000%
0,3	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Fungsi kendala : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.3$ $0,0 \leq 3,0003PKO \leq 0,3$ $5,3 \leq 47,2357PKO \leq 5,9$ $3,1 \leq 1,1849ST+1,0835RBD+16,3761PKO+0,7990RPO \leq 3,7$ $42,0 \leq 56,8467ST+45,1169RBD+8,5752PKO+39,4739RPO \leq 42,6$ $3,7 \leq 3,6113ST+4,4245RBD+2,8983PKO+3,4925RPO \leq 4,3$ $34,7 \leq 30,3654ST+38,7143RBD+17,9860PKO+44,5404RPO \leq 35,3$ $9,3 \leq 7,9918ST+10,6610RBD+2,9230PKO+11,6284RPO \leq 9,9$	ST = 25,269% RBD=33,730% PKO=6,708% RPO=30,000%
0,4	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Fungsi kendala : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.3$ $0,0 \leq 3,0003PKO \leq 0,4$ $5,2 \leq 47,2357PKO \leq 6,0$ $3,0 \leq 1,1849ST+1,0835RBD+16,3761PKO+0,7990RPO \leq 3,8$ $41,9 \leq 56,8467ST+45,1169RBD+8,5752PKO+39,4739RPO \leq 42,7$ $3,6 \leq 3,6113ST+4,4245RBD+2,8983PKO+3,4925RPO \leq 4,4$ $34,6 \leq 30,3654ST+38,7143RBD+17,9860PKO+44,5404RPO \leq 35,4$ $9,2 \leq 7,9918ST+10,6610RBD+2,9230PKO+11,6284RPO \leq 10,0$	ST = 27,637% RBD=29,412% PKO=12,559% RPO=30,000%
0,5	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Fungsi kendala : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.3$ $0,0 \leq 3,0003PKO \leq 0,5$ $5,1 \leq 47,2357PKO \leq 6,1$ $2,9 \leq 1,1849ST+1,0835RBD+16,3761PKO+0,7990RPO \leq 3,9$ $41,8 \leq 56,8467ST+45,1169RBD+8,5752PKO+39,4739RPO \leq 42,8$ $3,5 \leq 3,6113ST+4,4245RBD+2,8983PKO+3,4925RPO \leq 4,5$ $34,5 \leq 30,3654ST+38,7143RBD+17,9860PKO+44,5404RPO \leq 35,5$ $9,1 \leq 7,9918ST+10,6610RBD+2,9230PKO+11,6284RPO \leq 10,1$	ST = 31,493% RBD=26,482% PKO=12,914% RPO=30,000%

ST = stearin; RBD = minyak sawit yang dimurnikan, dipucatkan, dan dideodorisasi; PKO = minyak inti sawit; RPO = minyak sawit merah

Tabel 3. Pengaruh peningkatan jumlah minyak sawit merah yang digunakan dalam formulasi terhadap komposisi formula minyak margarin yang disarankan

Jumlah minyak sawit merah (%)	Fungsi tujuan dan fungsi kendala	Komposisi formula minyak margarin yang disarankan
31	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Fungsi kendala : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.31$ $0,0 \leq 3,0003PKO \leq 0,4$ $5,2 \leq 47,2357PKO \leq 6,0$ $3,0 \leq 1,1849ST+1,0835RBD+16,3761PKO+0,7990RPO \leq 3,8$ $41,9 \leq 56,8467ST+45,1169RBD+8,5752PKO+39,4739RPO \leq 42,7$ $3,6 \leq 3,6113ST+4,4245RBD+2,8983PKO+3,4925RPO \leq 4,4$ $34,6 \leq 30,3654ST+38,7143RBD+17,9860PKO+44,5404RPO \leq 35,4$ $9,2 \leq 7,9918ST+10,6610RBD+2,9230PKO+11,6284RPO \leq 10,0$	ST = 27,998% RBD=28,156% PKO=12,180% RPO=31,000%
32	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Fungsi kendala : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.32$ $0,0 \leq 3,0003PKO \leq 0,4$ $5,2 \leq 47,2357PKO \leq 6,0$ $3,0 \leq 1,1849ST+1,0835RBD+16,3761PKO+0,7990RPO \leq 3,8$ $41,9 \leq 56,8467ST+45,1169RBD+8,5752PKO+39,4739RPO \leq 42,7$ $3,6 \leq 3,6113ST+4,4245RBD+2,8983PKO+3,4925RPO \leq 4,4$ $34,6 \leq 30,3654ST+38,7143RBD+17,9860PKO+44,5404RPO \leq 35,4$ $9,2 \leq 7,9918ST+10,6610RBD+2,9230PKO+11,6284RPO \leq 10,0$	ST = 18,358% RBD=26,899% PKO=11,800% RPO=32,000%
33	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Fungsi kendala : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.33$ $0,0 \leq 3,0003PKO \leq 0,4$ $5,2 \leq 47,2357PKO \leq 6,0$ $3,0 \leq 1,1849ST+1,0835RBD+16,3761PKO+0,7990RPO \leq 3,8$ $41,9 \leq 56,8467ST+45,1169RBD+8,5752PKO+39,4739RPO \leq 42,7$ $3,6 \leq 3,6113ST+4,4245RBD+2,8983PKO+3,4925RPO \leq 4,4$ $34,6 \leq 30,3654ST+38,7143RBD+17,9860PKO+44,5404RPO \leq 35,4$ $9,2 \leq 7,9918ST+10,6610RBD+2,9230PKO+11,6284RPO \leq 10,0$	ST = 28,718% RBD=25,642% PKO=11,421% RPO=33,000%
34	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Fungsi kendala : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.34$ $0,0 \leq 3,0003PKO \leq 0,4$ $5,2 \leq 47,2357PKO \leq 6,0$ $3,0 \leq 1,1849ST+1,0835RBD+16,3761PKO+0,7990RPO \leq 3,8$ $41,9 \leq 56,8467ST+45,1169RBD+8,5752PKO+39,4739RPO \leq 42,7$ $3,6 \leq 3,6113ST+4,4245RBD+2,8983PKO+3,4925RPO \leq 4,4$ $34,6 \leq 30,3654ST+38,7143RBD+17,9860PKO+44,5404RPO \leq 35,4$ $9,2 \leq 7,9918ST+10,6610RBD+2,9230PKO+11,6284RPO \leq 10,0$	ST = 29,079% RBD=24,385% PKO=11,041% RPO=34,000%
35	Fungsi tujuan : Maks. atau Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Fungsi kendala : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.35$ $0,0 \leq 3,0003PKO \leq 0,4$ $5,2 \leq 47,2357PKO \leq 6,0$ $3,0 \leq 1,1849ST+1,0835RBD+16,3761PKO+0,7990RPO \leq 3,8$ $41,9 \leq 56,8467ST+45,1169RBD+8,5752PKO+39,4739RPO \leq 42,7$ $3,6 \leq 3,6113ST+4,4245RBD+2,8983PKO+3,4925RPO \leq 4,4$ $34,6 \leq 30,3654ST+38,7143RBD+17,9860PKO+44,5404RPO \leq 35,4$ $9,2 \leq 7,9918ST+10,6610RBD+2,9230PKO+11,6284RPO \leq 10,0$	ST = 29,439% RBD=23,128% PKO=10,662% RPO=35,000%

ST = stearin; RBD = minyak sawit yang dimurnikan, dipucatkan, dan dideodorisasi; PKO = minyak inti sawit; RPO = minyak sawit merah

Tabel 4. Sifat margarin acuan dan margarin hasil formulasi

Sifat	Margarin acuan	Margarin hasil formulasi
Komposisi asam lemak :		
- C 10:0	-	-
- C 12:0	5,6027	5,6427
- C 14:0	3,4320	2,9849
- C 16:0	42,3213	44,0751
- C 18:0	4,0154	3,6794
- C 18:1	34,9871	34,6714
- C 18:2	9,6415	8,9466
Titik leleh (°C)	42,75	45,75

KESIMPULAN

Minyak sawit merah dapat digunakan untuk formulasi margarin kaya provitamin A sampai sebanyak 34% dari fase minyak. Komposisi formula minyak margarin yang disarankan adalah stearin 29,079%, minyak sawit yang dimurnikan, dipucatkan, dan dideodorisasi 24,385%, minyak inti sawit 11,041%, dan minyak sawit merah 34,000%. Titik leleh margarin hasil formulasi adalah 45,75 °C dengan kandungan karoten sebesar 84 ppm. Sebagian besar karoten tersebut memiliki aktivitas provitamin A.

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Margarine rich of provitamin A formulation from red palm oil

Angga Jatmika

Abstract

Research on further usage of red palm oil has been carried out at Indonesian Oil Palm Research Institute. The objective of this research was to formulate margarine rich of provitamin A from red palm oil. Result of the study showed that red palm oil can be use as raw material for table margarine rich of provitamin A . The table margarine can be made from fat phase composed of palm stearin 29.079%, refined, bleached. Deodorized palm oil of 24.385%, palm kernel oil of 11,041%, and red palm oil of 34.000%. Testing of properties matching showed that the melting point and fatty acid composition of the formulated margarine were nearly close to those of reference margarine. The carotene content of formulated margarine was 84 ppm. Most of that carotene has provitamin A activity.

Key words : margarine, provitamin A, red palm oil

Introduction

Indonesian people, especially urban people, have commonly consumed margarine. Margarine consumption showed increasing trend in 1990's. The increasing of consumption was followed by the increasing of domestic production. In the period 1991 - 1996 the growth rate of production of margarine in Indonesia was 15.02% (4).

Palm and palm kernel oils and their fractions have been widely used in the manufacture of 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 (6).

The principal materials used for margarine preparation were mixture of oil and fat which form a fat phase, water and or milk which form an aqueous phase, and emulsifier. In addition, it was frequently added other constiuent such as vitamin. Based on store observation, the vitamins which were incorporated to the margarine were vitamin A, D, E, and K. If margarine rich of carotene having provitamin A activity can be formulated, then addition of vitamin A can be reduced or even omitted. Based on this background, the research was conducted to find margarine rich of provitamin A formulation made of red palm oil.

Materials and Methods

Materials

Materials used for margarine rich of provitamin A formulation were red palm oil, palm kernel oil, palm stearin, refined, bleached, deodorized palm oil, non fat dry

milk, salt, and emulsifier. 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 three stages: 1) determination of margarine oil formula by linear programming model using *Linear Interactive Discrete Optimizer* computer program (5), 2) preparation of margarine oil based on that formula, and 3) preparation of the margarine product.

The output of the LINDO computer program used for margarine oil formulation was 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. While, preparation of margarine product was done according to Vaisey-Genser and Vane methods (3). The properties which was used for matching with the reference were melting point and fatty acid composition. 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 using 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. In addition to melting point and fatty acid composition, it was carried out carotene content analysis by spectrophotometric method (8).

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, the 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, dominated by palmitic and oleic acids. All of the fatty acids were found in oils used for raw material of the formulation.

Result of the previous experiment (5) showed that composition of recommended margarine oil formula did not always include red palm oil as one of its constituent. Therefore, in this formulation experiment additional constraint function that aimed toward red palm oil usage in margarine oil formulation was attached. In this case, it was determined

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

Properties	Reference margarine oil	Palm stearin	Palm kernel oil	Refined, bleached, deodorized palm oil	Red palm oil
Fatty acid composition (%) :					
- C 10:0	-	-	3,0003	-	-
- C 12:0	5.6027	-	47,2357	-	-
- C 14:0	3,4320	1,1849	16,3761	1,0835	0,7990
- C 16:0	42,3213	56,8467	8,5752	45,1169	39,4739
- C 18:0	4,0154	3,6113	2,8983	4,4245	3,4925
- C 18:1	34,9871	30,3654	17,9860	38,7143	44,5404
- C 18:2	9,6415	7,9918	2,9230	10,6610	11,6284
Melting point (°C)	42,75	48,75	26,75	34,75	*

*melting point of red palm oil was not determined because red palm oil was in the liquid form in the room temperature

that the content of red palm oil in the recommended margarine oil formula was at least 30%.

To determine the optimal value of deviation of individual fatty acids content in order to achieve the quantity of each oils used for raw material of margarine oil formulation closed to 100%, simulation of the model with individual fatty acid content were 0.1, 0.2, 0.3, 0.4, and 0.5% (Table 2). If the deviations of individual (each) fatty acid were 0.1, 0.2, 0.3, 0.4, and 0.5% then the quantity of each oils used for raw material of margarine oil formulation would be of 93.599, 96.041, 95.707, 99.609, and 100.889%, respectively. Based on that result, it was concluded that the optimal value of deviation of individual (each) fatty acid falls 0.4% with recommended composition of margarine oil formula consisted of palm stearin falls 27.637%, refined, bleached, deodorized palm oil falls 29.412%, and palm kernel oil falls 12.559%, and red palm oil was 30.000%.

The main fundamental of margarine rich of provitamin A was to incorporate red palm oil as much as possible in the margarine oil formula. However, result of the simulation of the model (Table 2) showed that red palm oil usage was only 30% although in the constrain function it was determined that usage of red palm oil was at least 30% (RPO $\geq$ 0.30). Based on this result, in this formulation experiment additional constraint function that aimed

toward greater red palm oil usage, i.e. 31%, 32%, 33% and so on (Table 3).

Table 3 showed that if incorporation level of red palm oil in the margarine oil formulation was of 31, 32, 33, 34, and 35% then the quantity of each oils used for raw material of margarine oil formulation would be of 99.333, 99.057, 98.781, 99.505, and 98.229%, respectively. Based on that result, it was concluded that the maximum quantity of red palm oil used in the formulation should be 34% with recommended composition of margarine oil formula consisted of palm stearin falls 29.079%, refined, bleached, deodorized palm oil falls 24,385%, and palm kernel oil falls 11,041%, and red palm oil was 34.000%.

Critical observation to the Table 2 showed that addition of red palm oil quantity would affect decreasing the quantity of refined, bleached, deodorized palm oil as well as palm kernel oil. Decreasing the quantity of refined, bleached, deodorized palm oil might not have any deletiorius effect to the quality of margarine. But, decreasing of quantity of palm kernel oil could influence the quality of margarine especially if it was dropped to less than 10%. Palm kernel oil influences mouth quick-melting properties of the margarine (7). This fact also supports on reason to restric red palm oil usage in the margarine oil formulation as much as 34%.

Based on composition of margarine oil formula recommended by LINDO linear programming computer program, preparation of margarine oil (fat phase of margarine) was carried out using blending technique. The next step was to made margarine from this fat phase and others constituent. The margarine composition consist of margarine oil (fat phase) 89.319%, non fat dry milk 2.627%, water 7.881%, and salt and emulsifier 0.173%. Result of the study showed that the fatty acid composition and melting point of the formulated margarine were nearly close to those of reference margarine (Table 4). Slightly difference in term of fatty acid composition may cause the additional constraint function due to the necesity of using of red palm oil of 34% in the formulation, and then this fatty acid composition difference may caused difference in melting point of the margarine product. The carotene content of the formulated margarine was 84 ppm. Most of the carotene have provitamin A activity,

Conclusions

Red palm oil could be used for margarine rich of provitamin A formulation with quantity as much as 34% of fat phase. Composition of the recommended margarine oil formula was of palm stearin 29.079%, refined, bleached. Deodorized palm oil of 24.385%, palm kernel oil of 11,041%, and red palm oil of 34.000%. The melting point of formulated margarine was 45.75 °C with carotene, which most of them have provitamin A activity, was 84 ppm.

Table 2. Effect of deviation of individual fatty acids content on recommended composition of margarine oil formula

Deviation of individual fatty acids content	Objective function and constraint functions	Recommended composition of oil margarine formula
0.1	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Constrain functions : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.3$ $0.0 \leq 3.0003PKO \leq 0.1$ $5.5 \leq 47.2357PKO \leq 5.7$ $3.3 \leq 1.1849ST+1.0835RBD+16.3761PKO+0.7990RPO \leq 3.5$ $42.2 \leq 56.8467ST+45.1169RBD+8.5752PKO+39.4739RPO \leq 42.4$ $3.9 \leq 3.6113ST+4.4245RBD+2.8983PKO+3.4925RPO \leq 4.1$ $34.9 \leq 30.3654ST+38.7143RBD+17.9860PKO+44.5404RPO \leq 35.1$ $9.5 \leq 7.9918ST+10.6610RBD+2.9230PKO+11.6284RPO \leq 9.7$	ST = 26.272% RBD=33.995% PKO=3.333% RPO=30.000%
0.2	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Constrain functions : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.3$ $0.0 \leq 3.0003PKO \leq 0.2$ $5.4 \leq 47.2357PKO \leq 5.8$ $3.2 \leq 1.1849ST+1.0835RBD+16.3761PKO+0.7990RPO \leq 3.6$ $42.1 \leq 56.8467ST+45.1169RBD+8.5752PKO+39.4739RPO \leq 42.5$ $3.8 \leq 3.6113ST+4.4245RBD+2.8983PKO+3.4925RPO \leq 4.2$ $34.8 \leq 30.3654ST+38.7143RBD+17.9860PKO+44.5404RPO \leq 35.2$ $9.4 \leq 7.9918ST+10.6610RBD+2.9230PKO+11.6284RPO \leq 9.8$	ST = 28.118% RBD=31.257% PKO=6.666% RPO=30.000%
0.3	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Constrain functions : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.3$ $0.0 \leq 3.0003PKO \leq 0.3$ $5.3 \leq 47.2357PKO \leq 5.9$ $3.1 \leq 1.1849ST+1.0835RBD+16.3761PKO+0.7990RPO \leq 3.7$ $42.0 \leq 56.8467ST+45.1169RBD+8.5752PKO+39.4739RPO \leq 42.6$ $3.7 \leq 3.6113ST+4.4245RBD+2.8983PKO+3.4925RPO \leq 4.3$ $34.7 \leq 30.3654ST+38.7143RBD+17.9860PKO+44.5404RPO \leq 35.3$ $9.3 \leq 7.9918ST+10.6610RBD+2.9230PKO+11.6284RPO \leq 9.9$	ST = 25.269% RBD=33.730% PKO=6.708% RPO=30.000%
0.4	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Constrain functions : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.3$ $0.0 \leq 3.0003PKO \leq 0.4$ $5.2 \leq 47.2357PKO \leq 6.0$ $3.0 \leq 1.1849ST+1.0835RBD+16.3761PKO+0.7990RPO \leq 3.8$ $41.9 \leq 56.8467ST+45.1169RBD+8.5752PKO+39.4739RPO \leq 42.7$ $3.6 \leq 3.6113ST+4.4245RBD+2.8983PKO+3.4925RPO \leq 4.4$ $34.6 \leq 30.3654ST+38.7143RBD+17.9860PKO+44.5404RPO \leq 35.4$ $9.2 \leq 7.9918ST+10.6610RBD+2.9230PKO+11.6284RPO \leq 10.0$	ST = 27.637% RBD=29.412% PKO=12.559% RPO=30.000%
0.5	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Constrain functions : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.3$ $0.0 \leq 3.0003PKO \leq 0.5$ $5.1 \leq 47.2357PKO \leq 6.1$ $2.9 \leq 1.1849ST+1.0835RBD+16.3761PKO+0.7990RPO \leq 3.9$ $41.8 \leq 56.8467ST+45.1169RBD+8.5752PKO+39.4739RPO \leq 42.8$ $3.5 \leq 3.6113ST+4.4245RBD+2.8983PKO+3.4925RPO \leq 4.5$ $34.5 \leq 30.3654ST+38.7143RBD+17.9860PKO+44.5404RPO \leq 35.5$ $9.1 \leq 7.9918ST+10.6610RBD+2.9230PKO+11.6284RPO \leq 10.1$	ST = 31.493% RBD=26.482% PKO=12.914% RPO=30.000%

ST = palm stearin; RBD = refined, bleached, deodorized palm oil; PKO = palm kernel oil; RPO = red palm oil

Table 3. Effect of increasing of quantity of red palm oil usage in the formulation on recommended composition of margarine oil formula

Quantity of red palm oil (%)	Objective function and constraint functions	Recommended composition of oil margarine formula
31	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Constrain functions : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.31$ $0.0 \leq 3.0003PKO \leq 0.4$ $5.2 \leq 47.2357PKO \leq 6.0$ $3.0 \leq 1.1849ST+1.0835RBD+16.3761PKO+0.7990RPO \leq 3.8$ $41.9 \leq 56.8467ST+45.1169RBD+8.5752PKO+39.4739RPO \leq 42.7$ $3.6 \leq 3.6113ST+4.4245RBD+2.8983PKO+3.4925RPO \leq 4.4$ $34.6 \leq 30.3654ST+38.7143RBD+17.9860PKO+44.5404RPO \leq 35.4$ $9.2 \leq 7.9918ST+10.6610RBD+2.9230PKO+11.6284RPO \leq 10.0$	ST = 27.998% RBD=28.156% PKO=12.180% RPO=31.000%
32	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Constrain functions : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.32$ $0.0 \leq 3.0003PKO \leq 0.4$ $5.2 \leq 47.2357PKO \leq 6.0$ $3.0 \leq 1.1849ST+1.0835RBD+16.3761PKO+0.7990RPO \leq 3.8$ $41.9 \leq 56.8467ST+45.1169RBD+8.5752PKO+39.4739RPO \leq 42.7$ $3.6 \leq 3.6113ST+4.4245RBD+2.8983PKO+3.4925RPO \leq 4.4$ $34.6 \leq 30.3654ST+38.7143RBD+17.9860PKO+44.5404RPO \leq 35.4$ $9.2 \leq 7.9918ST+10.6610RBD+2.9230PKO+11.6284RPO \leq 10.0$	ST = 18.358% RBD=26.899% PKO=11.800% RPO=32.000%
33	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Constrain functions : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.33$ $0.0 \leq 3.0003PKO \leq 0.4$ $5.2 \leq 47.2357PKO \leq 6.0$ $3.0 \leq 1.1849ST+1.0835RBD+16.3761PKO+0.7990RPO \leq 3.8$ $41.9 \leq 56.8467ST+45.1169RBD+8.5752PKO+39.4739RPO \leq 42.7$ $3.6 \leq 3.6113ST+4.4245RBD+2.8983PKO+3.4925RPO \leq 4.4$ $34.6 \leq 30.3654ST+38.7143RBD+17.9860PKO+44.5404RPO \leq 35.4$ $9.2 \leq 7.9918ST+10.6610RBD+2.9230PKO+11.6284RPO \leq 10.0$	ST = 28.718% RBD=25.642% PKO=11.421% RPO=33.000%
34	**Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$** **Constrain functions : $ST + RBD + PKO + RPO = 100$** **$RPO \geq 0.34$** **$0.0 \leq 3.0003PKO \leq 0.4$** **$5.2 \leq 47.2357PKO \leq 6.0$** **$3.0 \leq 1.1849ST+1.0835RBD+16.3761PKO+0.7990RPO \leq 3.8$** **$41.9 \leq 56.8467ST+45.1169RBD+8.5752PKO+39.4739RPO \leq 42.7$** **$3.6 \leq 3.6113ST+4.4245RBD+2.8983PKO+3.4925RPO \leq 4.4$** **$34.6 \leq 30.3654ST+38.7143RBD+17.9860PKO+44.5404RPO \leq 35.4$** **$9.2 \leq 7.9918ST+10.6610RBD+2.9230PKO+11.6284RPO \leq 10.0$**	ST = 29.079% RBD=24.385% PKO=11.041% RPO=34.000%
35	Objective function : Max. or Min. $Z=1000ST+1500RBD+2500PKO+3000RPO$ Constrain functions : $ST + RBD + PKO + RPO = 100$ $RPO \geq 0.35$ $0.0 \leq 3.0003PKO \leq 0.4$ $5.2 \leq 47.2357PKO \leq 6.0$ $3.0 \leq 1.1849ST+1.0835RBD+16.3761PKO+0.7990RPO \leq 3.8$ $41.9 \leq 56.8467ST+45.1169RBD+8.5752PKO+39.4739RPO \leq 42.7$ $3.6 \leq 3.6113ST+4.4245RBD+2.8983PKO+3.4925RPO \leq 4.4$ $34.6 \leq 30.3654ST+38.7143RBD+17.9860PKO+44.5404RPO \leq 35.4$ $9.2 \leq 7.9918ST+10.6610RBD+2.9230PKO+11.6284RPO \leq 10.0$	ST = 29.439% RBD=23.128% PKO=10.662% RPO=35.000%

ST = palm stearin; RBD = refined, bleached, deodorized palm oil; PKO = palm kernel oil; RPO = red palm oil

Table 4. Properties of reference margarine and formulated margarine

Properties	Reference margarine	Formulated margarine
Fatty acid composition (%) :		
- C 10:0	-	-
- C 12:0	5.6027	5.6427
- C 14:0	3.4320	2.9849
- C 16:0	42.3213	44.0751
- C 18:0	4.0154	3.6794
- C 18:1	34.9871	34.6714
- C 18:2	9.6415	8.9466
Melting point (°C)	42.75	45.75

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